Wastewater Problems and Social Vulnerability in Megacity Delhi/India

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ABSTRACT

Wastewater management including sewerage and sanitation has a direct influence on environmental and public health security. Today, risk pertaining to inadequate wastewater disposal and sanitation facilities is one of the major threats faced by city dwellers. Delhi, with around 15 million populations generates more than 3,987 million liters of wastewater per day, out of which only 47% gets treated, using about 63% of the total treatment capacity. About 50% of its population lives in informal settlements with precarious sewerage and sanitation provisions grappling with numerous water and wastewater related problems. In this respect certain types and degrees of vulnerability exist, particularly among the marginalized population of the informal settlement quarters. The internal and external conditions and processes responsible for increasing defenselessness develop dynamically and need to be understood from various perspectives. This study is based on comprehensive household survey and attempts to analyse wastewater problems and related social vulnerability in different residential colonies of both formal and informal settings. It further explores the community and institutional coping responses and adaptations measures against the prevailing wastewater situation in Delhi. Inadequate wastewater management, locational disadvantages and poor socio-economic conditions finally manifest into environmental and health implications. Vulnerability is higher in informal settlements which remains invisible or only mildly perceived until it strikes as a major (disease) outbreak. People's perception also plays an important role in understanding social vulnerability. The manner in which an individual or social group perceives existing problem influences the extent of their exposure and moulds their response towards it. Social groups take to various adaptation and coping mechanisms to deal with the wastewater problems depending upon the perception, available options and their management capabilities. The findings of the present study, which are based on empirical field work, support the theoretical hypothesis that social vulnerability is the defenselessness of certain individual/households/social groups against various stresses which impact them through harmful implications of multiple types. The degree of social vulnerability is determined by the relation between their exposure to wastewater problems, related stresses and their coping capabilities.

KURZZUSAMMENFASSUNG

Abwassermanagement einschließlich Abwasserentsorgung und sanitärer Einrichtungen hat direkten Einfluss auf die Sicherheit von Umwelt und öffentlicher Gesundheit. Heutzutage stellt das Risiko, das von unzulänglicher Abwasserentsorgung und unhygienischen sanitären Einrichtungen ausgeht, eine der großen Bedrohungen dar, derer sich Stadtbewohner ausgesetzt sehen. Delhi mit einer Bevölkerung von ca. 15 Mio. Einwohnern erzeugt täglich mehr als 3,987 Mio. Liter Abwasser, von denen nur 47% aufbereitet werden unter Inanspruchnahme von 63% der gesamten Aufbereitungskapazität. Ungefähr 50% der Bewohner Delhis leben in informellen Siedlungen mit unzureichenden Abwasser- und Entsorgungsanlagen und mit daraus resultierenden zahlreichen wasser- und abwasserspezifischen Problemen. Vor diesem Hintergrund bestehen verschiedene Arten und Grade von Verwundbarkeit, besonders bei der marginalisierten Bevölkerung der informellen Siedlungen. Die für die wachsende Vulnerabilität verantwortlichen inneren und äußeren Bedingungen und Prozesse entwickeln sich dynamisch und müssen aus verschiedenen Perspektiven verstanden werden. Die vorliegende Arbeit stützt sich auf umfangreiche Haushaltsbefragungen und versucht, die mit der Abwasserproblematik zusammenhängende gesellschaftliche Vulnerablität sowohl in formellem als auch in informellem Siedlungskontext zu analysieren. Außerdem werden die Bewältigungsstrategien und Anpassungen an die Abwassersituation in der Megastadt Delhi auf kommunaler und institutioneller Ebene untersucht. Unzulängliches Abwassermanagement, Standortnachteile und schlechte sozioökonomische Bedingungen manifestieren sich schließlich in Umwelt- und Gesundheitsproblemen. Die Vulnerabilität ist größer in informellen Siedlungen; sie bleibt zunächst unsichtbar oder wird nur schwach wahrgenommen, bis sie sich beispielsweise in einem massenhaften (Krankheits) ausbruch zeigt. Die individuelle Wahrnehmung spielt eine ebenso wichtige Rolle beim Verständnis von sozialer Vulnerabilität. Die Art und Weise, in der Individuen oder gesellschaftliche Gruppen abwasserspezifische Probleme wahrnehmen, beeinflusst sowohl das Ausmaß ihrer Gefährdung als auch ihre entsprechenden Reaktionen. Unterschiedliche gesellschaftliche Gruppen eignen sich unterschiedliche Anpassungs- und Bewältigungsstrategien an, um sich mit der Abwasserproblematik auseinanderzusetzen. Diese sind abhängig von ihrer Wahrnehmung, den verfügbaren Handlungsoptionen und ihren

Managementfähigkeiten. Die Ergebnisse dieser Studie, die auf empirischer Feldarbeit beruhen, unterstützen die theoretische Hypothese, dass Vulnerabilität aufgefasst werden kann als Wehrlosigkeit bestimmter Individuen/Haushalte/sozialer Gruppen gegenüber multiplen Arten von Stress, die auf vielfältige Weise negativ wirken. Der Grad der sozialen Vulnerabilität wird bestimmt durch das Verhältnis von Exposition gegenüber Abwasserproblemen und dem damit verbundenen Stress und den entsprechenden Bewältigungskapazitäten.

PREFACE

Living with infrastructural inadequacies is increasingly becoming a common urban characteristic. Denial of rights to basic services like provisions of safe water, sewerage and sanitation threatens human security against harmful exposures which translates into hazardous environmental and health through specific patterns of vulnerability, of physical, socio-economic and political origins. Though there is a growing realization of the negative impacts that wastewater have had on the local environment and human health but nature of social vulnerability and health security challenges associated with long term damaging processes – risks and hazards pertaining to increase in inadequately managed wastes and sewage has not been adequately prioritized by urban managers and simultaneously less studied by the experts.

Simultaneously, it is emphasized here that human security is not only related to protection against threats and harmful exposures but is also concerned with enhancing people's capabilities to self-help, response efficiently towards the hazardous events - cope and adapt to the situation of stress and be prepared to face the unknown events as far as possible. Ensuring human security and providing adequate and easily accessible basic services to all are some of the major responsibilities of good urban governance. But in fast expanding cities particularly of developing countries management crisis is a commonly observed phenomenon. It therefore demands a continued political will for timely, efficient and transparent civic management from the administrators and a responsible civic behaviour from the social community.

This comprehensive study is organised under nine chapters and it brings forth important issues of social vulnerability related to the ongoing sanitation and wastewater management crisis in megacity Delhi. It also explores the factors influencing household exposure to wastewater, their management capacity and resultant health implications. On these bases it identifies categories of vulnerable groups and the reasons behind their defenselessness. It moreover, outlines the constraints to effective response by institutions and social community and subsequently emphasizes the need for combined structural as well as non-structural solutions for alleviating water system related social vulnerability.

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DECLARATION

LIST OF ACRONYMS

AIIH&PH	All India Institute of Hygiene and Public Health
BIS	Bureau of Indian Standards
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
CSE	Centre for Science and Environment
DCB	Delhi Cantonment Board
DDA	Delhi Development Authority
DFID	Department for International Development
DJB	Delhi Jal Board
DTW	Deep Tube Well
DPSEEA	Driving Forces-Pressures-State-Exposure-Effects-Action
DUEIIP	Delhi Urban Environment and Infrastructure Improvement Project
DWSSDU	Delhi Water Supply and Sewage Disposal Undertaking
ECLAC-IADB	Economic Commission for Latin America and the Caribbean–Inter American Development Bank
ENVIS	Environmental Information System
FANR	Food, Agriculture and Natural Resources Sector Development Unit
FAO	Food and Agriculture Organization
GCI	Galvanised Corrugated Iron
GGWB	Central Ground Water Board
GIS	Geographic Information Systems
GNCTD	Government of National Capital Territory of Delhi
HEI	Household Exposure Index
HMCI	Household Management Capacity Index
HP	Hand Pump
IMD	Indian Meteorological Department
INR	Indian National Rupee
INTACH	Indian National Trust for Art, Cultural Heritage
IPCC	International Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
JE	Junior Engineer
JJ	*Jhuggi-Jhompri*
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
lpcd	litres per capita per day
MBAS	Methylene Blue Active Substances
MCD	Municipal Corporation of Delhi
MLD	Million Liters per Day
MoEF	Ministry for Environment and Forestry
MoUDPA	Ministry of Urban Development and Poverty Alleviation
NCAER	National Council of Applied Economic Research
NCR	National Capital Region
NCT	National Capital Territory

NDMC	New Delhi Municipal Corporation
NGO	Non-Governmental Organization
NIUA	National Institute for Urban Affairs
NNE-SSW	North North East-South South West
NSS	National Sample Survey
NSSO	National Sample Survey Organisation
PAHO	Pan American Health Organisation
PAR	Pressure and Release (model)
PSP	Private Sector Participation
RBC	Reinforced Brick Concrete
RCC	Reinforced Cement Concrete
RR	Relative Risk
RWA	Residents Welfare Association
SADC	Southern Africa Development Community
SARS	Severe Acute Respiratory Syndrome
SES	Socio-Ecological System
SFI	Santa Fe Institute
SIIHH	Sulabh International Institute of Health and Hygiene
SoVI	Social Vulnerability Index
STP	Sewerage Treatment Plant
TDS	Total Dissolved Solids
TERI	Tata Energy Research Institute
TSS	Total Suspend Solids
TW	Tube Well
UN	United Nations
UMP	Urban Management Program
UNCED	United Nations Conference on Environment and Development
UNCHS	United Nations Centre for Human Settlements
UNDP	United Nations Development Program
UNDP-BCPR	United Nations Development Program-Bureau for Crisis Prevention and Recovery
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESCO-IHE	United Nations Educational, Scientific and Cultural Organization-Institute for Water Education
UNEP	United Nation Environment Program
UNFPA	United Nations Population Fund
UNICEF	United Nations International Children's Emergency Fund
UN/ISDR	United Nations/International Strategy for Disaster Reduction
UNU-EHS	United Nations University-Environment and Human Security
UP	Uttar Pradesh
USD	United States Dollar
UTC	Universal Time Coordinated
WFP	World Food Program
WHO	World Health Organization
YAP	Yamuna Action Plan

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Chapter 1

Introduction and Overview

1.1 Introduction

This chapter demonstrates the statement of problem, particularly explaining why wastewater and sanitation issue is of increasing importance for megacities. Wastewater and sanitation-related infrastructural and management inadequacies are introduced as threats, challenges, vulnerability or risks for environmental and human health security issues for the affected people. It also elaborates the frame of the project of which this study is a part and explains the relevance of the research for Delhi. It further outlines the major objectives, research questions and hypothesis. Finally, provides an overview about the structure of this thesis.

1.2 Megacities: Water System and Vulnerability

Megacities are not only concentrations of people, enterprises, growth and opportunities but also nodes of inadequacies, crises, shocks and vulnerabilities, which are marked by complex socio-ecological processes as well as exceptional dynamisms of formal and informal settings. There has been phenomenal growth of megacities[1] in recent past which accommodate about 10% of world's urban population (UNFPA, 2007: 10). These are highly dynamic urban centers and their maintenance relies upon chains of consumption that pull in resources like water, food and power on one hand and generates huge volumes of wastes on the other (Pelling, 2007). Today megacities are increasingly referred to as hotspots of multiple risks, which results from overcrowded living conditions, infrastructural stress, increasing inequality, marginalization and failure of governance to address the basic services need of the citizens and adequately care for environmental and social wellbeing. This condition is particularly true for the megacities of the south and highlights many linkages threatening the security of people all over.

Human security in a broader sense also encompasses deprivation from good governance, access to basic services, health care and basic human rights as well as impoverishment,

[1] "The United Nations (UN) coined the term megacities in the 1970s to designate all urban agglomerations with a population of 8 million or more. In 1990s, the UN raised the population threshold to 10 million, following the practice of institutions such as the Asian Development Bank. The UN estimates that there are 19 megacities in the world at the beginning of the 21st century" (Brockerhoff 2000: 10).

pollution, illiteracy and exposures to other maladies (Ogata and Sen, 2003). There is a broad consensus globally that health is central for human security and development. Increasing infrastructural stress and ill-designed urban regulation are making cities huge centres of harmful perturbations. These pose enormous threats to environment and public health securities. Disadvantaged social groups are continuously exposed to day to day crisis of food, water and sanitation access; they are compelled to spend time and money in securing for themselves food and water, managing their own wastes and treating themselves against avoidable water-related illnesses like diarrhoea, dysentery, cholera, malaria, dengue, etc.

Quantitative and qualitative undersupply of basic infrastructure; water and sanitation, among many others is one of the major concerns, affecting large parts of the urban population. This is particularly true for urban water system entrusted with the task of providing safe water supply and disposal of waste water. Exposure to infrastructural stress induced harmful perturbations translates into human impacts through specific patterns of vulnerability of physical, economic and social origins. The nature of vulnerability associated with long-term damaging processes like environmental risks pertaining to increase in inadequately managed wastes and sewage has been underestimated and less prioritized by urban managers and simultaneously less understood and studied by the experts. There are technical literatures on critical infrastructure, particularly urban water and wastewater system sorting engineering solutions, but this continues to remain outside the lens of most social science research and vulnerability studies.

Concern about water-related problems has long existed but it came to the forefront only in 1977 when the United Nations brought water issues on the global arena. Further, the United Nations Conference on Environment and Development in Brazil in 1992 prioritized the importance of treating water as a 'scarce economic resource' and highlighted the importance of an integrated approach for managing water system in the following terms:

"A prerequisite for the sustainable management of water as a scarce vulnerable resource is the obligation to acknowledge in all planning and development its full costs. Planning

considerations should reflect benefits investment, environmental protection and operation costs, as well as the opportunity costs reflecting the most valuable alternative use of water. Actual charging need not necessarily burden all beneficiaries with the consequences of those considerations. Charging mechanisms should, however, reflect as far as possible both the true cost of water when used as an economic good and the ability of the communities to pay. The role of water as a social, economic and life-sustaining good should be reflected in demand management mechanisms and implemented through water conservation and reuse, resource assessment and financial instruments" (UNCED, Agenda 21, 1992: Para 18.16-17).

Domestic water supplies, wastewater disposal and sanitation provisions are the fundamental requirements for a decent settlement which bears direct impact on environmental and public health. The WHO has recognized that lacking or inadequate basic services make urban areas world's most threatening human environments. Many water-borne and water-related diseases are associated with inadequate disposal of wastewater, including a group of diseases for which water or wastewater provides a habitat for disease vectors or host (UN-Habitat, 2003). Diarrhea due to unsafe water, sanitation and hygiene account for 1.73 million deaths each year and is placed as the sixth major burden of disease on a global scale, a health burden that is largely preventable (WHO, 2002). Other water-related and water-washed diseases related to poor water, sanitation and hygiene are dysenteries, trachoma, schistosomiasis, conjunctivitis, hookworm disease, malaria and Japanese encephalitis. These contribute to an additional burden of disease on the marginalized groups (Howard and Bartram, 2003).

The Joint Monitoring Program for water and sanitation of WHO and UNICEF has defined improved sanitation facilities as those more likely to ensure privacy and hygienic use, characterized in terms of connection to a public sewer, connection to septic system, pour flush latrine or ventilated improved pit latrines. According to this definition, 59% of the world's population had access to improved sanitation and only about 31% lived in houses connected to a sewer in 2004 (WHO and UNICEF, 2006). With more than half of the population not connected to sewerage, resort to open washing, restricted water usage and other practices of compromised hygienic behaviour.

Lack of access to safe water supply and sanitation is directly related to poor health and environmental degradation and indirectly related to weak governance reflected through inability of the government to control and administer planned urban expansion ensuring adequate investment in provision and improvement of basic infrastructures. Health of people is strongly influenced by the prevailing environmental conditions as well as their level of economic and social prosperity. Poor and near-poor are more likely to be malnourished and develop a low immune system against diseases. This coupled with low capabilities to adequately respond to risks by adopting preventive measures and access health care facilities makes them perceivably more vulnerable and susceptible to welfare losses. Additionally, increased expenditure on treatment of water-related illnesses which could have been largely avoidable adds to their impoverishment.

The standard sanitation technology in urban areas is the collection of wastewater in sewers, its treatment in the wastewater treatment plants for reuse or disposal in other water bodies. Subsequently, a sustainable water and sewerage system demands a favourable ecological setting, adequate infrastructure for waste handling, and favourable institutional and political settings. In the absence of which sewerage and sanitation scenario, in most urban areas continue to be inadequate, despite longstanding efforts made by the various levels of government and communities at merely improving coverage. Sewerage and wastewater management in the cities have direct influence on the reduction of environmental, economic and health risks which translates to overall social wellbeing. Therefore, provision of adequate sewerage and proper wastewater management must always form an integral part of urban water system planning.

1.3 Why Study Wastewater Management Issues of Megacities in India

One of the most significant changes in the process of worldwide urbanization has been the growth of megacities. Megacities offer numerous opportunities for progress and better standard of living but at the same time they often remain in a crisis mode with respect to housing, water and sanitation, health and other basic amenities which are prerequisites for an acceptable standard of living. Although they develop in different locational settings, they still contain numerous commonalities with each other irrespective of their location in developed or developing world (Laquian, 1994). Post World War II rapid process of urbanisation began in the developing world, followed by intensive industrialization and migration into the cities (Kraas, 2003; 2007). UN forecasts suggest that the proportion of population living in cities would reach 60.2% by 2030 (UN, 2002: 4). Subsequently, the number of megacities (those with 10 million inhabitants or more) will increase from 17 in 2001 to 21 in 2015 (UN, 2002: 3). Currently, two-third of these large cities is located in the developing world and one-seventh in India alone. Indian megacities are typically characterized by its haphazardness; extreme congestion, wide disparity and close existence of formal and informal quarters. These are some features that make Indian megacities unique and interesting to be studied in terms of basic service provisions and accessibility of environmental and social infrastructure, particularly water and sewerage.

According to the 2001 Census about 70% of India's urban population lives in Class-I cities with above 100,000 population (Govt. of India, 2001a). Urbanization in India is so rapid that the infrastructure facilities and services provided to support large concentrations of population are adequate neither quantitatively nor qualitatively. In almost all the major cities of India, namely, Mumbai, Kolkata, Delhi and Chennai, constant attention has been diverted to increase the level of water supply without a commensurate improvement in the drainage and sewerage sector. Many cities do not even have a sewerage system and in places where such systems exist, their coverage is unequally distributed and capacities are highly inadequate to cope with the increasing pressures of unsegregated sewerage from various sources.

Over the last decade, water supply to Class-I cities has increased by 40% (CPCB, 2005). With the increasing water supply, the drainage managers are faced with the task of managing the generated wastewater for which the existing drainage infrastructure is totally inadequate. In addition to the generated wastewater, the sewerage system of cities also needs to carry huge volume of storm run-off due to increasing 'concretization[2]'. India receives over 75% of the total annual rainfall during the monsoon season from June to September and a major challenge remains to manage the huge volume of monsoon discharges during these months. Incapacity of the existing city drainage has resulted in increased incidences of urban flooding followed by epidemics not only disrupting the

[2] Concretization in this context refers to conversion of pervious grounds to cemented impervious surfaces.

daily life during monsoons but also affecting the overall quality of life in most of the metro cities in India (Gupta, 2006).

Wastewater generation is calculated at a minimum of 80 percent of water supplied but use of water from multiple sources leads to additional wastewater generation which may not be documented in official figures. Out of 414 Class-I cities, only 252 of them have partial sewage network (covering 50-70% of the inhabitants) and sewage treatment facilities (CPCB, 2000: 19). As per the updated status for the year 2003, it is estimated that 22,900 MLD (Million liters per day) of domestic wastewater is generated from urban centres against 13,500 MLD of industrial wastewater. The treatment capacity available for domestic wastewater is only for 5,900 MLD, against 8,000 MLD of industrial wastewater. This account for about 17,100 MLD of domestic wastewater to be disposed untreated. Thus, there is a big gap in the collection and treatment of domestic wastewater (CPCB, 2005).

Mumbai, Kolkata and Chennai generate 2,228 MLD, 1,383 MLD and 276 MLD of domestic wastewater respectively but only about two-third of them gets collected (CPCB, 2000). Recent estimation for the capital city of Delhi states the total wastewater generation to be 3,276 MLD which also includes 218 MLD from industrial sources whereas only 1,478 MLD receives effective treatment before disposal (CPCB, 2004). Treated as well as partially treated and untreated wastewater is disposed into natural drains joining other fresh water sources or used on land for irrigation.

Drainage and sewerage network in most Indian cities is highly skewed towards more advantageous zones leaving large extent of comparatively poor residential areas uncovered by sewerage network. This leaves a huge volume of wastewater uncollected by the existing sewerage network thereby create stagnation within urban areas causing cess pools and breeding ground for disease-carrying vectors. Unsafe conditions so created by inadequately managed wastewater pose severe risks to ecological and public health. Since a large volume of wastewater finally drains into rivers which are the major source of municipal water supply for most of the towns along their course; it is believed that every consumer has over the years been exposed to unknown quantities of pollutants in the water (CSE, 1982). Prolonged exposures to unreliable water supply, improper management of wastewater and inadequate sewerage form the core explanation for increasing environmental and health risks in urban settings.

Urban system vulnerabilities has been studied more with respect to risk pertaining to one time extreme events whereas continuous exposure to unsafe conditions and urban unreliability are as well risky and taxing on social communities more in terms of un-rectifiable long term impacts. However, the present case study would highlight the criticality to focus on urban risks and social vulnerability due to perpetual exposure to harmful or unfavourable perturbations of varying nature pertaining to physical, environmental, institutional and economic stresses. These may not necessarily be extreme events but still pose increased threats to environmental and human securities.

Studying wastewater risks in megacities and related social vulnerability would help to identify gaps in the existing system, hindrances that prohibit social groups from equally accessing the basic services and understand options for alternate solutions. Alleviation of wastewater problems would directly help in reducing environmental pollution risks, restoring resource sustainability and indirectly influence susceptibility towards welfare losses in terms of economic gains through improved public health and better quality of urban life. Since megacities can be seen as representative of urban settlements, their analysis would further provide foresights for timely rectification of water and sewerage sector infirmities for high number of emerging cities of the increasingly urbanized world in general and India in particular.

1.4 Megacity Delhi

Megacity Delhi is situated between 28°24´17″ and 28°53´00″ North Latitude and between 76°50´24″ and 77°20´37″ of East Longitude. It is surrounded by Ghaziabad (UP) in the east, Rohtak in the west, Sonepat in the north and Gurgaon in the south. Its maximum length and breadth are 51.90 km and 48.48 km respectively. The National Capital Territory (NCT) of Delhi with an area of 1,483 sq. km is one of the smallest states of India. It is divided into nine administrative districts. The area of Delhi is generally plain with rocky ridge in the centre. River Yamuna dominates the water bodies of Delhi.

Being the capital city, it maintains a more direct relationship with the central government which brings in many advantages in forms of special grants and subsidies (Zerah, 2000). Its status as an old historic city and favourable location with respect to approachability has further added to its credentials. In addition, Delhi has the largest cluster of modern small scale industries and is a major distribution centre for trade and commerce for the entire northern region. It is a national and international centre for the commercial, administrative and banking sectors too. Due to its attractions as an employment generator, Delhi's population has increased manifold in the last three decades, reaching an astounding figure of 15.3 million in 2005 and becoming the third largest city in India, next only to Mumbai and Kolkata. The population density in the city is also widely divergent, ranging from 1,300 persons per sq. km to 70,000 persons per sq. km. The population of the state of Delhi as a whole is growing fast mainly because of internal migration largely from the neighbouring rural areas. This is evident from constantly increasing urban population with proportional decrease in the rural counterpart (Table 1.1).

Table 1.1: Decadal Growth of Urban and Rural Population in Delhi

Year	Total Pop.	Urban pop.	(%) Urban pop.	Rural pop.	(%) Rural pop.
1901	405819	214115	52.76	191704	47.24
1911	413851	232837	57.50	181014	42.50
1921	488452	304420	62.32	184032	37.68
1931	636246	447442	70.33	188804	29.67
1941	917939	695686	75.79	222253	24.21
1951	1744072	1437134	82.40	306938	17.60
1961	2658612	2359408	88.75	299204	11.25
1971	4065698	3647023	89.68	418675	10.32
1981	6220406	5768200	92.73	452206	07.27
1991	9420644	8471625	89.93	949019	10.07
2001	13782976	12819761	93.01	963215	06.99

Source: Census of India, 2001a-Delhi and GNCTD, Economic Survey of Delhi 2005-2006

The tremendous inflow of migrants is accommodated in different types of settlements that have come up in Delhi with distinctive features in terms of level of civic amenities and legal status. The JJ clusters (squatter settlements almost equivalent to slum areas in international terminology) accommodate about 15% of the population; resettlement colonies, which are the low cost housing, are inhabited by 12.7%; about 5% of the population live in unauthorised colonies which are the residential pockets that have come up without legal approval from the municipal corporation, in an unplanned manner in violation of the Master Plan and Zonal Plan regulations; urban villages, located at the city fringes where provision of basic services is precarious, are inhabited by about 6% of the population. Only about 24% of inhabitants live in planned colonies which are approved quarters with presumably acceptable standards of basic amenities (Table 1.2).

Table 1.2: Settlement Status in Delhi

Type of settlement	Estimated population in lakh in 2000	% of Total population
JJ clusters	20.72	14.8
Slum Designated Areas	26.64	19.1
Unauthorised Colonies	7.40	5.3
JJ Resettlement Colonies	17.76	12.7
Rural Villages	7.40	5.3
Regularized-Unauthorised Colonies	17.76	12.7
Urban Villages	8.88	6.4
Planned Colonies	33.08	23.7
Total	139.64	100.00

Source: DUEIIP, Delhi-21 and GNCTD, Economic Survey of Delhi 2007-2008

Delhi was one of the first Indian cities to implement city planning by developing its first master plan already in the year 1962 (Zerah, 2000) following which the National Capital Region was established in order to divert population growth to the neighbouring states surrounding Delhi. But various master plans have failed to serve their purpose. Hyper-urbanization has expanded the city in an unplanned manner leading to proliferation of informal quarters which exist in violation with master plans and other developmental norms. Occupancy within the city itself has become increasingly dense with more than 9,200 inhabitants per km^2 in 2001 as against 6,352 in 1991 (Census of India, 2001a: 19).

The administrative and institutional setting in Delhi is quite complex as it is made up of several entities and is highly fragmented. The State's legislator often faces confrontation with the Central Government that tries to keep a control over the development of the Capital (Nagpaul, 1996). Numerous Departments in various capacities are involved in service provision and development activities in Delhi. There is unclear division of responsibilities and lack of co-ordination within divided institutional setup which negatively affects proper functioning and maintenance of the city system.

The trend of urbanization in Delhi, the complexities of administrative and institutional constraints as well as the environmental and health risks caused by uncontrolled and unplanned expansions are in many ways similar to the other existing and emerging megacities. In this respect, the analysis of Delhi holds better chances of transferability and makes a classic megacity case to be studied.

1.5 Relevance of the Study for Delhi

Delhi, with a population of over 15 million, is still growing as a megacity and according the UN forecasts it will cross 21 million by 2015 even with a slowing growth rate. This means all the problems presently faced will simply be multiplied in number and severity.

The population of Delhi is growing fast largely as a result of immigration. Within the last decade, the population has increased by 46%. Out of which 55% of the increase was due to migration and only 45% was natural growth (Census of India, 2001a). This tremendous inflow of immigrants is the main reason for increasing informality and proliferation of slums. Currently, more than 45% of the population is residing in unplanned settlements and is plagued by various sewerage and sanitation related problems (DUEIIP, 2001). The question still remains that blaming high population growth for neutralizing development effort is justifiable to what extent? Existence of large informal settlement is not new to Delhi; then why has the government failed to plan adequately for them?

There are significant inequalities in the regional distribution of infrastructures, particularly water and sanitation services, depending on the social status of the respective neighbourhoods. Only a small proportion of the population is legally connected while large unserved population either remains unconnected or makes illegal connection arrangements and uses unsafe practices of compromised hygiene. Improvements in sewerage and sanitation have merely meant increasing physical coverage whereas the quality of provided services is of highly substandard quality and the maintenance is grossly neglected. The city itself is affected by a high degree of fragmentation between urban upper class quarters and squatter settlements of urban poor, attesting strong heterogeneity within close proximity. Such steep social gradient has lead to physical and social boundaries and different types of access to sewerage and sanitation has developed.

Drinking water sources within the Delhi NCR (National Capital Region) are also quite limited and depend to a large degree on agreements with neighbouring states, which form the basis for continual political conflicts. The main sources of drinking water are the river Yamuna as well as depleting groundwater. The amount of water available to the users is further reduced by losses caused by leakages of about 40% in the ageing water supply system. Moreover, frequent changes in water pressure within the public network during the day further weaken the system. Freshwater lines, which often run close to drains, are affected by the ‘siphon-effect’, which is the intake of contaminated wastewater into the freshwater system due to a decrease in pressure (Krafft, Wolf and Aggarwal, 2003).

Wastewater generated from domestic, commercial and industrial establishments enter the same sewer system without segregation. Additionally, Delhi receives about 89% of total rainfall only during the monsoon months of June-September (IMD, 2005). The dilapidated and silted drainage system of the city is further burdened by additional storm water causing severe problem of monsoon flooding and inundation of low-lying areas. Currently Delhi generates 3,267 MLD of wastewater including 218 MLD from industrial sources. The corresponding treatment capacity is 2,330 MLD and capacity utilised is only 1,478 MLD (CPCB, 2004).

The existing capacity of treatment plants is under-utilized because of deficiency in the sewerage network including insufficient coverage and siltation. The trunk sewers are heavily silted and the internal and peripheral sewers are old and damaged due to which only a part of total amount of wastewater generated is actually collected and effectively treated. The balance untreated domestic sewage, toilet water, discharges from unsewered areas as well as treated effluents and overflows from the sewer system are discharged in open drains finally joining the river Yamuna, which form drinking water source for downstream communities.

Domestic wastewater is a main cause for surface and groundwater pollution, which further reduces the availability of usable water for future supply and consumption of contaminated water, poses severe risks to public health. The government has upgraded the treatment capacity, expanded and rehabilitated sewers, provided community sanitation and invested more than 115 million euros for upgrading the water quality along the 23-km stretch of Yamuna traversing Delhi (CSE, 2005). All such plans have actually failed in reality as the social communities continue to be exposed to wastewater nuisance and grapple with sewerage system inadequacies. It seems imperative to review why the government has failed to grant basic rights of safe water and adequate sewerage to all even after decades of planning? What are the inhibiting factors that constrain social communities to act locally?

Sewerage contamination of water supply is a major cause for increasing water-borne diseases like diarrhoea, dysentery, typhoid, etc. in the city. Moreover, puddles of stagnant wastewater form the breeding ground for disease-carrying vectors. According to a survey report conducted by the National Institute of Health and Family Welfare, fevers including malaria are the commonest illness in both adults and children and diarrhoea amongst the children is about four times more than the national average which is quantifiably attributable to hand-pump water, open drainage, open defecation and refuse disposal. As indicated in Singh (2008) that, though there is no comprehensive health data available for the whole city, some reference hospitals provide basic index data. According to data reported by a small sample of 22 index hospitals under the Municipal Corporation of Delhi, 77,355 cases of Gastro-enteritis, 1,784 cases of cholera and more than 900 cases of malaria were reported in a 12-months period (January-December 2004).

Although sanitation and hygiene is a household decision but adequate provision of basic infrastructure and maintaining them in acceptable standard is a major responsibility of civic agencies. The quality of life for residents of Delhi is directly influenced by the standard of basic amenities and its accessibility and indirectly influenced by the quality of its management and overall urban governance. The common fundamental questions that still remain to be answered are:

- Why benefits of urbanization are coming at environmental and health costs?

- How can urbanization be balanced with ecological sustainability?
- Why is the present level of urban management and governance not effective?
- How can city system be made more resilient to inadequacies and stresses?

Though these questions cannot be answered fully but probing into them would provide some insight into existing gaps in urban management that is making city life increasingly vulnerable. It would further help in identifying the point of action and policy intervention and recognize appropriate approach for suitable or alternate solutions. At the same time, analysis of Delhi case can provide perspective for other cities grappling with similar problems.

1.6 Aims and Objectives

This study is embedded into a bigger project entitled “Vulnerability in Megacities: New Approaches to Analyse the Urban Water System in Delhi/India.” It aims at gaining a new perspective on vulnerability in megacities focusing on water supply, waste water disposal and health. In detail, the research project focuses on the following aspects taking the example of Delhi/India: (1) Analyzing the supply with water and waste water disposal – with respect to physical and socio-economic aspects at certain risk areas by identifying in detail those areas in which vulnerable population groups are living within the megacity. (2) Identifying and analyzing types and degrees of vulnerability pertaining to municipal and private water supply, waste water disposal and management. (3) Recognizing vulnerability by visible spatial structures with high-resolution satellite data and Geographic Information Systems (GIS). (4) Critically assessing the methods and developing combined analytical tools. Three individual PhD researches are proposed to work on different aspects (water, wastewater and remote sensing); taking up each in detail individually and later integration of the derived results is intended.

The present study was subsequently framed keeping the above objectives of the main project in mind as the findings from this study would later make important contribution towards the goals of the main project. In this context the main objective of this part of the project is to analyse potential risks related to wastewater and sewerage causes of defencelessness threatening environmental and human health securities of different social groups due to changes in the physical, socio-economical, infrastructural and institutional environments of the city and further to explore the social and institutional coping strategies and adaptation measures in response to the prevailing situation of multiple stresses that enable urban citizens to continue live with risk. It places a special focus on problem areas relevant for development policies and non-structural solutions aiming at reduction of social defencelessness and strengthening resilience.

With this as the main aim in mind certain objectives were outlined as follows:

1. Examining the wastewater generation and disposal system in selected areas;
2. Understanding the nature of wastewater problem and the factors contributing to it;
3. Identifying various means of wastewater exposures and risks;
4. Identifying and analyzing the types and degree of vulnerability with respect to sanitation and sewerage component of the city;
5. Understanding people's perception and awareness regarding wastewater-related problems and implications;
6. Identifying measures adopted by the community and those by the institution for wastewater management.

1.7 Research Questions

In order to achieve the aims and objectives, some specific research questions were raised:

1. Where mainly is wastewater generated and what is the status of its management?
2. What are the risks of wastewater mismanagement in the study areas?
3. How are people exposed to wastewater and what are the causes for their defencelessness?
4. What are the household and institutional responses and how effective are they?
5. Which individual/households/social groups are more vulnerable and why?
6. What are the possible solutions for prevailing wastewater problems?

1.8 Structure of the Thesis

The structure of the thesis more or less reflects the sequence of the major aims and objectives of the study mentioned earlier and are accordingly organised under nine chapters:

Chapter 1 introduces the research topic and elaborates the statement of problem. It highlights the need for studying wastewater problems of megacities and elucidates its relevance for Delhi. It further gives a broad overview of the project of which this study is a part. Later the major aim and objectives, research questions and hypothesis are outlined.

Chapter 2 focuses upon the state of art, explains the conceptualisation and elaborates upon the adopted research design for the study. Existing literature relating to urban water system and vulnerability has been reviewed chronologically, highlighting the paradigm shifts in research focus. Under the light of existing literature, a conceptual framework for the present study is discussed. Procedures for identification and selection of the test sites are explained and further the data sources, adopted approaches and methodology of analyses are outlined in this chapter.

Chapter 3 attempts at examining the existing wastewater and sanitation situation in Delhi. It further investigates the level of water supply, wastewater generation, collection, treatment and disposal as prevails in the study areas and compares it with that of the whole city. In general it highlights the nature of wastewater problems in formal and informal residential quarters, identifies the affected zones and presents a wastewater profile of the surveyed localities.

Chapter 4 explains social vulnerability related to wastewater. It introduces the perspective on social vulnerability with particular reference to wastewater hazards. It also explains the basis for identifying different types of vulnerability; particularly elaborating upon meaning and approaches for analyzing social vulnerability. Various components of social vulnerability in terms of exposure, coping capacity, people’s perception and result implications are further elaborated. Each component is then taken up individually in the succeeding chapters.

Chapter 5 is on the external side of social vulnerability and exposures to wastewater. It discusses the various routes of wastewater exposures as persistent in the surveyed localities. It further explores different physical factors which predispose communities to be exposed to wastewater nuisance in their locational setting. Finally a Household Exposure Index is developed to assess the external dimension of wastewater-related vulnerability.

Chapter 6 describes the internal aspects of social vulnerability discussing how socio-economic status, knowledge, awareness and social networking help strengthening the coping capabilities, which influence a community's response towards wastewater hazard. It brings forth the institutional and social constraints which hinders communities from helping themselves. Further, it makes a comparative study of people's perception of the exposure risk across colony types and shows how perception plays an important role in getting the resource capacity functional.

Chapter 7 explains the causes for wastewater mismanagement operating at different levels followed by identification of risks and potential implications. It primarily focuses on the implications of infrastructural stress on urban health in terms of environmental degradation, health burden and allied social and economic costs. Finally household exposure and morbidity relationship is worked for re-establishing the degree of causal links between them.

Chapter 8 outlines the community and institutional responses towards wastewater problems analysing the strategies adopted for its prevention as well as coping. It evaluates the effectiveness of the organised and unorganised responses and identifies the existing gaps. Further, it elaborates the institutional shortcomings and constraints at household level that have been acting as prohibiting factors for effective responses.

Chapter 9 concludes the thesis and summarises answers to all the proposed research questions. On the basis of major findings suggestions and recommendations are made to show how best social vulnerability to wastewater can be reduced. It explicitly mentions the required actions and interventions, and also reiterates the need for making a city a resilient system. Further, the scope and limitations of the study are outlined.

Chapter 2

Conceptualization and Research Design

2.1 Introduction

This chapter talks about the state of art and introduces the conceptual framework focusing on how water system inadequacies and infrastructural stress is a means of exposure and social vulnerability. The extensive literature on water and wastewater studies has been reviewed. It points out the shifting focus in water and sanitation sector research over time and brings forth the lacunae in knowledge about social vulnerability due to chronic and long-term damaging process. In the light of existing information the research framework is conceptualized with the idea to relate urbanization-led water system infrastructural stress to progressing social vulnerability and human insecurity. The research design, data sources, methodology of analysis and expected outcomes are then outlined.

2.2 Conceptual Framework

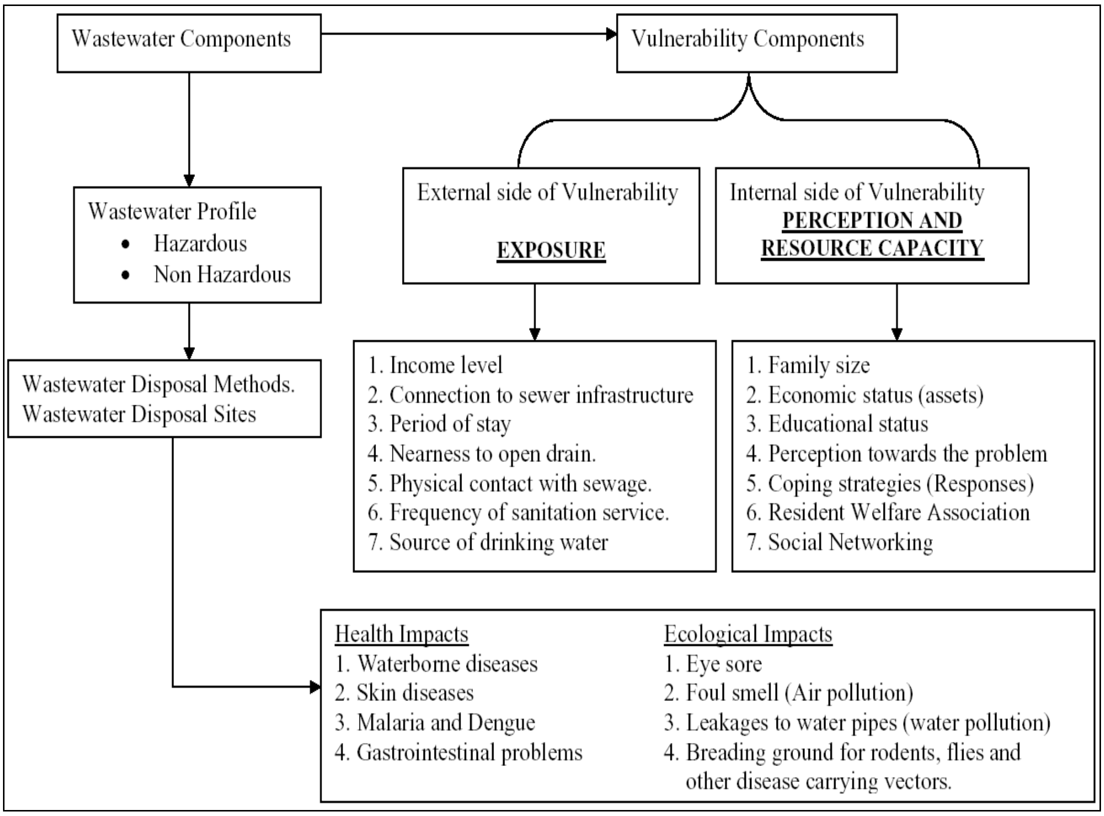
Social vulnerability is seen as one dimension in vulnerability study focusing on human inability to withstand adverse impacts triggered by multiple stressors and shocks (Blaikie *et al*., 1994; Henninger, 1998; Frankenberger, Drinkwater and Maxwell, 2000; Alwang, Siegel and Jørgensen, 2001; Oliver-Smith, 2004; Cannon, Twigg and Rowell, 2005; Wisner *et al*., 2004). In this context of analyzing social vulnerability to wastewater risks, the main focus remains to grasp the characteristics of households in terms of their susceptibility to harm caused by the existing wastewater and sanitation situation and their capacity to anticipate and cope with the situation within their given resources.

The study is conceptualized in two stages: firstly, looking at the interlinkages between the components of wastewater and vulnerability and later social vulnerability of wastewater related threats is further developed and conceptually positioned at the nexus of uncontrolled urbanization led infrastructural stress on one hand and environmental-health implications on the other. The study conceptualization was largely inspired by two main vulnerability models: PAR model (Blaike *et al*., 1994 and Wisner *et al*., 2004) and the double structure model of vulnerability developed by Bohle in 2001. The concept of environment and health linkages was also indirectly influenced by the Driving Forces-

Pressures-State-Exposure-Effects-Action (DPSEEA) framework of WHO developed by Corvalán, Briggs and Kjellstrom in 1996.

Firstly, a framework is developed for analysing link between wastewater and vulnerability components (Fig. 2.1). Exposure occurs when humans encounter the contaminants within the given environment. The manner in which an individual or social group perceives existing problem affects the extent of their exposure (external side) and moulds their response towards it (internal side). The external side of vulnerability (wastewater exposure) is primarily analyzed through their level of income, period of stay, nearness to open drain, connection to sewer system, physical contact with sewage, frequency of sanitation services and their sources of drinking water. While the internal side (resource capacity of the social groups) is analyzed with the help of factors like their family size, economic and educational status, perception and level of awareness, access to available preventive measures and level of social networking.

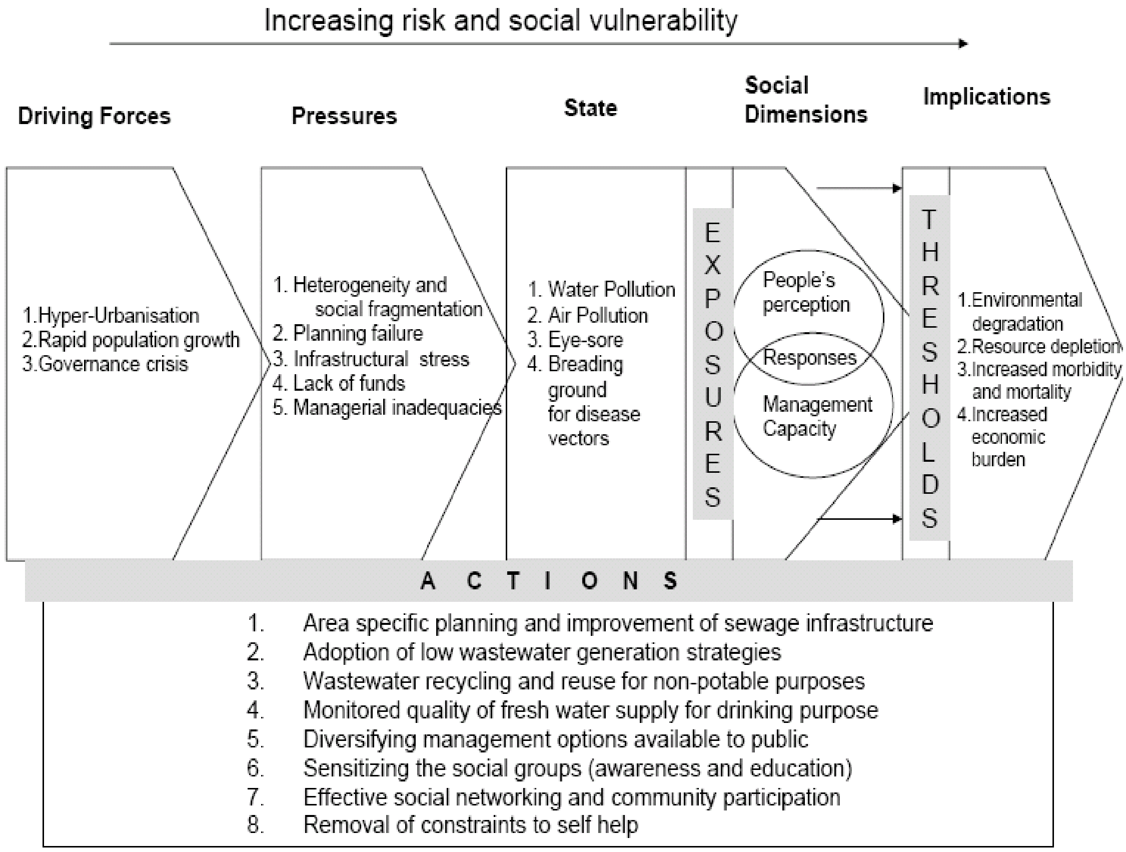
Fig. 2.1: Framework for Analysing Link between Wastewater and Vulnerability



Source: Own draft

In the second stage of conceptualization, framework for studying improper wastewater management/wastewater problems driven social vulnerability is developed following major vulnerability models by Blaikie *et al*., 1994, Wisner *et al*., 2004, Bohle, 2001 and DPSEEA model by Corvalán, Briggs and Kjellstrom, 1996 (Fig. 2.2).

Fig. 2.2: Components of Wastewater Problems Driven Social Vulnerability



Source: Own draft (Influenced by Blaikie *et al*., 1994; Wisner *et al*., 2004; Corvalán, Briggs and Kjellstrom, 1996)

Driving forces of unruly urbanization and improper urban governance leads to much pressures in the form of infrastructural stress giving rise to a state of unsafe conditions. Prolonged exposures to harmful perturbations are counteracted by various compensating forces in form of coping measures depending upon social perception and resource capacity. After crossing the threshold, harmful perturbations get manifested as environmental-health implications. Thresholds here are the limits when the environmental self-cleaning capacity is exhausted and for human's when the immunity level is crossed. A range of health implications may then occur from minor illnesses, to death, depending upon the intrinsic harmfulness of the pollutant and the severity of exposure and the susceptibility of the individual concerned.

People belonging to different socio-economic strata, gender and age groups adopt different management and adaptation strategies as well as develop varying levels of resistance to the harmful exposures and thus are affected differently. This is eventually reflected in the wellness of the environmental and public health. It is important to understand people's perception and the level of risk awareness among individuals and social groups, which in turn gets their responses mobilised. Awareness also helps to strengthen the coping capabilities of the social groups in terms of getting timely preventive measures in place and adopting the appropriate measures for recovery (in case the event has occurred). In this respect, people's perception is attempted to be placed theoretically as an important component in social vulnerability study.

2.3 Urban Water System and Vulnerability Researches

Urban water system refers to the natural as well as manmade system that exists in towns and cities and is entrusted with the task of safe water supply and wastewater disposal in an environmental-friendly manner. Wastewater component cannot be studied in isolation as it is entwined with and greatly influenced by the status of water supply which forms the input in a system that needs to be removed from the system after use in form of wastewater. Therefore, it seemed logical to review the state-of-art beginning for urban water system in general first and then narrowing down to wastewater system. This would involve studying how the focus of water and wastewater infrastructure provision and management experienced paradigm shifts over time and where we stand now.

Various issues related to water supply and wastewater disposal always existed and will possibly remain so for coming decades. It is only with the changing time that certain specific issues gained greater prominence and attention. Urban water system researches had geographical orientations since the beginning of the 19th century (Burkalow, 1959; Dietrich and Henderson, 1963) when it primarily focused on the reporting of spatial patterns and physical hindrances. Interestingly, in recent years this topic has attracted more social focus and expanded the dimension to include unreliability, societal defenselessness, ill-comings and allied economic penalty (Zerah, 2000; UN-Habitat, 2004; Collins and Bolin, 2007).

2.3.1 Urban Water Supply

The inadequacy of municipal water services in many cities has become more acute under the burden of population growth and urban migration. Majority of urban centres in the developing world have overloaded water supplies which are working at inadequate pressure, or are plagued with contaminated distribution systems (Pineo and Subrahmanyam, 1975; Dietrich and Henderson, 1963; Damme, 1973; Bannaga, 1979). Water related problem is not specific of developing countries only; even developed nations have their share of problem, but they are better equipped with measures and coping strategies to deal with it.

The growing problem of water had strong institutional reasons in developing countries. Saunders and Warford (1976) in their work on village water supply looked into the problems and policies related to water supply in the developing world. This was rather the first attempt of its kind. Kasperson and Kasperson (1977) edited a volume in which they examined the notions of how technological innovations occur in society and how diffusion takes place. Their integration of economic, sociological, political and public health issues allow the application of an important body of theory and method to an overall process, which has often been treated as piecemeal.

Water experts of 19th century emphasised the importance of water quality (Camp, 1963; Scott, 1970). Irrational human activities emerged as important factor for water resource degradation (Kudesia, 1980; Mahida, 1981; Chaphekar and Mhatre, 1986) primarily for rivers along which human occupancy developed. With threatened pollution of water resource base future supply was seen at stake.

It was during the late 1990s that the concept of sustainability was being applied to almost all the concerned resources, identifying the prospect of it from all sides ranging from analysis of usage pattern, identification of stress areas to analysis of prospects for sustainability (Raskin, Hasen and Margolis, 1996; Pickford *et al*., 1996) A long range conventional development scenario was introduced during this period based on a vision of the future in which the values, consumption patterns and dynamics of the western industrial society will be progressively played out on a global scale.

Later during the 1990s increasing severity of water problem and foreseen scarcity made it an 'economic resource' (Winpenny, 1994). Briscoe and Garn (1995) published a paper in Natural Resource Forum where they took up the view of attaching 'price tags' to water supply and sanitation, as was tentatively done in Agenda 21 and received wide acceptance by the world's water professionals. Analyzing the economies involved, cost and pricing of water and estimation of people's willingness and ability to pay for improved water supply and sanitation increases the understanding of its social benefits and assists governmental management of water sector (Briscoe, 1996, 1997; Rogers, Bhatia and Huber, 1998). It is further argued that water should be regarded as an economic and social good but in a broad rather than a narrow strictly economist sense.

Since water resources were discussed within the context of sustainable development addressing some practical and some more philosophical aspects of the matters, and how these relate to the concerns of different international organizations involved in the sector, all proposed measures aimed at attaining sustainable urban water system. This included management of water from demand as well as supply side (Nathanson, 1997) and sustainable infrastructural design at city scale (Jenks, Burton and Williams, 1996; Newman and Kenworthy, 1999) and neighbourhood (Rudlin and Falk, 1999; Berg and Nycander, 1997). Clark, Perkins and Wood (1997) emphasize the need for the integration and decentralization of water supply, wastewater and storm water systems and assessment of social, economic and environmental impacts.

While dealing with the management of water resources, one aspect of wastewater which was simultaneously dealt with was 'water pollution'. The main concern of wastewater management is not completely exclusive; it has its relation with water resource management itself. Be it management of wastewater to combat sewage pollution of water supply, reuse of renovated wastewater for curbing the demand of freshwater or provision of proper sewerage and sanitation for health gains, they all aim directly towards sustainable urban water system and indirectly towards reducing vulnerabilities related to environment and public health risks. In this regard there is much debate as to what extent water system can be improved through proper sewerage and wastewater management.

2.3.2 Urban Wastewater and its Management

What is wastewater? Wastewater is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industries, hospitals and/or agriculture. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources. Sewage is correctly the subset of wastewater that is contaminated with fecal matter but is often used to mean any waste water. It includes domestic, municipal, or industrial liquid waste products disposed via a pipe or sewer or similar structures. Smith *et al*., (2002) defines domestic wastewater as waste generated by household activities including toilet, bathroom, clothes washing and kitchen cleaning activities. Cities generate waste water in terms of 'grey water' (domestic wastewater without human excreta) and black water (domestic wastewater with human excreta). The total grey wastewater fraction has been estimated to account for about 75% of the combined domestic sewage (Pal, 2000 and Eriksson *et al*., 2002).

Understanding the type of wastewater and to what kind of issues it may lead to was enormously explored during the later half of the 1990s. Literature prior to 1990s dealt mostly with the treatment options of wastewater and produced sludge; all publications in this regard are highly technical, looking at the problem from the engineering point of view and simultaneously recommending ways and means of improving the performance of the existing system and subsequently reducing potential effects of wastewater on the environment (Shronts *et al*., 1996; Stoll, 1996). There remains documentation of the characteristics of wastewater which could determine the degree of its treatability and the effectiveness of the sewerage treatment system in combating environmental degradation (Kavvas, 2002). All these studies dealt with the handling of wastewater and thereby always aimed at improving the infrastructure supply to enhance performance and reduce the contaminants (Gray and Becker, 2002; Parkinson, 2003)

Keeping with the ongoing current of sustainable development, various studies aiming at developing strategies for sustainable wastewater management were conducted (Kärrman, 2001; Geerse and Lobbrecht, 2002). Much effort was being put into the development of tools for assessment and decision support. Subsequently, formulation of criteria, indicators and standards of various kinds were developed (Hellström, Jeppson and Kärrman, 2000; Ashley and Hopkinson, 2002). Various water supply and wastewater discharge standards are proposed in WHO and UNEP publications which are necessary to be maintained for protecting the environment and resource base. But to what extent such standards are met in real world with varying conditions is debatable. Sperling and Chernicharo (2002) in the paper entitled 'Urban wastewater treatment technologies and the implementation of discharge standards in developing countries', analyse the practical implementation of standards with special focus on typical problems with setting of such standards in developing nations with limited resources.

The quality and reliability of local services are taken for granted in developed countries but poor quality and limited access to the basic infrastructure services are major impediments and source of frustration among the population in the developing world. There exists simultaneous explanation from political point of view elaborating the governance issues in operation of urban services in developing countries, further arguing poverty as the basic issue in keeping majority of urban poor aloof from sanitation right (Harpham and Boateng, 1997; Chaplin, 1999). The poor households in developing countries often only have access to primitive or communal sanitation services. The lack of access to basic services reduces the quality of life and makes the communities in informal settlements particularly vulnerable to disease and epidemics (UN-Habitat, 2004; Biswas, Jayatilika and Tortajada, 2005).

It is evident that earlier water was the main focus and eventually the management of wastewater so generated started gaining importance in research. The management aspect of wastewater also experienced paradigm shifts with time. Since the early 20th century, the issue of wastewater was a thing of grave concern and a critical problem, and researches from various fields contributed immensely towards its management. Earlier the analysis of the problem was done trying to see which sector was the main culprit and how the problem could be addressed in a holistic manner, but soon the issues started getting more structured and so were the strategies of dealing with them, classifying them under domestic-, industrial- and commercial-based. It was only towards the later part of the 20th century that emerging health problem was also been seen as an impact of urban wastewater mismanagement, more so in India.

2.3.3 Wastewater Mismanagement Related Risks

Wastewater is a serious source of contamination for surface water as well as ground water (Fox, 1993; Hoxley and Dudding, 1994), especially through various effluent disposal practices like unsewered sanitation, mismanaged sewerage, on-site sewage treatment systems and sewage leakages (Reneau, Hagedorn and Degen, 1989; Scandura and Sobsey, 1997; Froese and Bodo, 1999; Foster, 2001). Foster further noted that as cities expand they degrade their own periurban water fields either directly through in situ sanitation, industrial discharges and leaking sewer or because of infiltration of polluted surface watercourses.

One of the earliest works related to wastewater and public health was done in 1982, where Berger discussed the engineering approaches in controlling microbial agents of water-borne diseases and the chemicals that have been actually or potentially implicated in producing human illness through the water supply route. Sir John Snow’s investigation in the 1850s led to the incrimination of the Broad Street pump as the cause for high cholera incidence (Longmate, 1970), and it has been followed by a number of other cases where polluted water has been proved to be the cause of various infections (WHO, 1973; Pineo and Subrahmanyam, 1975; Ho and Tam, 1998).

Concern about environmental and public health gained further ascendancy since 2000 when the American Public Health Association raised a serious apprehension over continued occurrences of illness and death caused by contaminated drinking water. Common contaminants of concern included Hepatits-A, Rotavirus and Cryptosporidum parvum. The bacteria, viruses and protozoa that are of major concern in drinking water are usually of fecal origin. Nitrates from seeping septic tanks or fertilizers can also be deleterious to health; especially the immune-deficient people, children and elderly are at a higher risk from contaminated water (American Public Health Association, 2000).

Such risks to public health arise only when wastewater contaminates drinking water, when water is used for recreational purposes or if there is direct contact with effluent especially in unsewered areas. Illnesses resulting from contact or ingestion of such bacterial contaminated water include skin rashes, irritation, vomiting, liver damages, hepatitis and gastroenteritis (Eynard, Mez and Walther, 2000; McDonald *et al.*, 2001; Gaffield *et al.*, 2003; Porto, 2004). Additionally, stagnant sewage form favourable habitat for vector borne diseases like malaria and dengue. Wastewater poses not only environmental and public health risks but also economic risks in terms of additional income incurred by the community which could be largely avoidable (Smith *et al.*, 2002). Moreover, trying to alleviate years of environmental contamination is costly and involves overcoming a host of practical issues; therefore, management should be focused on prevention of risks itself.

These aspects of wastewater contamination and related risks are not well documented in the Indian context. When coming to Delhi specific studies much of the focus have always been on the water problems in the city; very less social research has been done on the wastewater aspect. The existing literature on wastewater on Delhi are mainly institutional reports by Delhi Jal Board (DJB), Central Pollution Control Board (CPCB), Ministry of Environment and Forestry (MoEF), and Center for Science and Environment (CSE). From the various review of the reports, it is clear that the management (state), of late, is aware of the wastewater and sewage problem in the city. Since 2000, there are reports which elaborate the existing condition of sanitation in the city and call for immediate steps in this regard. But the area of public health and vulnerability of the disadvantaged groups has been considerably neglected. These reports are either descriptive or evaluatory of the existing system from the technical aspect, primarily done for reporting the status and largely sorting costly engineering solutions. The social aspect by so far has been ignored and the perception of people towards this problem is neither talked about nor represented in them.

2.3.4 Vulnerability

Vulnerability has been studied by various discipline including economics, sociology, anthropology, disaster management, environmental science and health/nutrition through different approaches which have been adapted over time. The term 'vulnerability' is often used in a number of contexts more prominently in development literature and relief field and as a fundamental aspect of global environmental change. It is increasingly being viewed also through the lens of social sciences (Chambers, 1989; Liverman, 1990, 1992; Dow, 1992; Watts and Bohle, 1993; Blaike *et al*., 1994; Kasperson, Kasperson and Turner, 1995). The point of concern for geographers, among all these, remains the spatial dimension of social vulnerability while some social geographers have also talked about vulnerable people. The focus here is primarily on people who for whatever reasons are reckoned to be at risk of being hurt, damaged and discriminated (Knox, 1989).

A range of vulnerability definition developed over the period of time has been brought together in table 2.1.

Table: 2.1: Selected Definitions of Vulnerability

Timmerman (1981: 21)	"Vulnerability is the degree to which a system acts adversely to the occurrence of a hazardous event. The degree and quality of the adverse reaction are conditioned by a system's resilience (a measure of the system's capacity to absorb and recover from the occurrence of a hazardous event)".
Susman *et al*. (1983: 264)	vulnerability is "the degree to which different classes of society are differentially at risk, both in terms of the probability of occurrence of an extreme physical event and the degree to which the community absorbs the effects of extreme physical events and helps different classes to recover".
Downing (1991: 372)	"Vulnerability has three connotations: it refers to a consequence rather than a cause; it implies an adverse consequence and it is a relative term that differentiates among socioeconomic groups or regions, rather than an absolute measure of deprivation".

G. Wilches-Chaux (1993: 17)	proposed the notion of vulnerability as "the incapacity of a community to absorb, via auto-adjustments, the impacts of a change in the environment"
Watts and Bohle (1993: 45-46)	"Vulnerability is defined in terms of exposure, capacity and potentiality. Accordingly, the prescriptive and normative response to vulnerability is to reduce exposure, enhance coping capacity, strengthen recovery potential and bolster damage control via private and public means".
Blaikie *et al*. (1994: 9)	by vulnerability we mean "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by a discrete and identifiable event in nature or in society".
Bohle *et al*. (1994: 37-39)	"Vulnerability is best defined as an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of potential harmful perturbations". "It is a multilayered and multidimensional social space defined by the determinate, political, economic and institutional capabilities of people in specific places at specific times".
Adger (1999: 252)	defines social vulnerability as the "exposure of individuals to stress as a result of the impacts of climate change and related climate extremes".
ECLAC-IADB (2000: 1)	vulnerability is "the probability of a community, exposed to a natural hazard, given the degree of fragility of its elements (infrastructure, housing, productive activities, degree of organisation, warning systems, political and institutional developments) to suffer human and material damages".
R. Pizarro (2001: 11)	defines social vulnerability in terms of two components: "the insecurity and defenselessness experimented by communities, families, and individuals in their livelihoods as a consequence of the impact of a socio-economic event of traumatic character; and the second component is the management of resources and strategies which are utilized by these communities, families, and individuals to cope with the effects of this event".
IPCC (2001: 388)	defines vulnerability as "the degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude and rate of climate variation to which the system is exposed, its sensitivity and its adaptive capacity".
Hewitt (2003: 299)	a vulnerability perspective "considers especially how communities are exposed to dangers, the ways in which they are

	readily harmed, and the protection that they lack." Vulnerability to a hazard is to a large extent created by the respective social order on the division of labour, cultural values and on legal rights. Thus, vulnerability is a "relative condition, and can only be defined and assessed in relation to the safety which others actually enjoy."
Turner *et al*. (2003: 8074)	defines vulnerability as "the degree to which a system, sub system or system component is likely to experience harm due to exposure to a hazard either a perturbation or stress stressor".
Pelling (2003: 5)	defines vulnerability as the "exposure to risk and an inability to avoid or absorb potential harm". In this context, he defines physical vulnerability as the "vulnerability of the physical environment"; social vulnerability as "experienced by people and their social, economic, and political systems"; and human vulnerability as "the combination of physical and social vulnerability".
UNDP-BCPR (2004: 136)	human vulnerability is defined as "a condition or process resulting from physical, social, economic and environmental factors which determine the likelihood and scale of damage from the impact of a given hazard".
UN/ISDR (2004: 16)	defined vulnerability "as a set of conditions and processes resulting from physical, social, economical, and environmental factors, which increase the susceptibility of a community to the impact of hazards". These conditions are shaped "continually by attitudinal, behavioral, cultural, socio-economic and political influences at the individuals, families, communities, and countries."

Sources: Compiled from Dow (1992); Cutter (1996); Hogan and Marandola (2005); Brauch (2005a) and Villagrán de León (2006)

Vulnerability has been defined in various ways, in synonymy to poverty or with certain kinds of production systems (Parry and Carter, 1987). While talking about production systems, Wisner (1993) argues that while farming in marginal areas vulnerability constituted is of the system and not the household. Under the notion of biophysical dynamics acting upon social, economic and political production of the environment, Blaike *et al*. defined vulnerability as "…the characteristics of person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Blaike *et al*., 1994: 9).

One of the most elaborated definitions of vulnerability to date is provided by Chambers. He defines vulnerability as: "…the exposure to contingencies and stress, and difficulty coping with them. Vulnerability has thus two sides: an external side of risks, shocks and stress to which an individual or household is subject; and an internal side which is defenselessness, meaning a lack of means to cope without damaging loss" (Chambers, 1989: 1). Coping would require people to reduce their physical exposure to a hazard and access resources needed to restore normalcy.

Watts and Bohle further refined the understanding of vulnerability and elaborate upon the space of vulnerability: "Vulnerability is a multilayered and multidimensional social space defined by the determinate, political, economic and institutional capabilities of people in specific places and specific times" (Watts and Bohle, 1993: 46). In their view space of vulnerability is defined by three distinctive processes: "human ecology, expanded entitlements and political economy" (Bohle, Downing and Watts, 1994: 39). They further reiterate that vulnerability implies some form of external as well as internal dimensions that increasingly predispose people to risk and it is further suggest integrating the micro perspectives more closely for a better understanding of vulnerability (Bohle, 2001; 2006).

Eventually, focus is changing from vulnerability to resilience study. Vulnerability comes from a loss of resilience (Holling, 1995). Resilience is emerging as a key concept in the rapidly growing field of socio-ecological studies. The concept of resilience emerged in ecology and the social sciences during the 1970s in recognition that nature is inherently dynamic. Its intervention was specifically linked to critiques of equilibrium theories of environmental sciences (Franklin and Downing, 2004).

Recent developments in the field of vulnerability has further tried to broaden its perspective to include cultural, psychosocial and subjective determinants and impacts arising from natural disasters and from the experience of risk and hazard, as well as the incorporation of the notion of resilience, sensitivity, social capital and collective action in several studies (Wisner *et al*., 2004). It emphasize that an adequate understanding of vulnerability would require consideration for biophysical, economic, political and social aspects of risk (Burton, Kates and White, 1993; Greenberg and Thomas, 1994; Cutter, 1996; Wisner *et al*., 2004).

Risk is also closely tied to vulnerability and has been seen as an important component. Communities which are vulnerable are probably the ones more at risk. However, "...the determinants of both biophysical vulnerability and risk are essentially the same - hazard and social vulnerability. The natural hazards community, which emphasizes risk, and the climate change community, which emphasizes vulnerability, is essentially examining the same processes. However, this has not always been immediately apparent due to differences in terminology. Both are ultimately interested in the physical hazards that threaten human systems, and in the outcomes of such hazards as mediated by the properties of those systems, described variously in terms of vulnerability, sensitivity, resilience, coping ability and so on..." (Brooks, 2003: 7).

The above discussion highlights that most of the definitions of vulnerability revolve around biophysical, spatial or social aspects. Since the term vulnerability is used in a number of contexts with different disciplinarily focus, they all have invisible yet implied adjectives preceding them (Wisner *et al*., 2004). Hence; natural vulnerability, infrastructural vulnerability, economic vulnerability and social vulnerability are distinguished.

"...the vulnerability of people and places is an inherently geographical problem, one that necessitates a spatial solution" (Cutter, 2001: 8). It is rather impossible to separate spatial and social aspect of vulnerability; in fact much empirical evidences are there suggesting that social vulnerability is closely connected with spatial structures and processes (Ravallion and Wodon 1997; Pender and Hazell, 2000).

After achieving a broad understanding of different aspects of vulnerability, risk and capacity, focus of attention is shifting towards it analysis and measurement methods. Studies from Scoones (1996), Chambers (1989) and Davis (1996) concur to a common conclusion that aggregated approaches, which make generalizations about social groups in rural settings, are inadequate.

"Research on social vulnerability frequently deals with elements that are difficult to measure either because the factor of interest is difficult to quantify or the data is precarious" (Warner, 2007: 18). It is rather difficult to translate local information about social vulnerability into numbers and values upon which political decisions can be based. Certain commonly used methods for vulnerability assessment evolved are indicator approach; household modelling approach, income estimation approach and domestic resource capacity approach (Diriba, 1997).

By and large all the above-mentioned approaches aim at identifying numbers of geographic locations of people vulnerable to food insecurity and famine, classifying them as slightly, moderately, highly or extremely highly vulnerable. Household income is used as the framework for vulnerability. Households are divided into socio-economic groups and data are sought on various finite and objective indicators. These data are further combined with other subjective data to draw information on current levels of vulnerability in the various groups relative to baseline vulnerability (Vogel, 1998).

All these approaches suffer their share of drawbacks and, therefore, measurement of vulnerability in terms of risk-response-outcome components will continue to be a difficult undertaking since each discipline has its own reasons for defining and measuring vulnerability (Alwang, Siegel and Jørgensen, 2001).

The next step in vulnerability research is to move beyond measurement and aim at creation of tools to analyze the underlying causes of defencelessness and sort possible solutions (Birkmann, 2006). "We are either too focused on local social dynamics (qualitative case studies) or too analytical (empirical global models) to adequately address and explain the complex interactions between social, natural, and engineered systems" (Cutter, 2001: 8). What is needed now is a set of methodologies that can be used to transfer the findings of specific case studies to larger geographical areas (Bankoff, Frerks and Hilhorst, 2004).

2.3.5 Differential Focus of Water System and Vulnerability Researches

It can be derived from the above discussion that water and wastewater have been studied extensively by a range of experts and management specialist from various backgrounds and discipline. In order to better represent differential focus of the huge array of water and wastewater-related literature and to evaluate the extent of its linkage to vulnerability components, the available information was generally categorized under few major heads and their treatment was evaluated on the basis of approach, main focus and their link with vulnerability components: risk, perception, response and outcome (Table 2.2).

Table 2.2: General Treatment of Water and Wastewater Theme in Existing Literature

Literature	General Treatment							
	Approach		Main Focus		Link with Vulnerability			
	Conceptual	Empirical	Problem	Solution	Risk	Perception	Response	Outcome
Demand and Supply	+	++	+	++	0	0	+	+
Planning and Engineering	+	++	0	++	0	+	0	+
Management and Sustainability	++	+	++	+	+	0	0	+
Environment Aspects	+	++	++	+	++	0	0	++
Social and Health Aspects	+	+	++	0	+	0	0	+
Policies	0	+	+	++	0	0	0	0

0 Implicit treatment + Average treatment ++ Explicit treatment

Source: Own draft, after Alwang, Siegel and Jørgensen, 2001; Bohle, 2006

Some broad conclusions that can be made from above are:

- A concern with biophysical and environmental dimension guide approaches to water and wastewater management.
- Vulnerability study too usually concentrates on one of the key components: risk, perception, response or outcome.
- People’s understanding of risk, experience and perception has been only implicitly treated.

- Studies which are strong conceptually lack empirical testing while purely empirical studies are weak on conceptual fronts which limit their scope of transferability.

The above analysis of literature further suggests that a major proportion of vulnerability study till date has been focusing primarily on risks related to one-time extreme events like flood, drought, earthquake, volcano eruption etc. There exist very few research works on vulnerability related to long-term events like water scarcity, food insecurity and prolonged exposures to harmful environmental perturbations in forms of water pollution, wastewater exposures, air pollution etc. Therefore, this attempt to analyse social vulnerability to wastewater risks against the backdrop of uncontrolled urbanisation and infrastructural stress find much scope in developing vulnerability study.

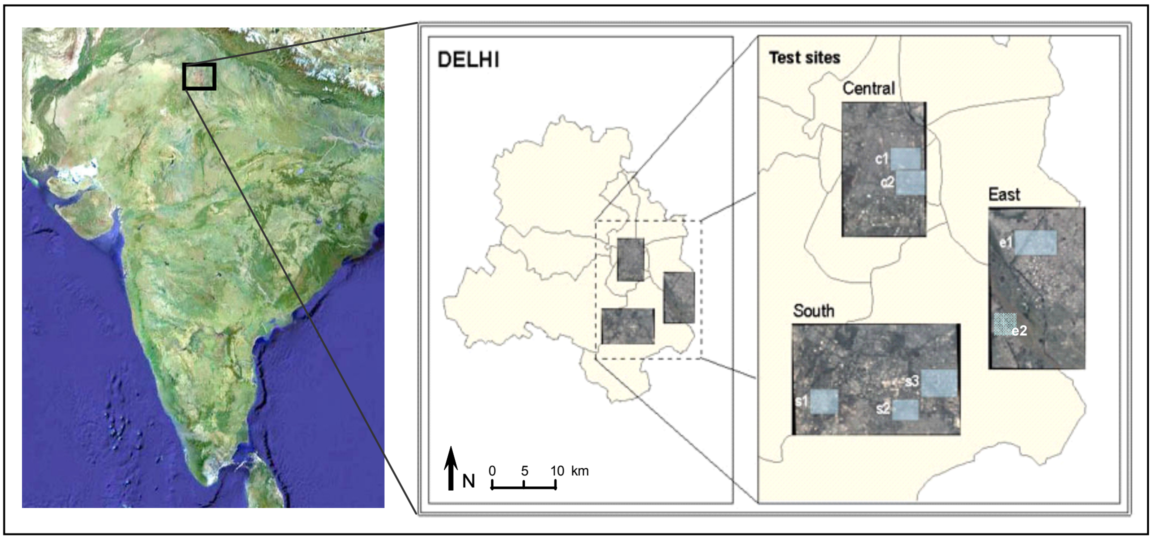
2.4 Research Design

It is again imperative to mention that the project, of which this study is a part, aimed at an integrated approach of remote sensing and social science research. Since covering the entire stretch of Delhi with high resolution images was beyond the financial scope of the project, therefore, specific area representation was needed. In this respect common test sites were selected for social as well as remote sensing analysis which was to be carried out by other colleagues working on the project.

2.4.1 Identification of Test Areas within NCT of Delhi

The present study intends to grasp a holistic picture of the city trying to cover information across different locational, social and settlement types. Therefore a kind of deductive approach was adapted. On the basis of a comprehensive literature review, satellite image information and prior knowledge of the local conditions, three different locational areas were selected where water and wastewater-related problems were best perceived and representative of the heterogeneous nature of the city. The locations of the test areas in Delhi are shown in figure 2.3.

Fig. 2.3: Selected Test Areas and Test Sites in Megacity Delhi



Source: Drafted by S. Niebergall

The specific selection of these test areas can be summarized as follows:

[1] Central Delhi (Central District), which represents a complex urban development evident in its mixed land use, co-existence of high rise and slums at very close quarters etc. It is the oldest part of the city ailing with ageing infrastructural problems. The walled city at the centre is also a notified slum area under city regulation with legal provision of water and wastewater infrastructure unlike the other informal residential quarters.

[2] South Delhi (South District), which is more disadvantageous in terms of water availability due to its location at the tail-end of the water provision system. This area represents the fringe of the city, dotted with urban villages also experiencing ground water depletion and contamination problems.

[3] Trans-Yamuna area (East District), which is experiencing mushrooming of lower and lower-middle class housing complexes primarily on marginal land. This part of the city is comparatively low-lying and consequently more affected with flooding and sewerage problems.

2.4.2 Selection of Test Sites within the Test Areas

The next step was the selection of test sites within each test area, following a new gradient approach (i.e., selection of particularly those areas in which structurally highly different residential areas are situated in direct vicinity) while specific care was taken to include various types and gradients of residential areas. The gradient approach would assist in system analysis and later help in transferring the results to other areas of similar gradient, thereby facilitating the city wide coverage. The different textures of the image represented different types of residential areas (such as so-called 'colonies') on the ground. In total, seven test sites were selected from three test areas (Table 2.3).

Table 2.3: Selected Test Areas and Localities in Delhi

Test Areas	Test Sites	Name of Localities
South Delhi (S)	S1	Mehrauli
	S2	Dakshinpuri, Harijan camp, Madangir camp, Deoli, Tigri, Nai Basti, Ambedkar Nagar
	S3	Navjeevan camp, Jawaharlal Nehru camp, Bhoomiheen camp, Tughlaqabad ext. Kalkaji DDA flats, G.KII
East Delhi (E)	E1	Abdul Fazal Enclave and Okhla village
	E2	Trilokpuri, New Ashok Nagar and Vasundhara Enclave
Central Delhi (C)	C1	Dujana House, Haweli Azam Khan, Chudiwalan, Khwaja Mir Dard Basti,
	C2	Pahar gunj, Aram Bagh, Rajiv Gandhi camp, Gole Market, Ashram Marg, Chuna Mandir

Source: Selected jointly by R. Singh, V. Selbach and S. Niebergall

In each test site, comprehensive field survey was carried out based on household interviews selecting samples from various kinds of formal and informal residential colonies, including respondents from different socio-economic groups. Attention was also given to further factors, such as the geo-location of water- and wastewater-related infrastructure such as canals, water and sewer pipes, open drains, hand pumps etc. Additional information was gathered through guided interviews of the key informants from the Resident's Welfare Association (RWA) if any in the surveyed colony, qualitative techniques, observation and digital photograph documentation.

2.4.3 Validation of Selection Approach

Having selected the common test areas and sites, it was necessary to validate the selection approach. In a kick-off workshop held in Delhi during the autumn of 2005 jointly with numerous experts in the field of water and waste water as well as urban health, the project in general and the three individual PhD research projects were presented. The common conceptual approach was discussed and further developed and validated with the knowledge of experts. Moreover, the chosen test sites were acknowledged to be promising in respect to the research project.

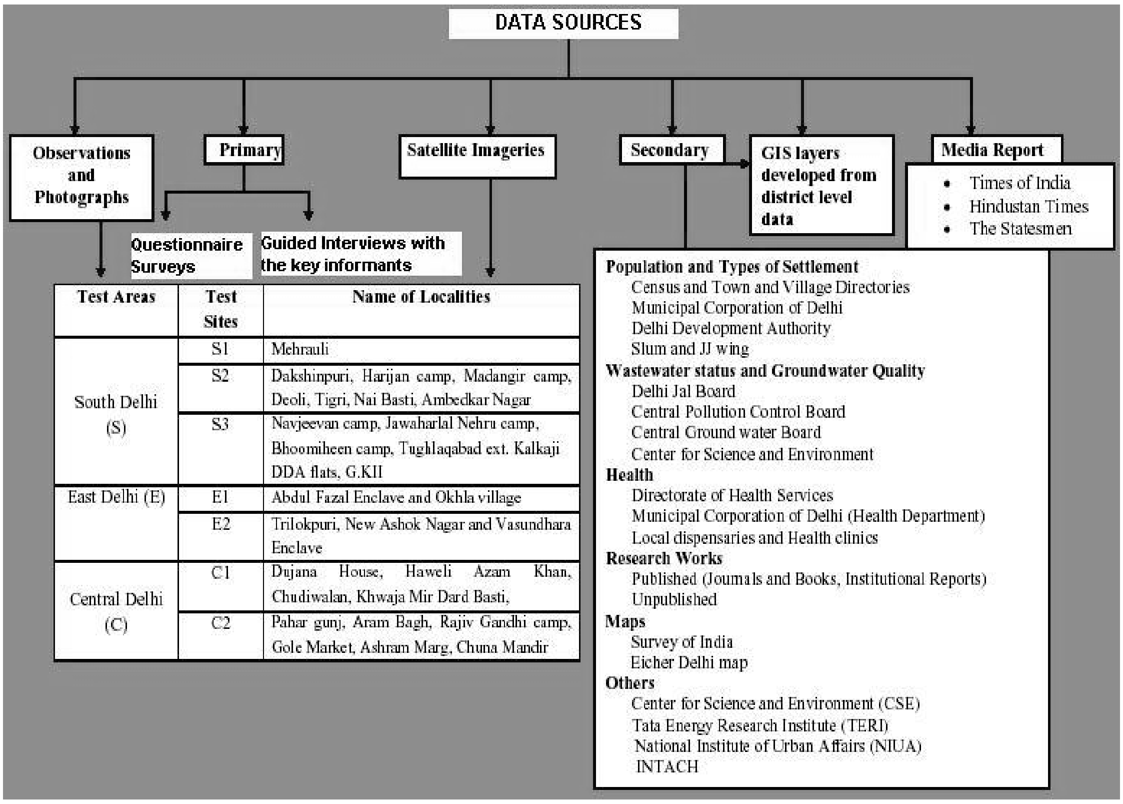
2.4.4 Pre-testing of Household Questionnaire and Initial Ground Survey for Remote Sensing

An elaborate questionnaire was designed to be administered in the selected test sites. Before the actual household survey, these questionnaires were pre-tested in order to see if they were yielding good and relevant responses. The questions were then re-framed and adjustments were made accordingly. Irrelevant and overlapping questions were eliminated and attempt was made to keep the questions in a sequence so that a conversational flow is maintained during the interview. Simultaneously, initial ground survey and observation in the different test sites of various structures were done and recorded by the remote sensing partner. All partners were mutually convinced that the selection of test sites were promising to be studied for integrated remote sensing and social research.

2.5 Data Sources

The study involved extensive household survey and also incorporated secondary data to fulfil the desired requisite of the present study. Samples as large as possible were covered for household questionnaire survey. Various kinds of secondary data providing extensive information about the city demographic, water, sanitation and health scenario were collected from various sources (Fig. 2.4).

Fig. 2.4: Different Sources of Data



Source: Own draft

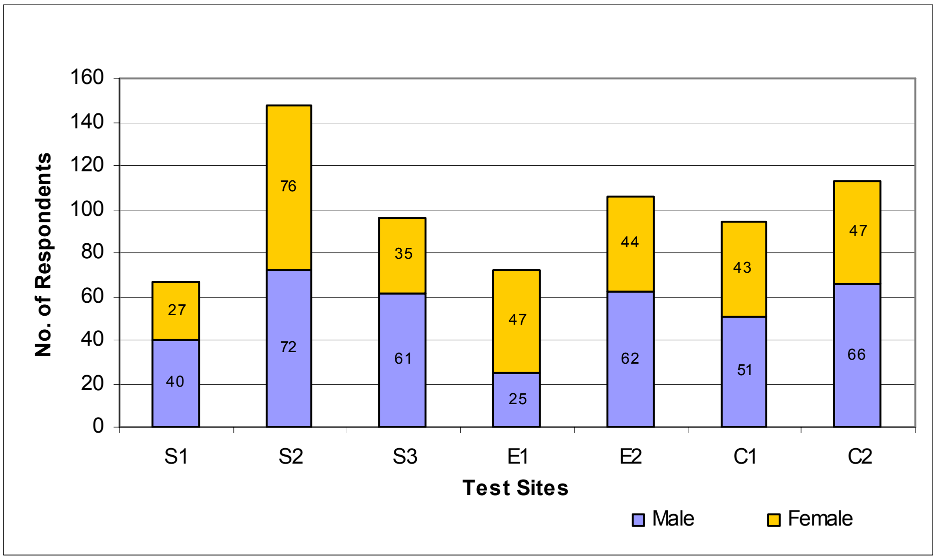
2.5.1 Secondary Data Sources

The background information pertaining to the area, demographic characteristics, trends in urbanisation have been collected from the Census of Delhi publication, and town and village directories, Delhi Development Authority and Slum and JJ wing. All information concerning the total water availability and region-wise wastewater generation and management including the information regarding the existing treatment plants were collected from Delhi Jal Board (DJB), Central Pollution Control Board (CPCB) and Central Ground Water Board (CGWB). General health information was collected from the Directorate of Health Services and MCD (Health Department). Other information have been collected from the Centre for Science and Environment (CSE), Tata Energy Research Institute (TERI), Indian National Trust for Art, Cultural Heritage (INTACH) and National Institute for Urban Affairs (NIUA), and various other published and unpublished research works. Along with information from these sources, topographical maps and other available thematic maps were put to use. Articles from various newspapers were collected throughout the research period in order to keep track of the important developments, policy measures, environmental issues and citizens' grievances on the issue.

2.5.2 Household Surveys and Interviews

Primary household data were collected through personal observation, household surveys and guided qualitative interview, primarily by adopting purposive-random sampling techniques, which contributed to the fulfillment of the outlined aims and objectives of the study. Purposive-random sampling techniques were applied to choose the respondent household from various kinds of settlements, including so-called JJ clusters, resettlement areas, planned quarters, unauthorised colonies and urban villages. Adequate representation of socio-economic hierarchies was also kept in mind as the household income status was intended to be used as an important frame for vulnerability analysis. In total, seven test sites were chosen from three different locational setting and 696 households were interviewed, covering a population of 4,358 persons (Fig. 2.5).

Fig. 2.5: Number of Households Interviewed at Various Test Sites



Source: Own household survey, 2005-2006 (N = 696)

These surveys were conducted by the author, with the help of students from the University of Delhi (who were carefully trained to administer the designed questionnaire), in the course of the years 2005 and 2006. The selection of households was made randomly from lanes adjoining the main road or main drain, using the Delhi Eicher map and satellite images. Preference was given to involve the households (wherever possible) within close proximity to canals, water and sewer pipes, open drains, hand pumps, etc. Key informants of the houses and households were interviewed, including both male and female participants. This allowed facilitating the understanding of gender-based differences in the perception of the respondents.

Sensitive questions (such as religion, caste and the exact income of the family etc.) were generally avoided if the respondent was not willing to answer; the impression whether the informants were responding openly and honestly was also taken into consideration in deciding about continuing of the interview. Besides, the availability of time for responding was essential for obtaining all information. Therefore, sometimes it was necessary to make adjustments during the interviews (i.e., shortening of questions). The questionnaire was translated in *Hindi* (the native language) in order to secure better and uniform understanding of the posed questions. The questionnaire (Appendix I) was designed to extract quantitative and qualitative information about the socio-economic background, water consumption pattern of the people, which was deemed to be necessary in order to anticipate the quantities of water demand as well as wastewater generated their disposal mechanism and routes of exposures.

It is intended to identify parameters for understanding the extent of wastewater-related vulnerability in the selected area, which would be representative of local conditions. A part of the questionnaire was also devoted to a basic health survey including the cases of illnesses reported. It also included sections to cover people's perception and response to the existing water and sewage situation and preferred solutions. The questionnaire was basically structured and open-ended in nature. Furthermore, it included narrative part the answers to which were recorded for later references. Each household interview lasted for 45 minutes on average.

In order to get additional institutional information, meetings with responsible local and state officials were agreed upon and a few in-depth interviews and discussions were conducted. These respondents included junior engineers for water and sanitation of the surveyed localities and key informants of the Resident Welfare Associations wherever existing (see Appendix II for the list). Apart from the questionnaires and guided interviews/discussions, techniques of personal observation and digital photography documentation were also involved for elaboration and better representation of the collected information in the field.

2.6 Methodology of Analysis

The data obtained from the various sources mentioned above are compiled according to different aspect of the study. Both quantitative and qualitative methods have been adopted for analyzing the information gathered from secondary sources and those extracted from the household questionnaires and interviews. Depending upon the nature of data, suitable statistical and cartographic techniques are applied for their representation in supporting the arguments of the study. Data is also represented through simple self-explanatory tables, diagrams and picture profiles.

Identification of sensitive regions and exposed communities within the selected sites involved investigating the kind of wastewater problems and routes of exposures, socio-economic background of the people, and their level of awareness as well as social networking. Categorising of the household on the basis of their legal status and level of sewer connection and co-relating them with the nature of wastewater problems reported helped to fulfill this objective. The overall pressure on the wastewater infrastructure and the status of sewerage in the study area is analysed by assessing the level and kinds of household sewerage connection in different types of residential colonies. Information about the type of wastewater, level of water supply, volume of wastewater generation and disposal methods is structured as the wastewater profile, which further facilitates a comparative analysis across colony types.

Social vulnerability is explored through the dimensions of exposure, resource capacities, implications and response. Exposures to wastewater is investigated on the basis of factors like demographic characteristics of the communities, settlement and infrastructure status, drinking water sources and consumption habits and means of direct contact with sewage. Household Exposure Index (HEI) has been developed based on selected indicators drawn from the mentioned factors. Each indicator has been rated on a 1-5 scale score where a low score indicates a larger contribution to exposure and a higher score indicates less exposure, thereby following an inverse relationship between the score and level of exposure. Since all the indicators are assumed to have the same weight, HEI was calculated as the average aggregate of all the scores. Households were accordingly classed as highly exposed, moderately exposed and least exposed.

Similarly, resource capacity dimension is investigated through factors like socio-economic status, knowledge and awareness, role of social capital as well as institutional and political economy. Based on the similar concept of HEI, indicators were identified to develop Household Management Capacity Index (HMCI) and accordingly households were categorised under high, moderate and low resource capacity. Additionally a detailed comparative analysis of perception and level of awareness of residents of different communities is done to get people's view of the problem and better understand the constraints and expectations from the user's end.

Environmental implication is analysed in terms of ground water contamination and degradation of environmental aesthetics. The ground water quality of the surveyed areas is assessed on the basis of secondary data obtained from CPCB. The data was compiled to see the potential threat to the resource base due to mismanagement of sewage and wastes. The conclusions are drawn on the basis of desirable limits provided by the Bureau of Indian Standards (BIS). Areas having chemical constituents in ground water above the desirable limits are considered to be unsafe and posing potential health threats.

Health impact is seen as a part of social vulnerability study. A small section of the questionnaire was also devoted to investigate about the kind of diseases which were common among different social groups in the studied localities. This was chosen as health effects are seen as a major outcome of exposure and vulnerability. It is a very complex issue to co-relate the exact health impact due to exposure to wastewater nuisance. Although it has to be underlined that not primarily an epidemiological study was conducted and therefore no attempt is made to establish a relation between the kind of diseases and wastewater nuisance. But some causal links between the degrading water and sanitation conditions and increasing water-related illnesses could not be overlooked. In this regard, morbidity was calculated (primarily the water-borne and water-related illnesses were asked for with recall period of last one year). Moreover exposure-morbidity co-relation is worked out using scatter plot method and Pearson's (r) is calculated to find the direction and degree of relationship between the two variables.

Household as well as institutional responses are further investigated to draw conclusions about the nature of adaptation and coping strategies and assess their effectiveness on short- and long-term basis. Household vulnerability is finally assessed by superimposing HEI and HMCI, which further highlights the reasons of household defencelessness against wastewater hazards. It further makes explicit indication to the point where rectifying interventions are required. On the basis of which final suggestions are recommended.

<u>Chapter 3</u>

Wastewater and Sanitation Situation in Delhi

3.1 Introduction

Water supply, safe wastewater management and sanitation are a few major determinants of urban health encompassing quality of life in terms of social well being. In this fast urbanising world it is becoming increasingly difficult for urban managers to meet the basic infrastructural needs, more so for water and sewerage, which predispose social community to numerous environmental and health risks. The fast changing dynamics of megacities present a challenge quite different from other cities. This chapter tries to look at the status of water system infrastructure with particular reference to sewerage and sanitation in megacities. Therefore the requirement, status and limitations of sewerage provision are discussed for megacities in general and Delhi in particular. It further elaborates upon wastewater profile of the study area and outlines the nature of wastewater problems prevalent in different types of surveyed colonies.

3.1.1 Urbanisation and Wastewater Management

Good quality infrastructure leads to substantial gains in productivity and a rise in the standard of living, reduces poverty, and at the same time increases life expectancy through improved health and sanitary condition and better utilization of the natural resources (World Bank, 1992). Rapid urbanization process poses enormous stress on the existing infrastructure and sustainable urban development. This coupled with existing un-sustainability factors and risks inherent to conventional urban water system management future cities will experience difficulties in efficiently managing scarcer and unreliable water resources, providing safe wastewater disposal and reducing urban flood risk (UNESCO-IHE, 2007).

During the period 1990-2000 it is estimated that the global population increased by 15%, within this figure urban population increased by one-quarter with only 8% increase in the rural population. This trend towards urbanisation is set to continue. It has been observed that large parts of the urban residents lack access to basic civic facilities, most essentially to water supply and proper drainage and sanitation systems. During the last decade constant effort was diverted towards water and sanitation sector to serve this additional population. Although some inroads have been made into the backlog of people requiring water and sanitation services, there still remain 1.1 billion people without access to improved water supply and 2.4 billion without access to any sort of sanitation facility (WHO and UNICEF, 2000).

On an average about 75% of the global population has access to water supply. But what we often forget is that the more water we use, the more waste water is discharged demanding its safe disposal. There exists a gap between the amount of wastewater generated and its safe disposal due to lack of proper sewerage and sanitation facility, which is a major source of surface water pollution in many urbanising settlement. In nearly every country, water supply coverage is better than that of sewerage coverage. Despite improvements in the sewerage sector and advances in science, engineering and legal frameworks only about one-third of the wastewater is collected. About 95% of the wastewater in the world is released into the environment without treatment. Only 5% of global wastewater is properly treated using 'standard' sanitation facilities, mainly in developed countries. As a result, the majority of the world's population is still exposed to waterborne diseases, and the quality of water resources has been rapidly degraded, particularly in developing countries (Ujang and Henze, 2006).

Almost all mega urban areas are particularly prone to supply crisis, social disorganization and political unrest; at least many of them are facing numerous similar problems and risk factors (Kraas, 2003), water and sanitation being only one of them. Insufficient infrastructure and ill designed urban regulation is leading to deterioration of the quality of environment and public health. Though there has been enormous technological advancements in wastewater management and sanitation strategies (Harremoës, 1997; Smerdon, 1997; Burkhard, McPherson and Cosstello, 2001), still a major challenge in this sector is to improve the levels of service and making it equally accessible by all, particularly by the low-income communities, who often live in poorly drained areas, where urban runoff mixes with sewage from overflowing latrines and sewers, causing pollution and a wide range of environmental and other health related problems.

The major urban environmental issues and implications are set out clearly in UNDP/UNCHS/World Bank UMP Policy Paper on Environmental Strategies (UMP, 1994). It describes the environmental and health implications of urban pollution that results from inadequate water, sanitation, drainage and solid waste services, poor urban and industrial waste management, water and air pollution. These set of problems are collectively termed as 'brown agenda' and are closely linked to the social defenselessness against harmful environmental perturbations (Forbes and Lindfield, 1997). Important underlying issues typically involve inappropriate and inadequate housing, road, transport, water, and wastewater and sanitation infrastructure in fast expanding urban areas.

3.1.2 Sewerage and Sanitation Scenario in Megacities: South Asia vis-à-vis India

Mega cities, in every part of the world, providing home to millions of people are marked by exceptionally ongoing dynamisms. The unplanned and uncontrolled growth has had serious negative implications on urban dwellers and their environment. Faced with an increased demand and growing population problems, cities are not able to provide quantitatively and qualitatively adequate services to all its inhabitants. In this case we particularly refer to sewerage and drainage infrastructure which has direct influences on environmental resource base and indirect influence on public health and quality of life. In the absence of adequate sewerage network wastewater stagnates within urban areas causing cess pools and breeding ground for mosquitoes and other vectors besides contaminating piped water supply and polluting groundwater which is the main source of drinking water in many urban areas.

The urban scenario of South Asian countries presents a grim picture with regard to availability of wastewater disposal and sanitation service. At the aggregate level although nearly 90% of the urban population is reported to have access to safe drinking water supply, there are severe deficiencies with regard to sewerage access by urban residents. In spite of the significance of sewer and sanitation as an essential necessity for the healthy survival of humankind, the overall situation of sewerage access especially in South Asian urban areas continues to be unsatisfactory. China provides water supply to

94% of urban population but only 68% have sewerage access. Pakistan and Sri Lanka appear to be closest in the run by providing sewerage and sanitation to 94% and 91% of its population consecutively. India could only reach out to 73% in 2000, although was able to provide water supply to 92% of its population (Table 3.1). Apart from insufficient sewerage wastewater treatment facilities are inadequate in many cities of the South Asian region. At many places, untreated domestic and industrial wastes are discharged directly into canals and rivers, thus creating conditions for the spread of diseases (UNEP, 2001).

Table 3.1: Urban Population with Access to Water and Sanitation in South Asia

Countries	**(%) Population Having Access to**			
	Potable Water		**Sewerage and Sanitation**	
	1990	**2000**	**1990**	**2000**
Bangladesh	98	99	78	82
Bhutan	NA	86	NA	65
India	92	92	58	73
China	99	94	57	68
Nepal	96	85	68	75
Pakistan	96	96	78	94
Sri Lanka	90	91	93	91

Source: WHO and UNICEF, 2000

Rapid urbanisation and unprecedented growth has transformed cities into huge centres for demand and resource consumption. Consequently, cities become generators of different kinds of wastes. Indian cities, like many of their post-colonial counterparts are beset by immense environmental problems at the end of the twentieth century. As the growth of urbanisation continues these problems are escalating. While the environmental problems such as air pollution and toxic wastes are occasionally addressed by governments when given publicity, the most profound of these environmental problems, the unsanitary living condition of a large section of the urban population is largely ignored (Chaplin, 1999).

According to the 2001 census, 10 per cent of Indian's urban population lives in the mega cities Mumbai (Bombay), Delhi, Kolkata (Calcutta) and Chennai (Madras). In 1947, only 60 million people (15 per cent of the total population at that time) lived in urban areas. This has been doubled to 30.5 percent in 2001 (Table. 3.2). The steep growth in urban population is partly due to the skewed development that has led to proliferation of commercial activities and great job opportunities in cities. Inspite of the prominence of urban sector development and its increasing contribution to national income and economic progress (evident through 60% contribution to national income in 2001), urban India faces the serious problem of deteriorating urban environment and quality of life. There is a huge and widening gap between demand and supply of essential services and infrastructure. Urban poor in India are forced to live under unhygienic conditions in slums, lacking in basic amenities.

Table 3.2: Urban India Population 1901-2001

Year	Urban Population (Million)	Percentage of Urban to total Population	Decadal growth rate (percent)	Estimated contribution to national income (percent)
1901	29.9	10.8	-	NA
1911	25.9	10.3	0.40	NA
1921	28.1	11.2	18.3	NA
1931	33.5	12.0	19.1	NA
1941	44.2	13.9	32.0	NA
1951	62.4	17.3	41.4	29
1961	78.9	18.0	26.4	NA
1971	109.1	19.9	38.2	NA
1981	159.5	23.3	46.1	47
1991	217.6	25.7	36.4	55
2001	306.9	30.5	41.0	60

Source: http://www.indiacore.com/urban-infra.html (last accessed on 09.01.2008)

Urban settlement in India is classified in six categories according to their population (Table 3.3). Class I cities having a population of above 1,00,000 have grown rapidly to 393 in 2001 inhabited by more than two-third of the country's urban population but only about one fourth of them have partial sewerage systems and treatment facilities (CPCB, 2005). Unlike water supply, specific standards for sewerage have not been spelt out in physical plans. Many cities do not have a sewerage system, even where they exist, their capacities are not adequate to cope with requirements. The coverage in terms of organised sewerage systems ranged from 35 per cent in Class IV cities, to 75 per cent in Class I cities (CPCB, 2000; Govt. of India, 2001b). As per the 2003 updated status 22,900 MLD of domestic wastewater is generated from urban centres, against 13,500

MLD of industrial wastewater. The treatment capacity available is only for 5,900 MLD; the rest 17100 MLD is disposed untreated. Total available wastewater treatment capacity works out to be 32% of waste water collected and about 24% of the wastewater generated emphasizing the huge gap between generation and treatment of domestic wastewater. The level of treatment available in cities with existing treatment plant varies from 2.5% to 89% of the sewage generated. Treated, partly treated and untreated wastewater is disposed into natural drains joining other freshwater bodies or used on land for irrigation (CPCB, 2005). Both practices raise serious concerns about pollution and health implications.

Table 3.3: Urban Morphology

Class	Population Range	No. of Towns	Share of Urban Population
I	Above 1,00,000	393	68.60 %
II	50,000 to 99,999	401	09.67 %
III	20,000 to 49,999	1151	12.20 %
IV	10,000 to 19,999	1344	06.80 %
V	5,000 to 9,999	888	02.30 %
VI	less than 5,000	191	00.20 %
All Classes		**4368**	**100.00%**

Source: Census of India, 2001b

The state of sanitation in India as a whole is very poor and at the same time it remains considerably difficult to measure access to sanitation and sewerage with accuracy as most of the officially announced figures are figures of infrastructure and do not tell us the access by individuals or households (Kapur, 2007).

According to WHO estimates, while access to water supply in India has reached 92%, sewer and sanitation is still 73%. With the provision of these services being poor, majority of urban population seems to have evolved their own mechanism to gain access to water and sanitation privately (WHO and UNICEF, 2000). However, there are considerable state-wise variations too. Sewerage is virtually non-existent in Bihar, Madhya Pradesh, Orissa and Assam where the coverage is less than 5 percent. Though Punjab, Maharashtra, Delhi and Gujarat fare better but the coverage is still below 50%. The national average was only 22.5% in 1998 (NSSO, 1999) and the situation has not improved sufficiently over the last years. According to the estimates of Central Pollution

Control Board, sewerage for urban India still remains below 70% (CPCB, 2003). The concentration of population in cities with poor sewerage and wastewater management is affecting urban health through degrading water environment – urban sewerage and sanitation is emerging as a major challenge for India.

Plan outlays for the urban sector have been inadequate compared to the requirements of basic urban infrastructure such as water supply, sanitation, solid-waste requirement management, urban transport etc. The most significant environmental problem and threat to public health in both rural and urban India is inadequate access to clean drinking water and sanitation facilities. The Ninth Plan (1997-2002) recognized that urban drinking water supply strategy needs to address the priority concerns of universal coverage, adequacy and regularity of supply. Along with improvement in urban water supply, the plan envisaged provisions of reasonable levels of sanction to population in urban areas through rapid expansion and improvement of sanitation in line with the goal of 'Health for All'. The allocations made by Ninth Plan were far below the estimated requirement for urban infrastructure sector made by the Rakesh Mohan Committee on Indian infrastructure (Govt. of India, 2001b).

In India domestic sewage and sullage is the main source of water pollution, especially in and around urban centres. About 75% of the wastewater produced is from the domestic sector (Indira Gandhi Institute of Development Research, 2003). During the last few decades, although water supply has been significantly augmented, sewage disposal has not kept pace. Even if the water is supplied to a community, there is no corresponding pipe to remove the wastewater. This has resulted in generation of huge amount of wastewater without adequate arrangements for collection, treatment and disposal. The wastewater treatment capacity as an indicator of safe sewage disposal shows a decreasing trend over the decades. With the volume of wastewater increasing from 7,007 MLD in 1980 to 16,738 MLD in 2000, the wastewater treatment capacity has decreased from 39% in 1980 to 24% during 2000 (Table 3.4).

Table 3.4: Decadal Trend of Sanitation Status in Class I Cities in India

Parameters	1980	1990	2000
Numbers	142	212	>300
Population (millions)	60	102	140
Water supply (MLD)	8,638	15,191	20,923
Wastewater generated (MLD)	7007	12145	16738
Wastewater treatment capacity (MLD)	2756 (39%)	2485 (21%)	4037 (24%)

Source: CPCB, Parivesh- 2005 and CPCB, 2000

A few years back cholera-gastro entities epidemic in which hundreds of people died in Delhi and other areas of the country was one of the most tragic results of poor sanitation and unhealthy environmental conditions in Indian cities and towns. The prevailing conditions are indicative of gross neglect of sanitation services by the municipal authorities.

3.2 Perspective on Drainage/Sewerage Management in Delhi

A major issue confronting Delhi's planned development is the apparent and frequent violation of the planning and development control norms. In Delhi, the approach of planned urban development has been mentioned since the 1960s, incorporated in the first and the second Master Plans. The Delhi Master Plan became law in 1961 and has been the framework based on which the growth and development of Delhi has been controlled. From a settlement of less than one million in 1947, its population increased to 13.8 million in 2001 at a growth rate of about 4.6% (1991-2001) reaching 15.3 million in 2005. The Master Plan, Delhi (MPD) 1962 was meant for a population of 5.3 million and MPD 2001 was for 12.8 million. The MPD- 21 (the Third Master Plan for Delhi for the period 2001-2021) envisages a population of 23 million by 2021 (CPCB, 2004).

This increasing population is likely to be affected by various inadequacies owing to decreasing food and water supply, inadequate sewer, sanitation and health facilities, etc. The massive increase in demand for basic infrastructure for urban populations and skewed distribution of investment towards affluent zones resulted in the rapid expansion of illegal or unplanned and unserviced settlements, with unhealthy living conditions and overcrowding. The number of people living in these settlements is expanding so rapidly that urban local bodies are unable to keep up with infrastructure development. Much of the problems are attributed to the city's unusual amalgamation of planned and unplanned settlements. This is why Delhi's urban scenario has become complex and unmanageable.

The development of sewerage system in Delhi started soon after New Delhi was built in 1938. Earlier, the wastewater system in Delhi consisted of open surface drains in and around the area of the city with disposal of wastewater into the river Yamuna. Later an underground wastewater system was laid that drained southwards to Okhla, where the first sewerage treatment plant (STP) was constructed some sixty years ago of 82 million liters per day (MLD) treatment capacity. By 1956 the capacity of this plant was augmented to 164 MLD. Additional STPs were later constructed at Coronation Pillar (55 MLD) and at Keshopur (55 MLD) in 1957 and 1960, respectively. The treatment capacity increased from 273 MLD in 1961 to 1273 MLD in 1993. The present total treatment capacity of 17 STPs in Delhi stands at around 2330 MLD (CPCB, 2004).

3.2.1 Overview of Present Drainage/Sewerage System in Delhi

Delhi, like most of the urban areas is served by a network of sewers, pumping stations and sewage treatment plants (STPs). The drainage system in Delhi can be arranged hierarchically as internal drains that collect the runoff at the residential level; these then find their way into peripheral drains further joining the main trunk drains. The discharges from peripheral drains find their way into a larger main/trunk drain or directly into the river Yamuna.

Presently, the urban area of Delhi is served by gravity collection sewerage system involving a large network of branch sewers, intercepting sewers, peripheral and trunk sewers, of about 6000 km length. There are 28 main trunk sewers with size 700 mm to over 2400 mm diameter with a total length of around 140 km while the balance length comprises peripheral sewers with smaller diameter that form the linkage between trunk sewers and the smaller internal sewers in colonies with the smallest internal sewers having a diameter of 150 mm. There are 36 major pumping stations of capacities ranging from 6 MLD to 455 MLD (CPCB, 2004).

Though the system was conventionally designed to carry storm water but as a result of an inadequate sewerage network, a large quantity of untreated sewage finds its way into these storm water drains and ultimately into the river. This not only renders the water in these drains unfit for use but also results in pollution of other water sources. 70% of the pollution in the river is caused by dumping of sewage that is transported from the households to the river via these channels reducing them to the role of urban sewers in the absence of an adequate sewage collection and disposal system in large parts of the city. The urban area of Delhi, based on topography is divided into five main drainage zones namely, Okhla, Coronation Pillar, Keshopur, Rithala, and Trans-Yamuna. The remaining area within the boundary of NCT is the drainage zone of Outer Delhi in general and marked as Dwarka, Ghitorni, Vasant Kunj, Mehrauli, Najafgarh and Narela zones in the sewerage map of Delhi (Appendix III).

3.2.1.1 Okhla Drainage Zone

Okhla drainage zone is the largest extending from Timarpur in the North to Deoli in the South and from the river Yamuna in the East to Ridge in the West. It is served by 13 sewage pumping stations connected by 42.58 km of trunk sewers and 1500 km of secondary and internal sewers. Presently Okhla STP receives sewage from three main sewage pumping stations, located at Ring Road, Kilokri and Andrewsganj. It has three sewage treatment plants working with varying capacity, viz., Okhla STPs with a total capacity of 636 MLD, Delhi Gate and Sen Nursing Home with 10 MLD each. About 60% of the sewage network in this zone is silted, structurally weak and partially abandoned.

3.2.1.2 Coronation Pillar Drainage Zone

The drainage zone of Coronation Pillar is predominantly residential. There are two sewage treatment plants in this zone; Coronation Pillar STP working with a capacity of 136+45 MLD and Timarpur STP working with a capacity of 27 MLD. These STPs receives sewage through two main trunk sewers i.e. university sewer and North Delhi truck sewer of 10.84 km in length; along with that the length of secondary and internal sewers in this zone is 400 km in length. Nearly 40-60% of the trunk sewer is not functioning due to siltation.

3.2.1.3 Keshopur Drainage Zone

The Keshopur drainage zone is also mostly residential, comprising of residential area of Patel Nagar, Prasad Nagar, Naraina, Moti Nagar, Rajouri Garden, Janakpuri, Vikaspuri etc., including cantonment area industrial area of Naraina, Najafgarh and Mayapuri. There are three STPs in this zone with the existing capacity of Keshopur as 327 MLD, receiving sewage from Najafgarh Road truck sewer, relieving trunk sewer and Punjabi Bagh trunk sewer. Pappankalan STP working with present capacity of 91 MLD and Nilothi STP with 182 MLD. The total length of the trunk sewers in this zone is 27.06 km, which is connected with secondary and internal sewers of 1104 km in length. But the inflow of sewage is much less as 30-60% of the trunk sewer is silted rendering the treatment plants to work below their capacity.

3.2.1.4 Rithala Drainage Zone

Rithala drainage zone comprises of Rohini in North, Delhi Ambala railway line in North-East, Rohtak railway line in the West and Nangloi in the South, besides area such as Karol Bagh, Model Basti, Kishangunj, Gulabi Bagh and Shastri Nagar it also includes planned residential areas of Ashok Vihar, Shalimar Bagh, Pitampura, Saraswati Vihar as well as industrial areas of Badli, Mangolpuri and Wazirpur. Rithala STPs in this zone has a treatment capacity of 364 MLD and Rohini STP works with a capacity of 66 MLD. It has 10 existing and 2 proposed pumping stations.

3.2.1.5 Trans Yamuna Drainage Zone

The Trans-Yamuna drainage zone comprises of the entire Trans Yamuna area, including Dilshad Garden, Vivek Vihar, Geeta Colony, Preet Vihar, Mahuban Chowk, Kalyanpuri and Mayur Vihar. The total length of the trunk sewer in this zone is 16.6 km and a network of 1008 km of secondary and internal sewers. There are two sewage treatment plants in this zone, Kondli I, II, III with a total capacity of 206 MLD and Yamuna Vihar

I, II with a capacity of 91 MLD. Nearly 30-60% of the trunk sewer in this zone is silted and the sewage treatment plants here too are performing below their capacity.

3.2.2 Institutional Arrangement for Water and Sewerage in Delhi

Governance of Delhi is in the hands of different bodies - Delhi Development Authority (DDA), Municipal Corporation of Delhi (MCD), New Delhi Municipal Committee (NDMC) and the Cantonment Board (DCB). 94% of the total urban area is under MCD while NDMC and DCB cover 3% each (Delhi Jal Board, 2004a). The responsibility of the drainage system at the Master Plan and Zonal Plan levels rests with the Delhi Development Authority (DDA). But DDA does not involve itself in the areas under the jurisdiction of the other governing bodies. Thus, the Municipal Corporation of Delhi (MCD), the New Delhi Municipal Committee (NDMC) and the Cantonment Board (DCB) are responsible for the drainage systems within the areas under their jurisdiction. The Irrigation and Flood Control Department of Delhi is responsible for planning and executing the main drains whose drainage capacity is more than 1000 cusecs (UNESCO, 2001).

In general, water and sewerage services are provided by the Delhi Jal Board (DJB) to areas under the jurisdiction of MCD. DJB also provides bulk supply services for NDMC and DCB areas and the internal water distribution and sewage collection is taken up by these agencies themselves. The Implementing Agency, under the Govt. of NCT of Delhi was constituted on 2nd April 1998 with the Chief Minister as its Chairperson, replacing the former Delhi Water Supply and Sewage Disposal Undertaking (DWSSDU), created in 1958. DJB was given extended power and is suppose to be financially autonomous. It is also responsible for the production and distribution of drinking water, treatment and disposal of wastewater as well as water quality control and water pollution monitoring in the Municipal Corporation of Delhi (Ruet, Saravanan and Zerah, 2002). In addition, the Board implements schemes for providing, laying, jointing, rehabilitation and de-silting of trunk and branch sewers (internal/peripheral sewers) so that sewage is conveyed to sewage pumping stations and sewage treatment plants (Comptroller and Auditor General, 2004).

Although the corporation is effective in the planning and construction of water supply and drainage, progress has been below expectation for collecting and treating urban sewage and for proper maintenance of the same. The key reasons are managerial fragmentation, unclear responsibility, poor coordination of work and deficient planning (Comptroller and Auditor General, 2004). Since the city is divided into various zones for managing water and sewerage by DJB, which does not necessarily match with the administrative zoning of MCD, the responsibilities of the management remains unclear e.g wastewater management is under the responsibility of the DJB whereas sanitation falls under the direct responsibility of the MCD and apart from DJB there are many other departments that also have a role to play regarding the water policy and the management of resources and infrastructure. These departments are mutually exclusive in their activities and functioning. Many times the viewpoints of these departments differ widely to the extent where no convergent action plan emerges due to lack of coordination and understanding (CPCB, 1999a). The involvement of various authorities at various level of governance and their responsibilities are cited in Table 3.5.

Table 3.5: Drain-Related Responsibilities of Various Authorities in Delhi

Name of the Authority	Government	Responsibility related to Drain
Irrigation and Flood Control Department	National Capital Territory of Delhi (NCT) / State Government	Maintenance, such as desludging, desilting and widening.
Delhi Water Board (DJB)	Municipal Corporation of Delhi (MCD)	Water supply, collection of sewage through sewerage network and disposal.
Conservancy and Sanitary Engineering (CSE)	Municipal Corporation of Delhi (MCD)	Collection of sewage from domestic connection to trunk sewer.
Delhi Development Authority (DDA)	Central Government	Development of colonies including infrastructure, such as water supply, sewerage facilities etc. and maintaining them till MCD department takes over.
Delhi Pollution Control Committee	National Capital Territory of Delhi/ State Government	Pollution control under the Water and Air Acts in the NCT areas.

Source: CPCB, 1999a

In such a complex administrative situation, there is often confrontation between the State and Central Government that tries to keep a control over the development of the capital. In fact, no single institution has enough autonomy to take clear decision about the pricing, policing and management of basic services of water and sewerage. Further the appointment of head members of DJB is not completely aloof from political compulsions as was demonstrated during the electoral period of 2001 (Ruet, Saravanan and Zerah, 2002). In such case political interference in the decision making matters of DJB cannot be ruled out. Therefore, although the city has numerous managers, the actual state of management is highly fragmented and un-coordinated with a weak financial base and suffers from continuing political interference.

3.3 Wastewater: Generation, Collection and Treatment

Delhi is one of the fastest growing megacities in the world; today Delhi supports a recorded population of about 15 million (tenfold more than it was originally planned for). Hyper urbanisation, steep population growth and planning failures in Delhi are the most important factors that have led to increased resource demand, waste generation both liquid and solid and deteriorating quantity of water supply and inadequate sewerage and sanitation services available to its habitants.

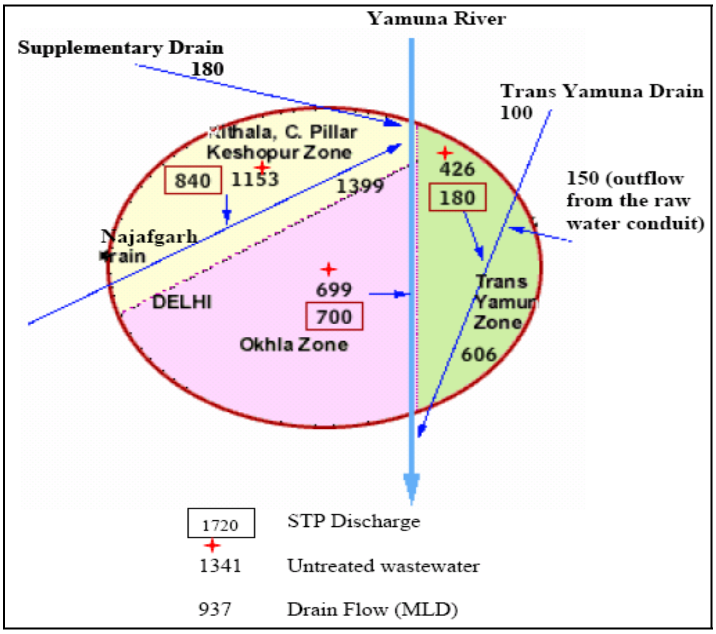
Water after use or anthropogenic influences gets adversely affected in quality which is then regarded as generated wastewater. The domestic source is mainly domestic sewage and toilet wastewater. Apart from the domestic wastewater originating from residential households, there are also commercial wastewater originating from hotels, restaurants and parlors, which are also situated within the residential complexes, thereby making it difficult to separate domestic and commercial wastewater. Additionally, the industrial estates also generate their share of liquid waste which further adds to the maladies of wastewater management.

3.3.1 Status of Wastewater Generation

Currently, Delhi generates 3,267 MLD of wastewater including 218 MLD from industrial sources. Normally 80% of water supply is generated as sewage which in this case was officially estimated to be 3,267 MLD. However, the flow of wastewater in various drains was observed as 3,998 MLD, including raw water discharged by Haryana into Najafgarh drain and wastewater entering from adjoining NCR borders (Govt. of India, 2008). Such an offshoot of wastewater generation also confirms the use of groundwater as well as packed water for drinking and other purposes (CPCB, 2004).

In Delhi, people try figuring out solutions to water shortage problems. If the supply of water is less, they look out for alternative sources like installing their own hand pumps or booster pumps for extracting ground water, buying water from vendors, or getting water from other places to fulfill their need of water consumption. Therefore, even if the DJB is supplying an estimated quantity of water but much more water is being used at the consumer end and thereby the sewerage generation is definitely above the quantity estimated by the institutions. Moreover, the wastewater generation by the unsewered areas and informal settlement quarters are also difficult to be gauged correctly. Total wastewater observed to be joining Yamuna includes an approximate of 1,720 MLD sewage treatment plant (STP) discharges, 1,341 MLD untreated wastewater and about 937 MLD of overflows in the drains (Fig. 3.1).

Fig. 3.1: Wastewater Discharges into River Yamuna - Delhi



Source: Estimated from Govt. of India, 2008

Sewerage zone wise analysis of wastewater generation shows that major contribution to the total generated wastewater is from the Okhla sewerage zone. This can be attributed to the ease of water supply accessibility in this zone and water usage pattern of the inhabitants. Whereas the least water consumption and minimum wastewater generator is in the Coronation Pillar zone. Trans-Yamuna zone covers all the residential area on the left bank of the river and generates 375 MLD of wastewater (Table 3.6).

Table 3.6: Estimated Zone-Wise Wastewater Generation: Delhi

Sewerage Zones	Water supplied (MLD)	Estimated wastewater generated (MLD)
Rithala	480	384
Coronation Pillar	300	240
Keshopur	744	595
Trans-Yamuna	468	375
Okhla	1296	1037
Outer Delhi	796	634
Total	4084	3267

Sources: Delhi Jal Board, 2002; CPCB, 2004 and DUEIIP, 2001

In order to have a better understanding of the prevailing water consumption and consequent wastewater generation status in the surveyed areas and further to compare the field generated primary data with documented government records elaborated above, it is imperative to view these parameters also from the survey results. All the selected test sites for the household survey fall in the two major sewerage zones highlighted in the table above. C1, C2, S1, S2, S3, E1 comes within Okhla drainage zone on the right bank of river Yamuna and E2 is covered in the Trans-Yamuna drainage zone on the left bank of the river.

Some of major water and wastewater generation related parameters as compiled from the household survey results are listed in Table 3.7. This shows an altered picture, where the per capita water consumption and consequent wastewater generation is more in Trans-Yamuna zone than compared with Okhla. Delhi's average per capita wastewater generation is about 214 liters per capita per day (lpcd), and that for Okhla and Trans-Yamuna zones as per official record is 270 lpcd and 139 lpcd respectively (DUEIIP, 2001).

But the results from household survey during 2005-06 estimate the per capita wastewater generation to be 103 lpcd and 120 lpcd respectively for Okhla and Trans-Yamuna zones. This further indicates that probably the water supply crisis over the year has restricted the consumption habit and thereby reduced the per capita wastewater generation although the total volume of wastewater generated from the city has been constantly increasing from 2728 MLD in 2000 to 3276 MLD in 2004 and is estimated to reach 5340 MLD by 2011 (CPCB, 2004).

Table 3.7: Water Consumption and Wastewater Generation in Surveyed Areas

Parameters	Okhla Zone (C1, C2, S1, S2, S3, E1)	Trans-Yamuna Zone (E2)
Total population of households surveyed	3619	600
Total water consumption (liters per day)	463232	89598
Average per capita water consumption (lpcd)	128	149
Estimated wastewater generation per day (liters)	370586	71678
Average per capita wastewater generation (lpcd)	103	120

Source: Own household survey, 2005-2006 (N = 696)

The field experience shows that, although the water supplied by Delhi Jal Board is less in Trans-Yamuna region, people find alternatives to meet their water consumption demand from various other sources which have not been correctly gauged by the government estimation record as they are 'informal' in nature. This also attests supply variability by the city. The level of water supply in the city centre is the highest (200-600 lpcd), whereas in South Delhi and Trans-Yamuna area it is in the lower ranges between 18-122 lpcd although the demand in these area is considered to be high as these fall in medium to high residential areas (DJB, 2002).

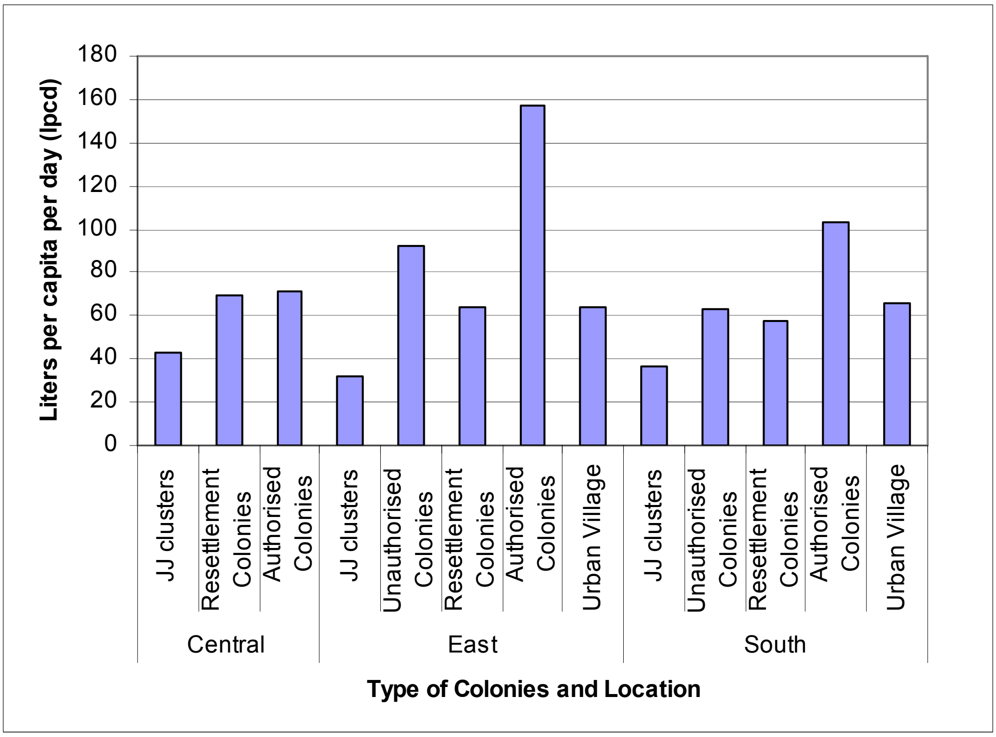
Trans-Yamuna area is experiencing upcoming of new residential quarters and it also has a major proportion of unauthorized and resettlement colonies with comparatively neglected level of such civic facilities. The condition of related water supply in authorized colonies in East Delhi is also similar, but social groups organised in Resident

Welfare Associations (as seen in the case of housing complexes, comparatively new authorized residential quarters) and having favourable economic resources establish their own booster pumps to draw groundwater for fulfilling their water consumption needs. This can be confidently ascertained from field survey results which show authorised colonies of East location to be generating highest per capita wastewater (157 lpcd). Similar situation prevailed in the authorised colonies of South location where the per capita wastewater generation was averaging 103 lpcd. Resettlement, unauthorised colonies and urban villages cutting across all the locations had per capita wastewater ranging between 60 to 90 lpcd whereas the generation of wastewater from the JJ clusters was always between 32-42 lpcd (Fig. 3.2). This may be attributed to the facts that the provision of water supply in JJ clusters is the lowest due to their informal status and lack of piped connections.

Moreover, toilet facility was not available in households; therefore the residents had relied on public convenience or paid toilets (sulabh sauchlayas[3]). This avoided the need to fetch water for sanitation in households as water was made available at the paid public toilets. This also limited the frequency of toilet use, since each visit costs around a rupee, thereby curbing unnecessary wastage of water in the form of flushing of toilets. Therefore it can be concluded that apart from other factors like informal status, lower level of water supply, poor economic condition and unfavourable water accessibility location, restrictive water usage habit of marginalized population was also one of the main reasons for the lower wastewater generation from these informal and poor colonies. But such restrictive water usage habits and minimum wastewater generation did not protect those communities from facing various wastewater related nuisance at their households and immediate neighbourhood as they frequently faced wastewater flooding and physical exposures due to unavailability of even the very basic sewerage infrastructure.

[3] The Sulabh technology is a very simple device. It consists of two pits and sealed cover. While one is in use, the other pit is left to manure. And, finally, it is cleared to be used as manure. By using this technology, there will be no need to physically clean human excreta. This was named as Sulabh Shauchalaya, which could be adopted in different hydrogeological conditions with some precautions. Dr. Pathak convinced administrators, planners and engineers about the successful functioning of the two-pit pour-flush toilet in urban areas which could be affordable, safe and hygienic system for the disposal of the human waste in absence of sewers and septic tanks (http://www.sulabhtoiletmuseum.org/profile.htm).

Fig. 3.2: Average per Capita Wastewater Generation in Different Surveyed Colonies



Source: Own household survey, 2005-2006 (N = 696)

3.3.2 Status of Wastewater Collection and Treatment

With the growing population and increasing industrialization over the last decades, the demand for water and consequent wastewater generation by the city has increased tremendously. At present, the estimated sewage generation is 3,267 MLD whereas the capacity of existing sewage treatment plants in Delhi is 2,330 MLD (CPCB, 2004). The capacity of STPs have been augmented from 1,372 MLD in 1999 to 2,330 MLD in 2003, but the pace of augmenting the STPs capacity by DJB appears to be still slow when compared to the increase in the generation of wastewater. The STPs are already under utilized and highly under pressure due to various reasons such as insufficient ancillary works of laying internal, peripheral and outfall trunk sewers and sewage pumping stations, low flow of sewage to STPs, trunk and peripheral sewer lines still to be connected to STPs, poor maintenance of the sewer networks, improper wastewater collection, blocked sewers due to the problem of siltation etc. (CPCB, 2004; DUEIIP, 2001; Govt. of India and GNCTD, 2001).

Seventeen localities having thirty sewage treatment plants are catering to the five sewerage zones of Delhi working at a composite capacity of 2,330 MLD. But actual treatment is only given to 1,446 MLD of wastewater (Table 3.8) and the remaining 54% untreated sewage finds its way into the Yamuna through the 22 drains. It is therefore necessary that the sewer coverage is extended to all the other residential areas of the city currently not networked so that the sewage generated by colonies are effectively collected and pumped to the treatment plants ensuring their full installed capacity operation.

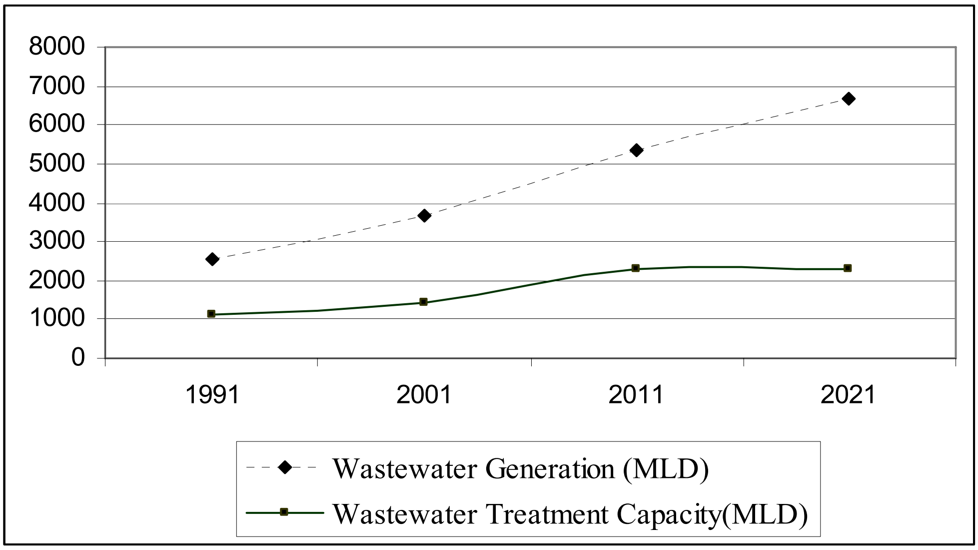
Table: 3.8 Designed Sewage Treatment Capacity Vs Actual Sewage Treatment in Delhi

Sl.No.	Name of STP	Capacity(MLD) 2003	Actual Sewage Treatment (MLD) 2003
1.	Okhla	636	616
2.	Keshopur	327	337
3.	Coronation Pillar	182	114
4.	Rithala	364	152
5.	Kondli	204	86
6.	Yamuna Vihar	91	37
7.	Vasant Kunj	23	7.0
8.	Ghitorni	23	-
9.	Pappankalan	91	41
10.	Narela	45	2.3
11.	Najafgarh	23	0.9
12.	Delhi Gate	10	11
13.	Sen Nursing Home	10	10
14.	Rohini	68	2.3
15.	Timarpur	27	-
16.	Nilothi	182	27
17.	Mehrauli	23	2.3
	Total	**2330**	**1446**

Source: CPCB, 2004

In the past more emphasis was given to augmenting the provision of drinking water supply only but the sewerage facilities has not been commensurate with it resulting in creation of sewerage problem areas; areas where no proper sewer and drainage lines are laid. The target of STP capacity to achieve as proposed by DJB for the 9th Five Year Plan (1997-2002) was 2,771 MLD whereas it could only achieve 2,330 MLD STP capacity: an augmentation of about 70% over the start period whereas the actual treatment could only be increased by 35% for the same period of 1999-2003 (CPCB, 2004). These secondary data clearly attest that while the wastewater generation is constantly increasing, treatment provision is not keeping pace resulting in a growing lag between increased wastewater discharges and treatment capacities at the existing level of infrastructural provision which has been deteriorating the quality of raw water sources (Fig. 3.3).

Fig. 3.3: Wastewater Generations and Treatment Capacity - Delhi



Source: NCRPB, 1999 and Delhi Jal Board, 2002

Even today, about 45% of the total population is not serviced by acceptable sewerage system. More than 50% of the sewer lines do not reach the existing treatment plants due to lack of proper coverage and functioning. As per 2001 census records, in the NCT of Delhi, 10% of the census household lacks any kind of drainage connectivity for wastewater outlet. Closed drainage is only a privilege for 49% of the households and the remaining 41% households have access to open drainage system (Table 3.9). Closed drainage is more extensive in Central Delhi, for it being the city centre and oldest part of the city, sewerage system was developed over the years, but the condition of infrastructure is dilapidated and ageing. Comparatively, New Delhi district has newer infrastructure and about 71% closed drainage system (Census of India, 2001c).

Table 3.9: Drainage Connectivity for Wastewater Outlet: Delhi

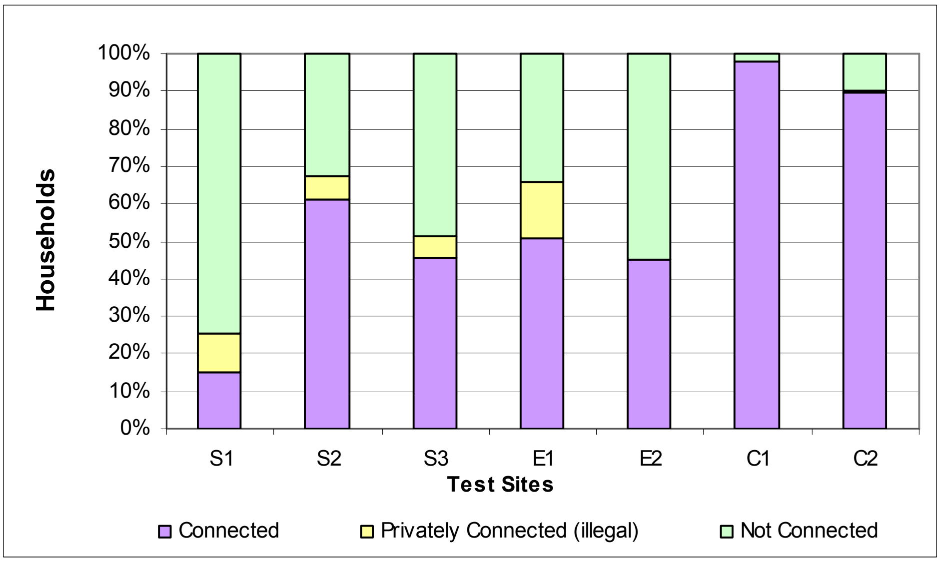
Districts	Total Households	Closed Drainage	Open Drainage	No Drainage
NCT of Delhi	2554149	1255574(49)	1041655 (41)	256920 (10)
North West	522254	247345 (48)	220419 (42)	54490 (10)
North	140688	85458 (61)	38226 (27)	17004 (12)
North East	292357	40585 (14)	220492 (75)	31280 (11)
East	**265990**	**106119 (40)**	**152862 (57)**	**7009 (3)**
New Delhi	38120	27119 (71)	8262 (22)	2739 (7)
Central	**116182**	**92354 (80)**	**18638 (16)**	**5190 (4)**
West	407473	242265 (59)	117731 (29)	47477 (12)
South West	331373	182617(55)	115378 (35)	33378 (10)
South	**439712**	**231712 (53)**	**149647 (34)**	**58353 (13)**

Source: Census of India, 2001c Figure in the parenthesis indicate %

The central district (covering C1 and C2 test sites) has highest proportion of covered drainage covering 80% of the households and only 4% with no drainage. The South district (covering S1, S2 and S3 test sites) comes across as the area with as high as 13% of households with no drainage facility. East district (covering E1 and E2 test sites) has a comparatively higher proportion of open drainage and an average of 40% households accessing covered drains. Similar status of sewer coverage also emerges from the household surveys (Fig. 3.4), thereby validating the precision of primary survey result.

The test sites of central location shows as high as 95% of the household having access to sewer facility. South locations again emerge as the most underprivileged with regard to the sewer connection, showing higher proportions of households not connected to sewer system. East location stands at an average of about 55% of households having access to some kind of sewer coverage. Insufficient sewage collection network in terms of sewer and drainage lines cases the wastewater to get flooded in many places in the form of muddy pits, which serve as breeding ground for various disease carrying vectors.

Fig. 3.4: Sewer Coverage at Surveyed Test Sites in Delhi



Source: Own household survey, 2005-2006 (N = 696)

The wastewater not trapped and treated in STPs find its way into various drains and sub-drains from their respective catchments areas and discharged into the river Yamuna causing numerous environmental and health implications. It has prompted the decision makers and the key stakeholders to explore and probe into other viable options of wastewater management, a detailed insight of which is beyond the scope of the present study but they have been briefly mentioned later in Chapter 9.

3.4 Safe Disposal of Wastewater: Need and Coverage in Delhi

All the wastewater treated, partially treated or untreated is finally disposed in the river Yamuna, which serves as the renal artery for Delhi as it carries the sewage of the city downstream. Flow in Yamuna is from the following sources:

- Treated effluents discharged from the sewage treatment plants
- Overflowing from sewer system into storm water drains
- Discharge from unsewered areas (informal residential quarters)
- Industrial wastewaters from industrial estates
- Release from Wazirabad barrage.

Delhi contributes more than 50% of Yamuna's pollution load, although the total catchment of the river in the capital is less than 2%. The river is virtually rendered sewer between Wazirabad and Okhla barrage. The flow downstream of Wazirabad barrage and up to the Okhla barrage is on account of release of excess flow and also discharge from the various drains along the right bank of river Yamuna. Although there are sewerage treatment plants located at various points for reducing the pollution load, they are grossly under-equipped and insufficient in their functioning. Even after continuous efforts by the Delhi government to augment the treatment capacity, improve sewerage systems, and reduce the pollution load entering the Yamuna, the river condition has deteriorated.

However, high rate of population growth and unmonitored discharge of sewerage into the urban water bodies and drains is nullifying the results of improvement in wastewater management. The extent of environmental imbalance is so severe that the water quality of river Yamuna is rendered unfit even for agricultural use. A study conducted by the Ministry of Water Resources on river Yamuna indicated that there is no easy solution to this multidimensional problem of maintaining the desired water quality in Yamuna. The Biological Oxygen Demand (BOD)[4] increases from 3 mg/l at Wazirabad (where the river enters the city) to 19.8 mg/l at Agra canal (where the river leaves the city); this attests its abuse during its course in the capital (Delhi Jal Board, 2004a).

Wastewater generated from all the zones enters Yamuna through numerous left and right bank drain of Najafgarh and Trans-Yamuna basin. Presently a large part of the sewage flows through the open sewer drains, which is full of organic matter (most important polluting constituent of sewage in respect of its effects on the receiving water bodies). If untreated sewage is discharged into natural water bodies, biological stabilization of organic matter leads to depletion of oxygen in water bodies (CPCB, 2005). Partially

[4] Biological Oxygen Demand (BOD) is a chemical procedure for determining how fast biological organisms use up oxygen in a body of water. It is used in water quality management and assessment, ecology and environmental studies. BOD is not an accurate quantitative test, although it could be considered for determining the extent of pollution in a stream. BOD can also be used as a gauge of the effectiveness of wastewater treatment plants. Most pristine rivers will have a 5-day BOD below 1 mg/l. Moderately polluted rivers may have a BOD value in the range of 2 to 8 mg/l. Municipal sewage that is efficiently treated would have a value of about 20 mg/l. Untreated sewage would have varying level of BOD (Free encyclopedia: Wikipedia-Biological Oxygen Demand, c.f. Sawyer, McCarty and Parkin, 2003; Clescerl, Greenberg and Eaton, 1998).

treated and untreated effluent enters the river from 22 drains carries mostly domestic sewage with high levels of BOD (CPCB, 2004). It is of vital environmental importance to reduce the BOD levels of the effluent so as to minimize the quality degradation of the receiving water bodies.

3.4.1 Need for Wastewater Treatment and Safe Disposal

Wastewater treatment involves breakdown of complex organic compounds present in the sewage into simpler compounds that are stable, nuisance-free and non-hazardous for human beings, either by chemical or biological treatment. Untreated wastewater emanates malodorous gases and fowl smell, known as 'sewage sickness[5]'; it depletes the dissolved oxygen of streams and other receiving water bodies causing undesirable effects in the aquatic ecosystem. It may lead to eutrophication of lakes and streams as well as contaminate land and water bodies where such sewage is disposed. Inadequate treatment of wastewater raises the nitrate levels in groundwater and also allows bacteria, viruses and other disease causing pathogens to enter groundwater and surface water. All these reasons make treatment and safe disposal of wastewater not only desirable but also necessary (SulabhENVIS, 2003).

The credit for the introduction of sewage treatment goes to Louis Pasteur and other scientists, who proved that sewage-borne bacteria were responsible for many infectious diseases. In the 1900s sewage treatment merely consisted of spreading the sewage over the open land where it decomposed under the action of micro-organisms. It was soon found that it led to the problem of making the land 'sick'. Subsequently the wastewater was discharged to the rivers or water bodies directly, which further resulted in the deterioration of the water qualities of such bodies. All these methods completely depended upon the self-purifying capacities of the land and water but there is a threshold to these capacities beyond which the deterioration begins and thereby in response to the adverse conditions caused by the discharge of wastewater to the environment and the

[5] The deleterious effects of sewage application to soils and the prevalence of unhygienic conditions on the sewage farms are generally referred to as 'sewage sickness'. This refers to the undesirable conditions sometimes brought about in soils by water logging, caused by excessive use of sewage (Mahida, 1981).

concerned public health various methods of wastewater treatment were developed (SulabhENVIS, 2003; United States Environmental Protection Agency, 2004).

Moreover, over the period of time the environmentalist, water experts and decision makers became more environmentally conscious due to their increased knowledge and understanding of the environmental problems caused by the discharge of some of the specific constituents found in wastewater. Also, as populations grew, the quantity of wastewater generated rose rapidly and the deteriorating quality of this huge amount of wastewater exceeded the self-purification capacity of the streams and river bodies. Therefore, pressing the necessity of developing other methods of treatment that could possibly check long-term health effects and reduce adverse environmental impacts. As a consequence, while the early treatment objectives remain valid today, the required degree of treatment need has increased significantly and additional treatment objectives and goals have been added in accordance with the demand of time.

The collection, treatment and safe disposal of wastewater require a proper infrastructure, which needs to be developed keeping in mind various engineering, economic and environmental factors such as:

- Need of the population and area to be served
- Topography of the area, its slope and terrain
- Tentative sites available for treatment plant, pumping stations and disposal works
- Groundwater depth and quality where wastewater has to be disposed
- Soil type and quality where the wastewater is to be disposed
- Wastewater flow and characteristics
- Degree of treatment required
- Odor and mosquito nuisance which affects land values and ambience
- Availability of land, power, equipments and skilled staff
- Capital costs as well as the operational and maintenance cost.

The sewage treatment technologies used at the various STPs in Delhi are providing secondary treatment except at Sen Nurshing Home and Delhi Gate where treatment up to the tertiary level is done. The present level of sewage treatment in the city is incapable of controlling potentially harmful constituents in the effluents.

3.4.2 Coverage of Sewer Facility by Settlement Types

More than half of Delhi population lives in some kind of informal settlements. Heterogeneous planning levels and settlements characterize the city. A distribution of population by type of settlements shows that the planned colonies contain only 23.5 per cent of the total population of Delhi; the rest of them are categorized as rural and urban villages, resettlement colonies, regularised unauthorised colonies, *jhuggi-jhompri* clusters and so on (Batra, 2005). Several categories of settlements could be seen in just one block with divergent planning and varying levels of infrastructure and civic amenities. The status of sewerage facilities in various categories of habitation confirms that almost all the Jhuggi-Jhompri clusters and more than half of the unauthorized colonies are deprived of any sewage facilities. Moreover, nearly 27% of the regularized colonies and 31% of the urban villages also do not have access to sewer (Table. 3.10).

Table 3.10: Sewerage Facility in Different Types of Colonies in Delhi: 2006

Sl. N0.	Type of Settlement	Total No. of Settlements	Sewage Facilities Available in Settlements
1	Urban Villages	135	105
2	Unauthorised Colonies	1071	465
3	Regularised-Unauthorised Colonies	567	493
4	Jhuggi-Jhompri Clusters	1100	none
5	Resettlement Colonies	44	44

Source: GNCTD, 2006

3.4.2.1 Urban Villages

There are villages that have been overrun by the city of Delhi. By notification of the Delhi government and Urban Development Department, these have now been declared as urban villages (Batra, 2005). These urban villages, even within the city, do not show any character of 'village' and have become economic centers of informal activities. Owing to lower land prices and the closeness to urban colonies, urban villages attract many private builders for housing, construction and commercial activities without caring for civic amenities and infrastructure. Such villages are characterized by narrow, winding lanes which pose problems for laying water and sanitation lines. These mainly accommodate residential, commercial and industrial uses and function as a mix. Many small scale industries tend to thrive in these areas and raised the demand for water (Hoyt, Khosla and Cenopa, 2005). There are 135 urban villages on the outskirts of Delhi. These are not notified urban areas and are outside the jurisdiction of the Municipal Corporation. Therefore, these areas are devoid of the facilities of assured potable water, surface drainage system and sanitation arrangement. According to DJB, sewerage system has been laid in 105 villages (GNCTD, 2006).

3.4.2.2 Unauthorised Colonies

The unauthorized colonies are the residential pockets, which have come up generally on private land in an unplanned manner in violation of the Master Plan and Zonal Plan regulations. The houses are constructed with concrete and are not necessarily dilapidated like those of the slum areas. There are a variety of reasons for the phenomenon and growth of unauthorized colonies in Delhi. The issue of existing unauthorized colonies has engaged attention since the mid-seventies when a policy for regularization was formulated. There are a total of 1,071 unauthorised colonies and none have sewerage facilities. Most of these colonies are located in the Northwest, West and East of Delhi. The government of Delhi started a Plan Scheme in 1997-98 for providing minimum services, i.e., construction of road, roadside drain and filling up of low lying area so as to maintain the hygienic condition in these colonies. These minimum services are being provided only in those unauthorised colonies which are located on private land and their number in 2005-06 was only 465 (GNCTD, 2006).

3.4.2.3 Regularised Unauthorised Colonies

The present method of regularization of unauthorized colonies by the Government of India is for the provision of basic infrastructure to improve environment under a plan scheme initiated in 1979-80. Over the years, a large number of such colonies have been regularized, usually on political compulsions, on consideration of betterment levy for redevelopment of such colonies, but either the rate of such charges or the recovery of the same have been far too inadequate to actually implement such redevelopment plans which have lagged far behind the pace of growth, making most of such colonies only marginally better than many slum resettlements. Out of 567 unauthorised-regularised colonies, sewerage facilities have been provided in 493 colonies up to March 2005 and 11 more colonies will be covered soon (GNCTD, 2006). DJB sees provision of sewerage to be the main problem after regularization; though water supply can be provided but sewer lines cannot be laid due to physical and technical reasons (Box 3.1).

Box: 3.1

Can't ensure sewerage: DJB Clip

[Friday, February 06, 2004 11:11:38 pm TIMES NEWS NETWORK]

NEW DELHI: Regularisation of unauthorised colonies will be a definite strain on civic amenities, especially sewerage. According to the Delhi Jal Board, water would be less of a problem as compared to sewerage. Delhi Jal Board CEO P K Tripathi said: ‘‘Sewerage will be the main problem after regularisation.” He added that it would not be possible to provide a proper system in even 20 colonies out of over 1,071 colonies. “The main reason is that there is no space for putting a system in an already existing colony,’’ explained Tripathi. According to the Union urban development ministry guidelines, the unauthorised colonies eligible for regularisation need to have occupied at least 50 per cent of the area. In all the unauthorised colonies that are on undeveloped land the colonies are established and have their own temporary systems of sewerage system. The biggest challenge before the civic bodies would be to ensure proper development. ‘‘These colonies were never planned. Now they have made constructions in a haphazard manner,” said an official. “To suddenly expect us to put pipes and connect it with the main sewerage drains is not fair. Where do we get the space?” explained the official. “This is why the colonies would be given a choice of whether to pay the civic bodies for amenities or get their cooperative society to do the work,’’ he added. The Delhi Jal Board sends its water tankers to several unauthorised colonies. A senior Delhi Jal Board official said: ‘‘we may not be able to provide adequate water. We will, however, be able meet the minimum demand. Water would not be a problem.’’

3.4.2.4 Jhuggi-Jhompri Clusters

These are the slum clusters or squatter settlements, which have come up illegally on public or private lands all over the city and inhabited primarily by the urban poor and the migrants from the rural areas. In Delhi these are scattered all over the city in small settlements, usually along the railway tracks and roads, river banks, parks, public places and other vacant lands, which make the task of in-situ rehabilitation quite difficult and cost ineffective. The estimates of Slum Wing of MCD shows that the numbers of such squatter settlements have consistently been on the rise despite the efforts made to demolish and/or resettle them. There are a total of 1100 JJ clusters in Delhi with about 600,000 households (GNCTD, 2006). In these clusters, a family of 4-5 persons lives in one hutment of about 150 sq. ft area without any access to sanitation facilities. While water supply is provided through hand pumps and public hydrants located in different parts of clusters, community toilet complexes have been constructed by MCD for sanitation. However, many of the hutment dwellers do not use these toilets and prefer to defecate in open areas around the clusters. Effluents generated from community toilets complexes and run-off from the areas used for open defecation reach Yamuna through storm water open drains and open canals.

3.4.2.5 Slum Designated Areas

The notified slums are those which have been declared/notified as slum areas under Section 3 of the Slum Areas (Improvement and Clearances) Act, 1956. Under this Act those areas of the city where buildings are unfit for human habitation by reason of dilapidation, over-crowding, faulty arrangement and design or where due to faulty arrangements of streets, lack of ventilation, light and sanitation facilities, or any combination of these factors the living environment are detrimental to safety, health or morals. The major proportion of such notified slums is found in the walled city of Shahjahanabad and their extension, which was originally meant to accommodate 60,000 people, but where an estimated 2 million population is now living (Chakrabarti, 2002). Neither the provisions of Slum Areas Act nor of the Master Plan for the walled city have been implemented since the city was overtaken by problems of a different magnitude, which were created by the unending waves of fresh migrations. The area is connected to sewer system and has about 80% covered drains (Census of India, 2001c). But the infrastructure is in a very poor state of condition due to the problem of ageing and lack of proper upgradation and maintenance.

3.4.2.6 Resettlement Colonies

The scheme for resettlement was started in 1961 in Delhi for providing low cost housing facility. Around 44 resettlement colonies have been developed mainly on the outskirts of the city to resettle squatters and slum households, each provided with a plot of land measuring 18 sq. m at a highly subsidized price of Rs. 5,000 (US $106). These colonies suffer from various infrastructural inadequacies like water supply, sewerage, drainage, garbage disposal, electricity, schools, hospitals, roads etc. (Chakrabarti, 2002). A survey conducted by the Council for Social Development indicate that half of the families do not have individual water connections or toilet facilities and have to depend on community latrines and bath rooms, which are either so inadequate or maintained so poorly that many of the residents defecate in the open (Ali, 2003). All the 44 resettlement colonies have been provided with sewerage system which is extremely sub-standard with unsatisfactory performance and irregular maintenance; consequently, the residents are still grappling with the problem of wastewater flooding and improper drainage in their household and near their neighbourhood.

3.5 Wastewater Problems and Management Status in the Surveyed Areas

Wastewater management is emerging as a vital problem for Delhi's sustainable development. Poor condition of the sewers, shortage of treatment capacity and lack of sanitation facilities in unsewered areas are responsible for continued pollution of water sources (Govt. of India, 2008). Such a situation can be contributed to the fact that the city is expanding beyond its capacity; proliferating population, uncontrolled and haphazard expansion and lack of proper planning has led to the exponential rise in the water demand and consumption, which is not backed by an adequate level of disposal infrastructure, thereby leading to serious health hazards and ecological problems for the downstream population. In short, it calls for a system where the water consumption is lesser than the sewerage treatment capacity on one hand and the existing capacity is utilized efficiently on the other. But attaining such an ideal system has numerous planning, technological and socio-economic hindrances. Presently, the problems faced at the very basic level are lack of clear plan, deficit survey and unclear direction towards improvement (Box 3.2).

Although Delhi has the largest treatment and collection system in the country, large areas in the city are still unsewered. According to the survey results, only 53% of the population was connected to the sewer. 10% privately connected to the sewer in an illegal manner another 3% used septic tanks. As high as 34% of the population had no access to any wastewater disposal infrastructure which forced them to either restrict their water use so as to generate less wastewater and/to take other alternative disposal practices of compromised hygiene.

Box: 3.2

Sewer Network has not been Mapped for 30 years Clip

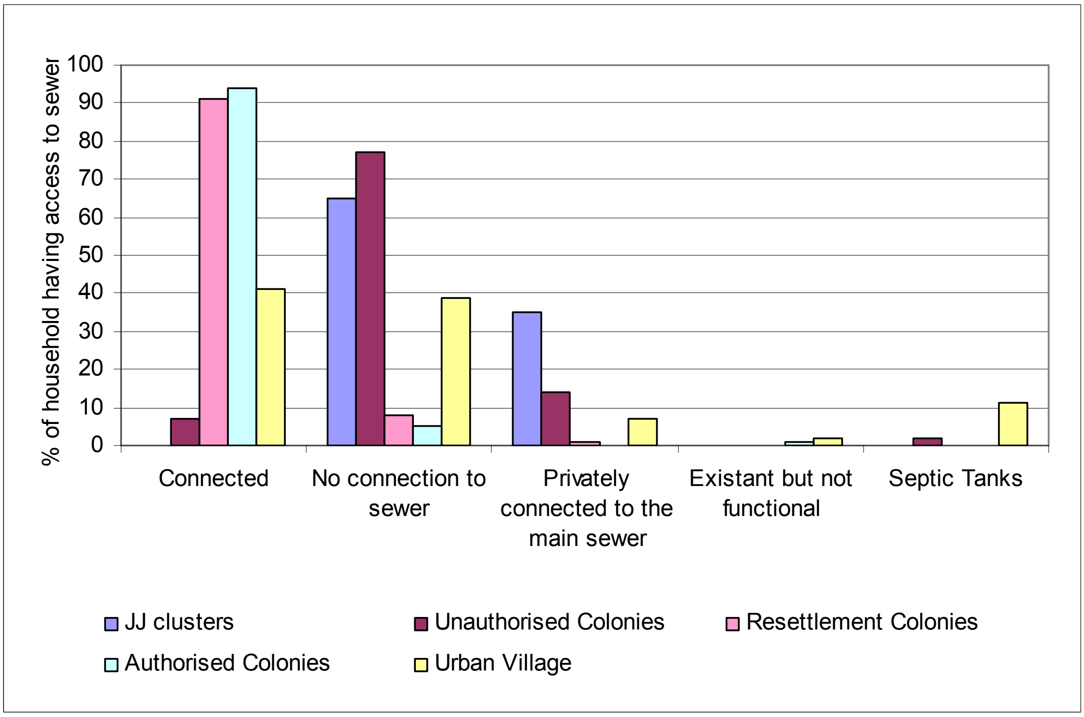
With Old Drains Unable To Handle Sewage Load, Roads Get Flooded

By Nidhi Sharma/Times News Network. 20.07.06

New Delhi: Here's why your city's roads get waterlogged within a few minutes of rain. Delhi does not have a drainage master plan. The civic agencies have not mapped the city's drainage system since the 1970s. The last comprehensive survey was done over three decades back. A committee was formed and a master plan framed in 1976. Since then, however, the city has developed rapidly. The entire trans-Yamuna sprawl has come up in that period, new colonies have been added in all directions and the city limits have advanced. However, no attempts have been made to improve the drainage capacity. As a result, these drains carry a sewage load that is much more than what they can handle. This leads to backflow of sewage in overflowing drains, which causes waterlogging on roads. There are many missing links in the system too. The Azadpur fruit and vegetable market is a case in point. The wholesale market was developed by DDA. In 1999, the terrible stench from the area made wholesale dealers complain to Delhi government about waterlogging. A consultant was appointed to survey the market. The study found that about 10 vital pipe links in the underground sewer network were missing. Due to this, the sewer water was seeping into the ground and even choking other networks. In another case, Vasant Kunj residents had complained to MCD and DJB about polluted water supply and also sewer water seeping into the foundation of their houses. A survey of the area revealed that DDA had simply forgotten to put a 25-metre sewer link. Since it did not have a detailed plan of the area, it could not zero in on the problem for over five years. Delhi urban development minister A K Walia said on Wednesday: ''We are trying to map the drainage system now. We need a new master plan and are in the process of framing one. But it will take time.'' Agencies like Delhi Jal Board (DJB) have separately undertaken surveys of the network but there have been no coordinated efforts.

Connectivity to the city sewer was highest ranging between 80-90% in authorized and resettlement colonies of all the locations whereas the informal settlement colonies were grossly deprived of this facility. One-third of the households of JJ clusters were having illegal private connection to the sewers network, primarily seen at the central location (Fig. 3.5). This was due to the easy accessibility to the sewer lines traversing the city centre. Residents, depending upon their affordability could easily dig a connection to the sewer running along their clusters; such convenient arrangement increased the burden on the poorly maintained drains and further aggravated the problems of wastewater disposal.

Fig. 3.5: Sewer Connectivity in Different Surveyed Colonies



Source: Own household survey, 2005-2006 (N = 696)

Management of wastewater in terms of treatment and safe disposal are dependent on the characteristics of the generated sewage which is largely unsegregated in Delhi. A large proportion of open drains and increasing illegal connection with improper outlet in the city also made segregation of sewage difficult, thereby leading to a generated mix of greywater and blackwater entering STPs. In the absence of any separation of toilet water from other domestic waste, sewage carries high level of faecal coliform bacteria which the sewerage treatment plants are not equipped to decimate. Consequently, all-time stinking effluent flows through the open drains traversing residential colonies were a monstrosity and source of major nagging concern for the residing groups (Fig. 3.6).

Open drainage with pools of stagnant water around them, garbage dumps and un-cleared mucks are common sight in such areas attesting its unhygienic setting. Lack of water and toilet facilities within the household forces people to carry out activities like bathing, defecating and washing clothes at public water points. In the absence of proper drainage facilities, wastewater gets accumulated at various places in the form of cess pools and muddy pits. These also act as breading grounds for various disease-carrying vectors such as mosquitoes and flies.

Fig. 3.6: Large Open Drains: A Nagging Source of Problem

Open Canal (E1) own photo

Open Drain (S2) own photo

3.5.1 Wastewater and Sewerage Profile of the Surveyed Areas

The level of wastewater generation depended on settlement location, status of colony, population size, accessibility and level of water consumption. Additionally, the kind of activities in the locality determined the characteristic of sewer generated. Certain selected parameters have been compiled on the basis of household survey results to analyse the wastewater and sewerage profile of the surveyed sites (Table 3.11). The wastewater generated from the colonies of east location was mostly domestic in nature whereas that of central and south test sites were domestic as well as commercial as gauged on the basis of socio-economic activities there.

Table 3.11: Wastewater and Sewerage Profile of the Different Surveyed Colonies

Location	Central			East					South				
Type of Colony	*JJ Clusters*	*Resettlement Colonies*	*Authorised Colonies*	*JJ Clusters*	*Unauthorised Colonies*	*Resettlement Colonies*	*Authorised Colonies*	*Urban Village*	*JJ Clusters*	*Unauthorised Colonies*	*Resettlement Colonies*	*Authorised Colonies*	*Urban Village*
Total No. of surveyed household	30	24	153	8	84	50	9	27	89	40	86	33	63
Total pop. of surveyed household	188	163	1009	57	491	321	30	205	532	267	587	165	343
Sewer connection	No- 34%	No-8%	No-0%	No-88%	N-75%	No-22%	No-0	No-7%	No-75%	No-80%	No-0	No-30	No-56%
	Yes-66%	Yes-92%	Yes-100%	Yes-12%	Yes-25%	Yes-78%	Yes-100%	Yes-93%	Yes-25%	Yes-20%	Yes-100%	Yes-70%	Yes-44%
Type of sewer (%)	Open-40	Open-29	Open-0	Open-100	Open - 100	Open -76	Open-0	Open-56	Open-100	Open-100	Open-48	Open-79	Open-89
	Covered-60	Covered-71	Covered-100	Covered-0	Covered-0	Covered-24	Covered-100	Covered-44	Covered-0	Covered-0	Covered-52	Covered-21	Covered-11
Total water consumption (LPD)	10152	14018	89125	2280	56465	25680	5880	16400	24472	21093	42264	21120	28126
Average per capita water consumption (lpcd)	54	86	89	40	115	80	196	80	46	79	72	128	82
Estimated wastewater generation (LPD)	8122	11214	71300	1824	45172	20544	4704	13120	19578	16875	33811	16896	22501
Average per capita wastewater generation (lpcd)	43	69	71	32	92	64	157	64	37	63	58	103	66
Type of wastewater generated	Domestic	Domestic and Commercial	Domestic	Domestic	Domestic	Domestic	Domestic	Domestic	Domestic	Domestic and Commercial	Domestic and Commercial	Domestic and Commercial	Domestic and Commercial
Disposal point of household wastewater (%)	Sewer-60	Sewer-92	Sewer-100	Ditch-38	Open Drain-100	Open Drain-84	Sewer-100	Open Drain-56	Open Drain-100	Open Drain-100	Open Drain-48	Open Drain-79	Open Drain-89
	Open Drain-40	Open Drain-8		Open Drain-62		Sewer-16		Sewer-44			Sewer-52	Sewer-21	Covered-11
Disposal point of Toilet water	Sewer-67	Sewer-92	Sewer-100	Open Drain-100	Open Drain-25	Open Drain-76	Sewer-100	Sewer-93	Open Drain-8	Open Drain-53	Sewer-95	Sewer-85	Open Drain-84
	No Toilet-33	Open Drain-8			Tank-75	Sewer- 24		Open Drain-7	Tank-2	Tank-47	No Toilet-5	Tank-15	Tank-16
									No Toilet - 90				

Source: Own household survey, 2005-2006 (N = 696)

The residential colonies at central district had a high number of local restaurants and food eateries joints. Wastewater generated by these units also entered the sewers which were designed for handling the estimated household wastewater generated only. The increased pressure by the tenfold increased population as well as the additional wastewater generation by commercial activities cannot be sustained by the ageing infrastructure of old city, which is very evident through the persistence of wastewater disposal problem there despite the area being properly networked with planned underground sewer system.

Similar kinds of commercial activities were commonly seen at the surveyed residential colonies of South Delhi. Households were commonly running activities like beauty parlours, envelope making, sewing, embroidery and various other kinds of handicrafts for augmenting the family income. Such activities involved employing considerable number of labours, who spent most of the time there and also had their usual water usage activities carried out which increased the demand for water as well as sewage generation. It was also commonly reported that the improperly managed paper and textile wastes were creating serious problem of blocking the drainage canals and *nalas* in the colony.

Non-provision of proper sewage disposal system in JJ clusters and unauthorized colonies oblige the resident for privately (illegal) connecting their household wastewater outlet to the open drain passing the locality. Most of the households in unauthorized colonies and urban villages had constructed septic tanks. Overflow from such tanks are usually connected to the surface drains. At JJ clusters, low cost sanitation facilities in the form of community bath and toilets were provided, which was certainly insufficient for the social group. No separate provision was made for women, which was particularly reported from JJ clusters of South location, this made women to carry out occasional bathing at their hutments itself, which left the discharged wastewater flow to the open.

The proportion of open surface drains traversing the residential colonies in east and South districts were as high as 57% and 34% compared to 16% at the central. Wastewater from the surveyed colonies of Central, South and East locations were discharging into the nearest drain in the region. In order to analyse the chemical profile of the wastewater generated from the studied sites and flowing in these open drains, secondary data from

CPCB is relied upon. Their characteristics in terms of TSS, COD and BOD for 2003 are presented in Table 3.12.

The strength of wastewater depends mainly on the degree of water dilution. Wastewater can therefore be categorized as strong, medium and weak. Strong wastewater has a higher BOD level (about 220-400 mg/l) than medium wastewater (about 110-220 mg/l) and so on (CSE, 2007). Pollution loads in these drains helps to conclude that wastewater generated from the surveyed test sites were basically domestic and commercial in nature with higher content of oxygen demands, suspended solids and presumably high level of fecal coliform as the toilet water was also entering the same sewerage system. On the basis of wastewater classification detailed in CSE's wastewater recycling manual the type of wastewater generated from the surveyed test sites can be classed as medium.

Table 3.12: Water Quality Status of Selected Drains Carrying Treated/Untreated Wastewater in the Test Areas

Drainage Basin	Name of the Drain	Location	TSS mg/l	COD mg/l	BOD mg/l
Najafgarh	Tonga Stand Drain	Central	654	225	95
	Moat Drain	Central	122	168	60
	Barapulla Drain	South	167	220	92
	Kalkaji Drain	South	53	122	47
	Tughlakabad Drain	South	430	182	59
Trans-Yamuna	Trilokpuri Drain	East	620	768	320
	Gazipur Drain	East	1370	736	400
	Dallupura Drain	East	240	332	182
	Kondli Drain	East	400	332	183

*TSS- Total Suspended Solids, COD- Chemical Oxygen Demand, BOD- Biological Oxygen Demand

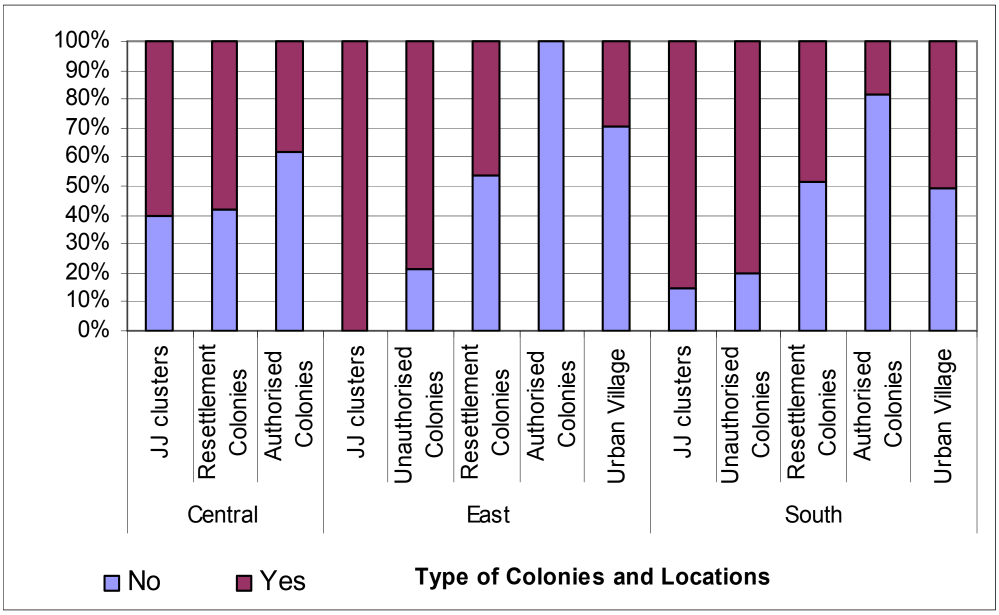
Source: CPCB, 2004

3.5.2 Nature and Type of Wastewater Related Problems

The prevalence of wastewater disposal related problems was very obviously visible in some of the areas surveyed. As discussed in the earlier text, authorised colonies and resettlement colonies were comparatively better placed with regard to the sewer coverage. However, further investigation showed that these areas were not completely aloof of the wastewater problems though they were 'legally' provided with the sewer facility but the problems related to improper disposal persisted due to overloading and poor maintenance.

At central location about 38% of the household even in the authorised colonies and 58% of resettlement colonies were facing wastewater disposal problem. Almost all the respondents of the JJ cluster at east location were facing the problem of wastewater flooding due to no proper outlet in their household and neighbourhood. In many cases where water was supplied through pipes there lacked corresponding pipes for removing the wastewater generated. The wastewater was simply allowed to flow by gravity of the landscape ending in low lying areas. Unauthorised colonies at the East as well as South location were similarly placed at having 80% positive response to the existence of wastewater disposal related problems followed by the resettlement areas (Fig. 3.7).

Fig. 3.7: Presence of Wastewater Disposal Problem in the Surveyed Colonies

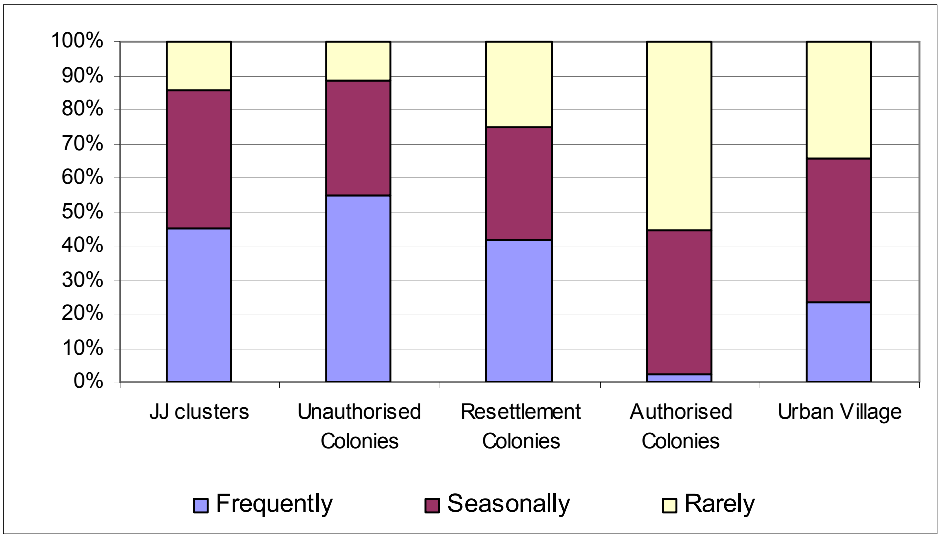


Source: Own household survey, 2005-2006 (N = 696)

At East location, comparatively newer residential areas of authorised status, where the sewer lines were newly laid (as seen in the authorized colonies), wastewater disposal was presently not a problem whereas 45% of the households in the urban villages and 30% in resettlement areas were facing some kind of wastewater disposal problems. Here again insufficient sewer coverage emerges to be the root-cause re-emphasizing that the present level of services provided wastewater disposal and management is not adequate.

The frequency of problem was reported to be mostly seasonal in nature, primarily during the rainy season. Authorised colonies rarely experienced wastewater disposal problem in their household and only seasonally in the neighbourhood, whereas it was a frequent problem in the JJ clusters and unauthorised colonies (Fig.3.8). Monsoon brings menace to the residents, when overflowing of sewage and water logging in the area remains persistent for days and weeks.

Fig. 3.8: Nature of Wastewater Disposal Problem in Different Surveyed Colonies

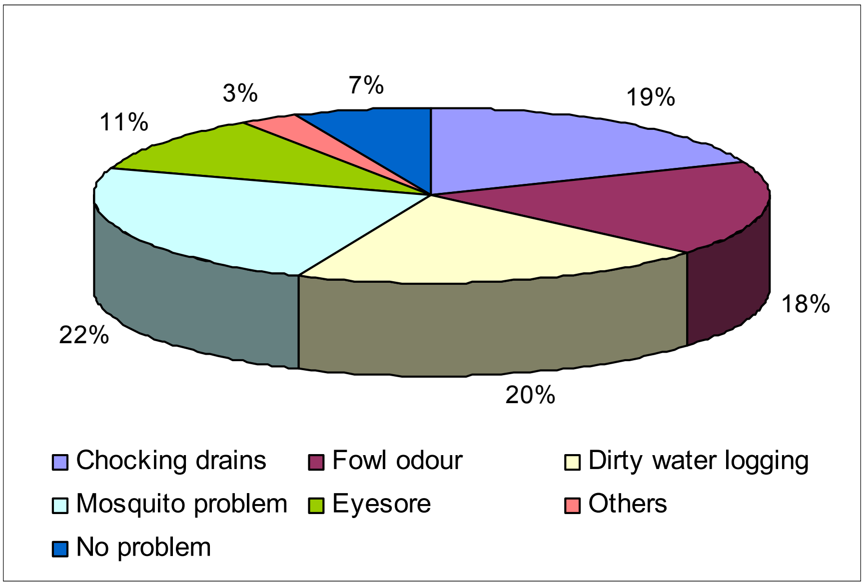


Source: Own household survey, 2005-2006 (N = 696)

Apart from the wastewater disposal problem in the household and immediate neighbourhood, other related problems were choking drains due to the dumping of garbage, stagnant sewage and unclear muck breeding mosquitoes and emitting fowl odour. Infrequent cleaning turned stagnant sewage a source of minor irritant emitting bad odor and people feared outbreak of an epidemic. Mere presence of sewer facilities did not save the residents of the wastewater nuisance. The location of the colonies (with respect to topography, nearness to open drains, etc.), maintenance of the sewer and people's concern towards it also played important roles in determining the magnitude of wastewater related problems in the surveyed areas.

Malfunctioning in sewer system disrupted the daily life activities of the residents as they had to postpone their household activities like washing and cleaning till the blocked sewer slowly drained the flooded water. Chocking drain, fowl odour and dirty water logging in the surrounding neighbourhood were the prominent problems in all the colonies cutting across Central, South and East locations. At East location, open drain ran along the wall of an authorized colony surveyed, which was a major source of fowl odour and mosquito in the area (Fig. 3.9).

Fig. 3.9: Types of Wastewater Related Problems in the Surveyed Households



Source: Own household survey, 2005-2006 (N = 696)

Sewage mixing with the water supply due to backflow was also frequently reported to be common during the rainy season. The problem was not only with the smaller drains in the locality but it had a wider dimension due to its connection with the trunk and peripheral sewers blockage. Municipal Corporation of Delhi (MCD) and Delhi Jal Board (DJB) need to clean up and desilt the drains yearly, preparing them for monsoon. But in reality, drains were left silted for years before the problem caught attention.

Apart from the specific studied test sites the existing sewers even in other parts of Delhi were highly silted and leaking causing raw sewage to overflow and flood the neighbourhood. During the monsoon period the condition deteriorated further as the bylanes remain flooded and drain spill into the houses. The complexity of sewerage malady and helplessness of the affected population is clearly evident from the media reported public grievance (Box 3.3).

Municipal accountability again can be called upon for maintenance failure. Most of the residents seem unconcerned about the filth and bad odour resulting from such condition. While people do seem to occasionally clean the drains inside their own houses, there is a general apathy towards the drain outside.

Box: 3.3

Here, Drain Water Spills into Houses

Mahavir Enclave Residents' Repeated Complaints To Civic Agencies Fall On Deaf Ears

Tanushree Roy Chowdhury | Times News Network. 10.02.07

New Delhi: After living in unhygienic conditions for about two years and repeated complaints, residents of Mahavir Enclave in southwest Delhi are far from getting relief from the mess. The residents have to grapple with choked drainage lines due to overloading and improper maintenance. The water not only floods the bylanes but also contaminates potable water. ''The drains outside our homes were built some 12 years ago. Ever since, there has been no maintenance. Very often the drains overflow and the water enters our homes,'' said Krishna Shawney, a resident of Mahavir Enclave. To add to the woes of the residents, a good spell of rain last weekend made the already-choked drains to spill. Also, residents complain of practically no supply of clean drinking water. ''We have written on innumerable occasions to the DJB and MCD officials but to no avail. The deputy commissioner of MCD keeps changing every few months for this area and hence our applications remain unanswered. They all promise to look into the matter but nothing much has changed,'' said S K Tyagi, another resident. While residents continue facing this everyday menace, authorities tried to steer clear of the problem. ''There is no problem of drainage as such in our zone. People attach extra bathrooms/toilets to the existing ones which do not have proper outlets because of which the water flows back. And also, the problem of sewage does not come under MCD, it's rather a management problem to be addressed by the DJB,'' said MCD counselor for the area, Ram Naresh Gupta. This leaves the residents to face it all by themselves.

3.6 Concluding Remarks

The discussions above bring one to the conclusion that the wastewater and sanitation situation in Delhi is scary, although the government is taking steps but still much is needed to be done in this regards. The sewage infrastructure in the city is grossly insufficient. Though augmentation of sewerage infrastructure has been done over the years (CPCB, 2004) and further plans to improve are there on proposal still the problem is not much solved as with time the sewage generation is also increasing and so the deficient remains the same. Inadequate wastewater disposal and sanitation services are facing a substantial proportion of the population. Much discussion has been undertaken to find the cause for the failure in providing adequate sewerage disposal facility for all.

From the above discussion and on the basis of both secondary literature analysis and personal findings major reasons for the wastewater disposal and sewer-related problems in Delhi can be summarized under the following heads:

Planning problems

1. Unruly expansion of the residential colonies on undeveloped lands
2. Rapid increase in informal settlement quarters
3. Increasing marginalized population
4. Wrong estimations of wastewater generation
5. Sewage flow exceeding the carriage capacity
6. Water supply not correspondingly backed by sewer lines
7. Poor design of sewerage

Locational problems

1. The suffering communities are located at high population density areas
2. Informal settlement locations
3. Dense and congested residential colonies difficult for laying sewer lines
4. Missing sewer links within the network
5. Upcoming of illegal colonies within close quarters of already existing ones faces problem of no sewer connectivity (neighbourhood gradient effect)

Infrastructural and engineering problems

1. Insufficient sewer network coverage
2. Incompatibity of treatment plants with the characteristics of sewage generated
3. Underutilized and underequipped treatment plants
4. Old and ageing sewer infrastructure
5. Deficiency of infrastructural documentation
6. Poor alignment of pipes in sewer water supply lines
7. Leaking joints between pipes
8. Siltation of sewer pipes
9. Improperly capped manholes
10. Non-segregation of wastewater
11. Existence of large proportion of open drains

Institutional problems

1. Confrontation between the State's legislators and the Central Government
2. Multiple agencies providing various civic facilities
3. Sub-divisions and unclear departmental responsibility
4. Separate water supply and sewerage zones for city
5. Lack of managerial co-ordination
6. Under-qualified operating and maintenance team
7. Irregularities among the lower grade sweeping staff
8. General apathy towards people's grievance

Citizens' apathy

1. Illegal connection to the main sewer
2. The caps of manholes are frequently stolen and sold as scrap metal
3. Lack of education regarding the proper use of sewer system
4. Dumping of solid wastes in the sewers
5. Lack of concern towards the drains outside individual households

Chapter 4

Understanding Social Vulnerability Related to Wastewater

4.1 Introduction

Researches on various aspects of vulnerability has existed for decades (Timmerman, 1981; Susman, O'Keefe and Wisner, 1983; Kates, 1985; Bogard, 1989; Downing, 1991; Dow, 1992; Smith, 1992; Watts and Bohle, 1993; Blaikie *et al*., 1994) but the concept of social vulnerability is yet to find a common understanding, therefore it still calls for much discussion and empirical validation (Cutter, 1996; Alwang, Siegel and Jørgensen, 2001). In broadest sense, it refers to the social dimension of vulnerability to multiple stressors and shocks most often described using the individual characteristics of social groups (age, sex, type of dwelling, period of stay, health, income and the options of social networking, etc.). This chapter tries to analyse various views regarding vulnerability which has stemmed from both natural and social science disciplines and points out the importance to distinguish social vulnerability. It introduces the perspective on social vulnerability with particular reference to wastewater hazards and explains various components of social vulnerability for understanding the approach. It further elaborates upon the role of people's perception in determining their vulnerability. This chapter lays the base for the succeeding chapters, which sequentially deals with each component of wastewater related social vulnerability individually.

4.2 Vulnerability Types: Need to Distinguish Social Vulnerability

It was in the 1980s that the term vulnerability became a buzzword and since then it has been continuously doing the rounds in various field of academics. Much of the debate around vulnerability is focused on conditions or factors which predispose people to risk (risk-exposure factors) and inherent capability, resilience or capacity of the exposed population to withstand the risk (e.g., Anderson and Woodrow, 1989; 1993; Watts and Bohle, 1993; Blaikie *et al*., 1994; Kasperson, Kasperson and Turner, 1995).

Over the past years the term vulnerability has been defined and refined for a better and common understanding. It is used with different meaning by various disciplinary groups, more prominently with reference to extreme natural events; climate change, hazards and disasters (Burton, Kates and White, 1993; Adger, 1999; Olmos, 2001; Brooks, 2003). The term is also widely used in poverty, livelihood, food insecurity studies, violence and crime (Liverman, 1990, 1992; Dow, 1992; Watts and Bohle, 1993; Cutter, 1996; Philo, 2005).

Academia has been continuously interested in analyzing all issues pertaining to vulnerability arising from physical, social, anthropologic, economic, and environmental to technical or engineering causes with the purpose of characterizing it to promote awareness on the subject (Villagrán de León, 2006). But even within academic context, usage of the term 'vulnerability' sometimes remained unclear. Economists have talked about it in terms of market vulnerability and social scientists use it for social defenselessness, hazard and disaster study focuses on the biophysical vulnerability at risky locations while regional food insecurity highlights the inherent vulnerability of the system. Thus, it sometimes becomes unclear whether we are referring to place or people to be vulnerable, whether it is the situation at a place which is vulnerable or status of individuals making them vulnerable to particular event which strikes them unexpectedly.

The different uses of the term have emerged from different disciplinary focus (Wisner, 2004). It is the inherent flexibility of the term which makes it applicable in a number of contexts. Research groups and professionals in academia, hazard and disaster management agencies, climate change community and development agencies have been working to develop a common understanding of vulnerability, but the broadness of the term makes it difficult for scholars to strictly bind it. Nevertheless, what commonly emerges out of various definitions of vulnerability stemming from both natural and social science disciplines is 'potential to be harmed from events', which may be natural or anthropogenic and 'capability to withstand' the event.

Vulnerability is rather a relative concept. In order to better understand the term, it is important to know what is vulnerable and to what it is vulnerable, when, why and where such vulnerability or defenselessness strikes. The 4 **W**s are therefore essential to be answered in order to identify or define the type of vulnerability one is talking about. Arising out of the permutation and combination of answers to the 4 **W**s are the different types of vulnerability:

WHAT?
WHEN?
WHY?
WHERE?

Answering the WHAT questions, vulnerability can be physical, social, economical and institutional. Pelling (2003) defines physical vulnerability as the vulnerability of the physical environment, social vulnerability as experienced by people and social group in their socio-political system and human vulnerability as a combination of physical and social vulnerability. Klein and Nicholls (1999) see natural vulnerability as one of the determinants of social vulnerability and Brooks (2003) regards social vulnerability as a determinant of biophysical vulnerability, whereas Cutter (1996) regards the biophysical and social dimensions of vulnerability to be independent which interacts to produce the overall place vulnerability (Cutter, Boruff and Shirley, 2003).

Identifying the nature of vulnerability through WHEN questions, it can be concluded on the basis of available literature that defenselessness may occur or strike at a particular event (the exact time of which may be unknown), may be seasonally as in the case of seasonal drought or flood, it may occur everyday which may be associated with the permanent condition of a marginalized place or people or it may be a periodic phenomenon. Lavell (2004) defines vulnerability at two levels of risk: exceptional vulnerability, which is associated with exceptional events and everyday vulnerability associated with permanent conditions of poor and marginalized poor people like malnutrition, poverty, illiteracy, domestic violence and alcoholism, etc., which limit their development. Similar situation was referred as recurrent vulnerability by Watts and Bohle (1993) vulnerability to recurring hazardous and disastrous events (Matsimbe, 2003; Wisner, 2004). The time factor is also an important dimension influencing vulnerability as it specifies the condition and status of a place or person at any given instant of time (Bohle, Downing and Watts, 1994).

Looking at vulnerability through WHY questions, which try to specify the reasons for defenselessness, a number of external and internal causes appear. According to Cardona

(2004), vulnerability emerges as a consequence of physical fragility or exposure, socio-economic fragility and lack of resilience. Wilches-Chaux (1993) on the basis of cause of origin proposed several dimensions of vulnerability: physical, environmental, economic, social, political, technical, ideological, ecological, institutional, educational and cultural, etc. Furthermore, vulnerability may also arise due to political weaknesses like week democratic system, unfavourable public policies, limited linkages between governments and civil organizations, inefficient handling and management of citizens demands and incapacity to meet them (ECLAC-IADB, 2000).

WHERE questions to vulnerability takes us closer to Cutter's notion of vulnerability of people and places to be "an inherently geographical problem that necessitates a spatial solution" (Cutter, 2001: 8). It is more specific for the occurrence of disasters in certain specific geographical areas e.g. the coastline community is more at risk for disasters like tsunami. Likewise defenselessness towards infection is more pronounced due to exposure to harmful occurrences at particular places (sudden disease outbreaks like H5N1 avian flu and SARS in Southeast Asian cities). Yet another good example of spatial vulnerability rendering both people and place vulnerable to harmful implications is seen in case of high rate of arsenic poisoning in Bengal delta; West Bengal (India) and Bangladesh (Hadi and Parveen, 2004; Harvey *et al*., 2005; Hassan, Atkins and Dunn, 2005; Pal *et al*., 2007; Cherry *et al*., 2008; Nahar, Hossain and Hossain, 2008).

Another approach to vulnerability has been proposed by Polsky *et al*. (2003: 2) that relates to global change vulnerability with "the likelihood that a specific coupled human-environment system may experience harm from exposure to stresses associated with the alteration of societies and the biosphere, accounting for the process of adaptation". In this context, the environment and human systems are considered as a single entity which is vulnerable with respect to global climate change in terms of three characteristics: exposure, sensitivity and adaptive capacity (Villagrán de León, 2006).

Additionally, within the Hazard Management Group, Dilley *et al.* (2005) define the physical system vulnerability in terms of fragility curves for infrastructure and quantified as a function of hazard intensity while social vulnerability is mentioned as being a complex function of social, economic, political and cultural variables.

The Pan American Health Organisation (PAHO/WHO, 2000), within the health sector defines vulnerabilities in health facilities as structural vulnerability referring to buildings and infrastructures which are required for physical support. Non-structural vulnerability comprises of element which are essential to the functionality in relation to health aspects. Administrative or organisational vulnerability in this regard refers to the drawbacks in the administrative processes and in the functional coordination between the different sections and departments.

Alexander (2000) makes an explicit connection between vulnerability and the research conducted to assess it, recognising that vulnerability can be reduced or enhanced depending upon the type of action taken towards the casualty or destruction with respect to a particular element. Deprived vulnerability arises when the research results are not disseminated or used in order to alleviate and eliminate the destruction, while wilful vulnerability arises when such knowledge is deliberately ignored, thereby enhancing vulnerability.

The different vulnerability types as discussed above emerged as per the need to understand the condition through various perspective and discipline. However, all the above cited conceptualisation of vulnerability distinguishes natural vulnerability from social vulnerability. Although considerable research has examined biophysical components of vulnerability (Mileti, 1999), we currently know very less about the social component of vulnerability. Socially created vulnerability is largely ignored mainly due to the problem of adequate quantification (Cutter, Boruff and Shirley, 2003).

Social vulnerability is also closely linked to risk and there is extensive discussion on how social groups manage a variety of risks they face (Reardon and Vosti, 1995; Siegel and Alwang, 1999; Rakodi, 1999). But still it emerges to be important to treat social vulnerability as a separate but linked topic to risk reduction and the pursuit of overarching development goals focussing on people, thereby making the debate more people-centred, considers the complex social systems as a whole and takes into account even the non-structural solutions (Warner, 2007). Examples of social vulnerability could be widening economic gaps and power relations that exclude certain social groups from getting the benefits of developments. In this respect social vulnerability has also emerged as a policy relevant research area.

Beginning of the 21st century has seen the onset of greater threat to environment and human security (Höppe and Pielke, 2006; IPCC, 2007) calling for researches addressing people and contributing to policy design to improve environmental and human health security. This saw the dynamic evolution of security paradigm which inseparably links humans and their social system and strives to achieve freedom from fear, freedom from hazard impact and freedom from want (Holzmann and Jorgenson, 2000; UNDP, 2004; Annan, 2005; Bogardi and Brauch, 2005; Brauch, 2005b).

The above discussion can be concluded by highlighting the importance for distinguishing social vulnerability from general vulnerability study primarily due to increasing need for:

- Understanding complex social-environmental system and their linkages
- Focusing primarily on ‘people’ and ‘society’
- Emphasising human security
- Improving environmental conditions and access to basic amenities; more so among the most vulnerable population
- Considering non-structural solutions as well for risk reduction
- Achieving greater societal resilience

It also becomes important to understand the various underlying factors and root causes for social vulnerability and rethink risk and vulnerability through a holistic perspective taking into account the day to day activities and stresses (as opposed to concentration on only one time extreme events, natural hazards and disasters). It would then further emphasise the necessity to focus on special social groups i.e. women, children, economically deprived, socially marginalised and even the politically underprivileged ones.

4.3 Social Vulnerability: Meaning and Approaches for Analysis

Social vulnerability is commonly seen as one dimension in vulnerability study focusing on social defencelessness to withstand adverse impacts triggered by multiple stressors including challenges of poverty, inequality, political factors, environmental and social problems. It can be defined as the degree to which humans, and the things they value, are susceptible to loss when affected by hazardous and disastrous events. It emerges as product of exposure, inadequate protection measures and/or limited capacities to absorb and rebound from loss (Mitchell, 2005). Though there are numerous definitions focusing on one aspect or other depending upon respective research discipline and focus area (Blaikie *et al.*, 1994; Kasperson, Kasperson, and Turner, 1995; Henninger 1998; Cutter, Mitchell, and Scott, 2000; Frankenberger, Drinkwater and Maxwell, 2000; Cutter, Boruff and Shirley, 2003; Cannon, Twigg and Rowell, 2005) few commonalities can still be drawn.

Two major point of consensus regarding the social vulnerability are its multifaceted character and numerous dimensions involving characteristics like socio-demographic, economic and other social milieu which forms the basis for vulnerability study of individuals, households or communities (Pinto da Cunha et al., 2005). Perhaps one of the definitions that best synthesises all these different aspects of social vulnerability is that presented by Cutter, Boruff and Shirley (2003):

"Social vulnerability is partially the product of social inequalities - those social factors that influence or shape the susceptibility of various groups to harm and that also govern their ability to respond. However, it also includes plane inequalities - those characteristics of communities and the built environment, such as the level of urbanisation, growth rates and economic vitality that contribute to the social vulnerability of places" (Cutter, Boruff and Shirley, 2003: 243).

This definition among other aspects highlights inequality to be the root cause of social vulnerability. Since marginalized groups of poor, women, children and elderly are amongst the vulnerable social groups who tend to be most affected persistent social vulnerability because of structural and political factors – non conducive policy directives, unsustainable and skewed development, lack of pro-poor initiatives and missing political commitments (Warner, 2007) social vulnerability can also be linked to unfavourable social processes, political policies and lack of societal resilience. Other factors that enhance social vulnerability from the coping side includes lack of information and awareness, gender discrimination, limited political representation and access to power relation, lack of effective social networking and cooperation, differential social customs, differences in beliefs, lack of common viewpoints etc. (Pulido, 2000; Cutter, Mitchell, and Scott, 2000, Putnam, 2000; Tierney, Lindell and Perry, 2001). Whereas, physical fragility like poor housing type and construction, lack of infrastructure facilities etc. enhances social vulnerability from exposure side (Heinz Center for Science, Economics and the Environment, 2000; Cardona, 2004).

Social vulnerability is "crucially about characteristic of people" (Cannon, Twigg and Rowell, 2005: 5) and differential impact upon them when faced with stresses. Therefore, it combines a complex set of characteristics including person's initial wellbeing, his livelihood and resilience, degree of self protection afforded by his affordability and willingness and his level of access to social capital (Cannon, Twigg and Rowell, 2005).

However, social vulnerability is not only a pre-existing condition that affects a community or group's ability to be prepared and recover from an unexpectedly harmful event (Warner, 2007) it also determines post-disaster condition via its influence on perception, decision and level of effective response. As social vulnerability is created through interaction of multiple stressors also including various social, cultural and political forces, it needs to be resolved also through social means considering non structural solutions (Alwang, Siegel and Jørgensen, 2001; Oliver-Smith 2003; Matsimbe, 2003; Cannon Twigg and Rowell, 2005).

Given the complexities of the multiple challenges, vulnerability assessments cannot be uni-directional exercise. This is reflected in all the definitions of vulnerability. As correctly pointed out by Vogel and O'Brien in a special issue of AVISO, the Information Bulletin on Global Environmental Change and Human Security (2004), most definitions of vulnerability include the idea of potential damage or adverse outcomes in relation to external stress. Such stress is usually refereed to as an external agent and it varies according to the context of the study or assessment.

Wisner (2004: 183-193) distinguished four approaches on social vulnerability: a) demographic; b) taxonomic; c) situational; and d) contextual or proactive approach. He criticized that many studies on social vulnerability have not sufficiently valued local knowledge and coping capacities. He further supported the need to understand why and how local knowledge is rendered inaccessible and find out ways in which people can be empowered to reclaim local knowledge and appreciate its usefulness.

In this study, social vulnerability of households is focused on urbanization-driven infrastructural stress (with particular reference to wastewater infrastructure) and is considered to be a function of (1) their exposure to wastewater through various routes like sewage contamination of pipe water supply, ground water pollution, physical contact with sewage etc., (2) the capacity of households to adapt and adjust and protect themselves from the wastewater hazards, and (3) the sensitivity of the population to such hazards in terms of both directly through health implications and indirectly through negative environmental and economic implications. On the basis of all the above discussion, a working definition of household vulnerability to wastewater is framed (Box.4.1).

Box 4.1: Household Vulnerability to Wastewater: Working Definition
Characteristics of household in terms of their susceptibility to be affected from the potentially harmful wastewater exposure (driven by increasing informality, unplanned expansion and inequitable allocation of infrastructural resources etc.) and the management capacity of social groups (in terms of economic capability, perception of the problem, level of social networking etc.) to anticipate, prevent and protect themselves against the implications (pollution, water related diseases).

Despite the concerns about the limitations of generalization about social vulnerability arising from the interests of varying practitioners, several attempts to measure vulnerability and to develop indicators of vulnerability have been developed (e.g. see

Diriba, 1997; 1999; Eilerts and Vhurumuka, 1997; Eldridge, 1997; Leichenko and O'Brien, 2002; Cutter, Boruff and Shirley, 2003).

Diriba looks into social vulnerability with respect to food security and offers some direction towards methods of its analysis. Accordingly, approaches to social vulnerability analysis include:

1. Indicator approach: This involves identifying the number of objective indicators capturing different aspects or dimensions of vulnerability.
2. Household modeling approach: Mix of objective data and household and community surveys to develop a sample of how household responds to risk.
3. Income estimation approach: Aims at estimating income levels to see if sufficient income was generated to help people overcome risk conditions.
4. Domestic resource capacity approach: It takes into consideration the community's ability to either collectively or individually allocate resources to mitigate risk.

Other similar efforts to estimate vulnerability in respect to global change and food security issue is attempted by understanding and identifying why populations are food insecure (e.g. Eilerts and Vhurumuku, 1997; Eldridge, 1997; WFP and SADC, 1997; SADC and FANR, 2000).

Following the bottom up approach, a few studies also attempted to understand what have been the root causes of vulnerability. A good example of this is seen in the application of vulnerability indices to climate change (Downing, 2001). Further attempts at multi-level indicators of vulnerability analysis have also been attempted (see for example, Moss, 1999; Huq *et al*., 1999; Hurd *et al*., 1999). Leichenko and O'Brien (2002) further suggest that macro vulnerability indicators need to be combined with local-level survey-based investigations in order to understand the linkages between them.

Based again on the indicator method, an index of social vulnerability to environmental hazard (SoVI) for the United States was constructed by Cutter, Boruff and Shirley (2003) using a factor analytic approach, wherein 42 variables were reduced to 11 independent factors that accounted for about 76 percent of the variance. These factors were then placed in an additive model to compute a summary score.

The approach for social vulnerability analysis pursued in this study combines elements from the above mentioned approaches. A detailed quantitative as well as qualitative investigation focused on 696 households from three different spatial locations in megacity Delhi was done. The range of qualitative method included recording of everyday experiences and responses related to wastewater and sewage problems in the household and immediate neighbourhood. Questionnaires administered in these household covered other related quantitative aspects too like demographic characteristics, dwelling period, household income, sources of drinking water, nearness to open drains, etc. The next step was to develop a set of indicators that reflect the core determinants of household vulnerability in different settings and residential areas in terms of exposure and management capabilities. It further investigates how frequently households with particular characteristics and at a particular setting experiences distress (including illnesses). It is indeed a difficult task to quantify social vulnerability, but an index of diverse indicators seems to provide a summary measure.

4.4 Components of Social Vulnerability: Exposure, Coping Capacity, People's Perception and Result Implications

Major vulnerability frameworks view vulnerability in terms of exposure and coping capacity, also referred to as the external and internal sides of vulnerability (Chambers, 1989; Bohle, 2001). Similarly for Cardona (2004), vulnerability originates as a consequence of three factors; physical fragility or exposure which is equivalent to external vulnerability, socio-economic fragility and lack of resilience which is equivalent to internal side or coping capabilities. Additionally, the outcome of exposure opposed by coping capabilities is also an important determinant of vulnerability. Therefore, identification of routes or means of harmful exposure, capacity to cope and resultant implications are important for holistic characterisation of social vulnerability.

Risk and exposure are closely tied to vulnerability, and can be seen as a function of vulnerability itself (Vogel, 1998). To be at risk is to be under threat of harm (Pelling, 2003). Risk in human terms is a situation in which human values (including human themselves) are at stake and where the outcome is uncertain (Jaeger *et al*., 2001). Many risks are eco-centric i.e. they are linked to environmental problems or related to environmental conditions (Jaeger *et al*., 2001) which threatens human security via greater probability of exposures.

The two sides of vulnerability in Chamber's (1989) and Bohle's (2001) model recognises the relationship between risk, vulnerability, coping capacities and assets; additionally Bohle puts them opposing to each other. Elaborating Bohle's double structure of vulnerability where;

The exposure/external side of social vulnerability is basically referring to exposures of social groups to risky environment which is influenced by human-ecological perspectives referring to population ways of managing the environment, entitlement theory (Sen, 1981; Watts, 2002), which relates vulnerability to incapacity of social groups to possess assets referring to the economic status of the population to fight the stressful event leading to the third strand of political economy approaches focusing on the concentration of resources in the hands of the affluent upper class and lack of rights for the deprived groups leading to conflict and struggle between the them, taken up to the political level. Lack of ownership rights still keep masses of population 'illegal' and thereby deprived of various civic privileges.

Opposing to the exposure side, the coping/internal side is influenced by action theory approaches taking into consideration the ways used by individuals and social groups to act to the event or stressful condition, either willingly or under compulsion, models of access to assets which refers to peoples responses and mitigation effort via their access to various types of assets, including economic, personal, socio-political as well as the social networking aspect of the group, primarily focusing on the social differences and lastly the institutional theory[6] which focuses on the prevalent institutional arrangements and

[6] Institutional theory attends to the deeper and more resilient aspects of social structure. It considers the processes by which structures, including schemas; rules, norms, and routines, become established as authoritative guidelines for social behavior. It inquires into how these elements are created, diffused, adopted, and adapted over space and time; and how they fall into

processes influencing social group's control over resources, assets and thereby capabilities to effective responses. The more assets an individual or a group controls less is the vulnerability, as the assets increases their capacities to cope with the risks and stressful situations. Thereby the capacities to successfully manage stress would automatically call for conducive institutional arrangement for effective action.

The strength of this model is its capacities not only to explain vulnerability but also its causes and origin (Villagrán de León, 2006). Vulnerability analysis that addresses the complexities, dynamics and challenges of rapidly growing urban areas should seek to bring together various dimensions of vulnerability by mean of an integrated approach (Bohle, 2006). Thereby, apart from the exposure and coping dimensions, the manifested outcomes, people's and institutional responses and limitations for the same are equally important to be considered for better understanding social vulnerability and paving the ways for policy intervention in the required direction.

Environment and health studies have mostly focused on the outcome of vulnerability, also taking into consideration the exposure and routes of such exposures, but people's response to the given stress and harmful environmental conditions have been rather under represented. It is important to analyse how people respond to them and better understand the factors influencing their responses in order to have a complete picture of social vulnerability. This in turn depends upon people's level of understanding and awareness of the problem and their perception towards its impact's severity.

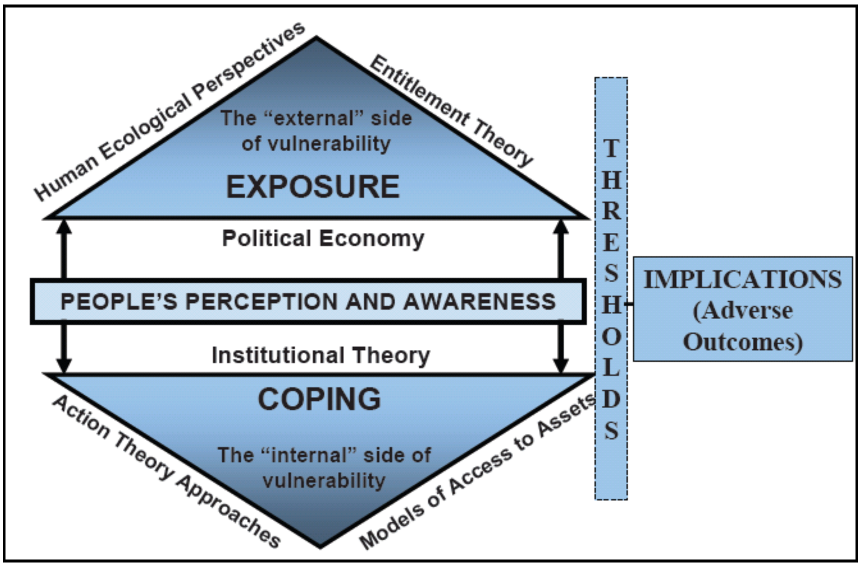
People's perception plays an important role in understanding social vulnerability. The manner in which an individual or social group perceives existing problem affects the extent of their exposure and moulds their response towards it. Moreover, it is perception which influences people's response towards events in general and ones occurring over long time in particular. Furthermore, it gets their resource capacity functional.

decline and disuse. Although the ostensible subject is stability and order in social life, students of institutions must perforce attend not just to consensus and conformity but to conflict and change in social structures (Scott, 2004).

With this view in mind Bohle's model of the double structure of vulnerability has been modified to encompass people's perception aspect, their level of stress endurance and the manifested implications and outcomes (Fig. 4.1).

As mentioned above that the major strength of this double structure of vulnerability is its ability to trace down the cause of vulnerability, which was tested in the field study done with respect to vulnerability related to wastewater management system (we call it infrastructural stress in this regard). Improper management of wastewater creates hazardous conditions; water pollution and environmental degradation, exposure to which is regarded as a matter of risk that threatens human and ecosystem health security.

Fig. 4.1: Various Dimensions of Social Vulnerability



Source: Own draft (modified after Bohle, 2001)

Opposing to exposure, there exist community's capacity to cope and respond effectively towards it, which among other factors is also highly influenced by people's perception, awareness and available options. At a given time and place, interaction between exposure of a social group or community and internal capability and social networking of that community filter through their sensitivity and endurance thresholds[7] and manifest itself

[7] A threshold is defined as a point between alternate regimes in ecological or social-ecological systems (Resilience Alliance and SFI, 2004: 1).

in various form of negative implications or hazardous outbreaks (e.g. health hazards, pollution, morbidity and degradation of environmental aesthetic).

In all cases of vulnerability the outcome is primarily seen on social groups and environment, in the sense how they are affected by adverse outcomes. But all outcomes are not necessarily exposure-specific, but relate to many different risk factors and uncertainties. Therefore, in order to grasp a better understanding of household vulnerability to wastewater nuisance it is necessary to analyse the different contributory risk factors too like structure of local governance and civic management, access to public resources, managerial efficiency, accessibility, level of economic self sufficiency of social groups and their capabilities to self help/defense.

Another dimension which emerged crucially important for social vulnerability analysis and needs to be mentioned is local knowledge and people's perception about the prevailing wastewater exposure risk and effect severity.

4.5 Role of People's Perception of Exposure Risk and Effects Severity

Human response to hazards usually fails to match the real probability of being affected by that hazard as individual understanding of the environment is always less than perfect, which creates perceptual uncertainty (Park, 1983). Understanding people's risk perceptions and motivations to adopt preventive behaviour is important in avoiding or at least reducing hazardous outbreaks. Perception of risk exposure and awareness of the severity of harmful impact is important for individuals and community groups in order to trigger their response towards its negation and take protective action.

Perceptions of insecurity or of 'things not being as they should be' open up a whole new area of research. Psychological research, for example, has provided empirical evidence that those who perceive themselves to be vulnerable to environmental risks, or who perceive themselves to be victims of injustice, also perceive themselves to be more at risk from environmental hazards of all types (Satterfield, Mertz and Slovic, 2004). Similarly, perceptions of barriers to actually adapting by the vulnerable groups do in fact limit adaptive actions, even when there are capacities and resources to adapt (Grothmann and Patt, 2005).

Risk, as defined by outsiders and as perceived by various social groups experiencing it is not univocal; prioritized risk by the poor are embedded in the poor living conditions (Heijmans, 2001). It is widely agreed that poor are the most vulnerable people and require special attention but an explicit mention of how these people perceive the situation, experience and understand risk has been grossly missing or under-represented. People's perspective in vulnerability assessments has been absent, although most actors agree and recognize that impoverished are the most vulnerable and require special attention, none speaks explicitly about how people at risk perceives and understand it (Heijmans, 2001).

People use their own capabilities, skills, talents, knowledge and technologies to face risks and deal with the situation of crisis and stress. This might not necessarily be sudden extreme events. Even in everyday life, people's knowledge and their level of understanding play an important role in perceiving the harmful situation and in turn it moulds their decision and action towards it. Apart from learning through personal day to day experiences, local coping and adaptation strategies are also learned from ancestors, neighbors and other family members. Such adaptation strategies also gets integrated in the daily life and made part of their traditions and culture (Blolong, 1996).

Although the description of people's coping strategies is typical among community members, there are different versions of these strategies depending on family particularities and available resources at household level. These influence risk perception and decision making on how they can best reduce risk. Apart from comprehending people's understanding of risk, their capacities, options and alternatives and the implications of their decisions are equally important to know. Therefore, it is imperative to understand both sides that make up local people's perception of risk.

In this regard numerous aspects of people's perception towards risk emerge:

- Perception of the nature of problem in terms of its occurrence pattern
- Perception of the resultant impacts in terms of its severity and magnitude

- Awareness of their own capabilities towards facing the occurrence
- Knowledge of the available options which can be accessible in time of need
- Adoption of coping strategies based upon its effectiveness
- Initiatives towards effective social networking and community participation

Households of equal socio-economic and cultural background living in the same condition are equally exposed to the harmful prevailing condition, but might still perceive the exposure-effect risk differently and as a consequence, have different response towards it, either escaping or enduring it. This in turn may either further aggravate or reduce their vulnerability. Therefore, strengthening self-defense from exposure risk and building up resource capacity for facing the critical situation requires some amount of foresight which is directly depended upon individual's or community's perception of the problem. It is only if an individual perceives the prevailing conditions which might put his well being at 'risk' or might adversely affect him that he prepares for its prevention, avoidance or reduction of its impact.

Secondly, the choices of their coping options are also directly influenced by their perception of the nature and magnitude of the harmful perturbation and simultaneously depended upon understanding of their own status and ability to manage it. Field experience shows that although there was wastewater related nuisance distinctly existing but at certain areas people did not even perceive them to be a problem. This was primarily due to their ignorance about the impact severity and also because they rated wastewater disposal problems low in their priority. It was more important to fulfill their water demand and comparatively less attention was diverted on its proper disposal and management.

Perception of risk is not irrational. It is influenced and depends upon their prior experience, knowledge and information about certain event and its resultant implications. This is also highly influenced by the extent of media reporting about it, propaganda by NGOs and other means of advertisements which can easily mould people's opinion. Sometimes over sensitizing them towards certain hazards may trigger panic situation or even lead people to take hasty decisions and actions which may not really be necessary.

Contrary, timely propaganda about potential hazard risk also safes people from facing adversities e.g. advertisement and sensitization about malaria causes and implications helps people to take precautions against mosquito breeding, identify symptoms and take timely actions.

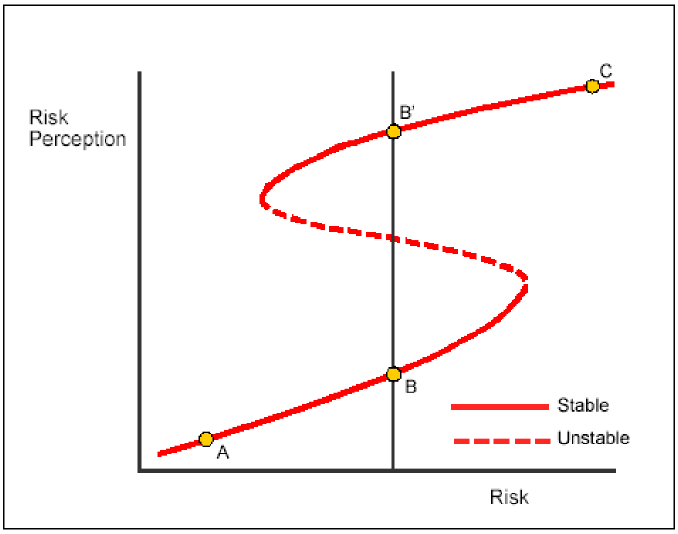
People make best choice from several alternatives and take actions regarding hazards based on their personal perception of risk rather than on some objectively derived measure of threat (Smith, 1996; Löfstedt and Frewer, 1998). According to the field experience other developments in the process (like extensive digging of ground for laying cables) usually disrupted the water supply and sewer pipes and was also a source of constant nagging for the community dwellers over a prolonged period of time. Since such work usually went on for months, residents reported numerous problems related to the ongoing work and even after the completion of it; ditches were not refilled properly which caused trouble mostly during the monsoon. In this case, though the digging was for betterment, still residents were aware about the potential problems associated with it and thereby were prepared to face the same.

The threat which a social group or individual feels is proportional to the severity and magnitude of impacts that it can bring, e.g., outbreak of life threatening cholera due to consumption of sewage contaminated water is well conceived as a severe threat of unsafe water consumption. Therefore, if the water is coming from unreliable source, people would make effort to clean it before direct consumption. But other subtle impacts of wastewater-related hazards which may have a greater relevance to individuals as well as communities in terms of their vulnerabilities and would only be visible after prolonged exposures concerning water related and water washed diseases like skin problems, aggravation of pre-existing stomach ailments and creation of conducive environment for rodents and vectors, were somehow underestimated. These further hindered preventive responses which could have avoided the event or at least lowered the magnitude of negative implications.

While making judgements of situations or activity in daily life, an infinite range of approaches is possible, of which all exist between two extremes of 'absolute rationality' (which is a theoretical approach based exclusively on scientific research and statistics) and 'emotionality' (which is based on feelings and intuition without hardly any factual knowledge considered at all), neither of the two are realistic but they illustrate the gap between expert foresight and local judgment (Hauger *et al*., 2003). Based upon one's own experience and words from others, an individual analyses the probability of running into a potential risk or hazard. Simultaneously they intuitively make judgement about its occurrence and severity. A combination of these may lead to differential perception of same risk.

Figure 4.2 explains the relation between actual and perceived risk quite contradictory to its often assumed linearity. At very low and very high risks (point A and C on the curve), the people's perception is more in correspondence with the real estimated risk than at moderate risks (point B and B' on the curve), where an individual can have very different perception of the same risk. However, there remains a large range of risks for which the related perception shows a random character (the unstable zone symbolized with a dashed line). It is within this zone that a social group or individual can either underestimate or overestimate the actual risk.

Fig. 4.2: Relation between Risk Perception and Actual Risk



Source: Hauger *et al.*, 2003

In society where the obligation of responsibility is not defined and individuals keep on assuming that somebody else is working towards making things right, risks are usually underestimated, which may lead to serious hazards, while in case of overestimation of risk as in situations when the society is so sensitized that it work towards risk prevention and get the available coping strategies in place much in advance. This may finally reduce or even completely prevent hazard outbreaks.

Choices of coping mechanism or strategy are made on the basis of awareness about its availability, accessibility and effectiveness. Not all the coping mechanisms are always easily accessible by all the social groups, due to various reasons of their economic and legal status. Therefore, it is important for people to be aware of the limitations and options available for risk mitigation. It is also noticed that responses of social groups towards certain problem depend upon their perception about its urgency and priority of their other activities. In most cases, the social groups were found to be too pre-occupied with earning their livelihood and in the course were somehow neglecting or rather had no time to act against the continued wastewater exposures at their locational setting itself, which was finally threatening their health security.

4.6 Concluding Remarks

The study tries to see social vulnerability through three major dimensions: external dimension, i.e., household exposure to wastewater; internal dimension, i.e., household capability influenced by perception and level of social networking; and implications i.e. effects of wastewater hazards. It takes the analysis down to household level seeing how risks from improper disposal of wastewater in megacities are threatening certain social groups or communities, placing them at different levels of vulnerability. It further attempts to analyse vulnerability of social groups with respect to water system infrastructural stress in formal and informal settings, investigating threats due to exposure to potentially harmful environmental conditions with specific reference to wastewater nuisance.

Since social vulnerability analysis for this case study is based on assessment of exposure, management capacity and implications, the succeeding chapters would take up each of these components individually and explore them empirically in context of the study area. These would finally help in concluding about the varying levels of social vulnerability in different surveyed areas; draw a comparison between them; help in tracing the underlying factors responsible, and show direction relevant for development policies and importantly non-structural solutions aiming at reduction of social defencelessness and strengthening resilience.

Chapter 5

Social Vulnerability: Exposure to Wastewater

5.1 Introduction

This chapter is a sequel to the previous ones, which focused on the fact that Delhi is facing serious issues of wastewater collection, treatment and disposal that have implication of harmful exposures. In this regard, here we explore in depth the external dimension of wastewater related social vulnerability: exposure and analyse the various routes of wastewater exposure and factors influencing them. Finally, this chapter elaborates the methodological construction of a Household Exposure Index on the basis of selected indicators from the conducted questionnaire surveys for a comparative household exposure analysis across different colonies and spatial location in Delhi. In this chapter the household exposure to wastewater is analyzed in detail, while the dimensions of management capacity and wastewater implications on public and environmental health are dealt with much elaboration in the succeeding chapters 6 and 7 respectively.

5.2 'External Side' of Social Vulnerability: Exposure to Harmful Perturbations

External vulnerability or exposure to threats may take place as a result of numerous causes, e.g., within environment and health sector study exposure may be of inhalation, ingestion or absorption to pollutants which have been carried or stored in the air, water, food, soil, which may finally be seen as health impacts in the form of morbidity and mortality. Exposure may occur simultaneously from many sources and through multiple routes which may be influenced by factors like settlement in hazardous areas, spatial segregation, environmental pollution, land use pattern and level of socio-economic status.

Poor urban pockets are faced with serious environmental problems. Social groups inhabiting these poor urban areas are often exposed to harmful perturbations in and around their houses which are created primarily due to lack of adequate public services (McGranahan, Leitmann and Surjadi, 1997). Inadequate sanitation, insufficient and contaminated water supply, flooded narrow lanes stagnant wastewater, uncollected solid wastes and pest infestation are all common characteristics of vulnerable areas correlated with threats to human and environmental health securities through direct, indirect, continuous and delayed exposures.

Exposures that are beyond individual control affect many people simultaneously, though showing implications of differential magnitude depending upon individual sensitivity. The variations in the sensitivity to exposure occur due to differences in the characteristics of the population and their behavioural habits. The attributes of a community influence the level of exposure that they experience within their immediate setting. The socio-economic conditions of the community vary in the same environment thereby, influences the level of exposures. Other features of the community like period of stay, income levels, house types, contact with raw sewage, water consumption habit, are all determinants of the magnitude of exposure.

In the study area social groups with low income levels higher period of stay living in dilapidated unsewered dwellings and consuming contaminated water are relatively more exposed than their privileged counterparts. Continued and prolonged exposure to wastewater nuisance makes the communities vulnerable to various kinds of heath and environmental risks. The problem may not be attributed solely to wastewater mismanagement but certainly also to people's perception, their own resource capabilities and social networking along with their sensitivity and endurance level determine the severity and magnitude of resulted impacts which in this case is seen through the resulted pattern of morbidity emphasizing higher frequencies of water-related, gastrointestinal and skin diseases reported by the exposed population.

5.3 Factors Influencing Exposures to Wastewater in the Study Area

Threats in the context of present study are not related to sudden onset of hazards but emanates from continuous exposure to potentially harmful effects of wastewater and raw sewerage. On the basis of information derived from extensive household questionnaire surveys, indicators were identified to pin down factors influencing wastewater exposure and evaluate varying levels of household exposures.

The external side of social vulnerability, i.e., exposure to wastewater is analyzed here by taking into account different demographic, residential and habitual characteristics and identifying the core indicators reflecting the same. These indicators aim to represent, at least in a generalised form some of the factors which can trigger negative implications on the household members at their present dwelling. The indicators take into consideration the demographic characteristics (sex, age and family size), which in a way would determine level of interaction with the surrounding; settlement and infrastructure status (occupancy of dwelling type and connection to sewage) to indicate entitlement aspect and access to infrastructure by households; water sources, consumption habit, nearness to drains, frequency of its overflowing etc. represents means of people's direct contact to raw sewage; additionally, it also encompasses aspect of duration of exposure represented by period of stay.

The factors taken into consideration for wastewater exposure analysis here are categorized under four major heads with specifically selected indicators as:

Demographic Characteristics of the Communities

- Sex composition
- Age composition
- Family size

Settlement and Infrastructure Status

- Kind of colony
- Type of house
- Connection to sewer
- Period of stay

Drinking Water Sources and Consumption Habit

- Source of drinking water
- Sewage and fresh water mixing
- Drinking water purification habit

Direct Contact with Raw Sewage

- Nearness to open drain/canal
- Frequency of drains overflowing
- Physical contact with wastewater
- Open defecation and public washing

On the basis of theoretical information as well as knowledge about the study area these indicators were selected during the course of field work and are therefore area-specific, aiming at household exposure analysis in a relative manner. The assessment is household-centered one but very informative as it traces the routes of exposures and the reasons for such exposures in the given setting of various surveyed areas. An unavoidable element of judgement cannot be ruled out in the above selection, which in this case reflects the knowledge and understanding of the problem by the author being a native of the area and also further experiences gained during the intensive field works. The individual factors will now be dealt in greater detail.

5.3.1 Demographic Characteristics of the Communities

Interpretation of occurrences cannot be reliably carried out without reference to the target population. The family or household level is at the base of any socio-economic process undergoing at a region; therefore, outlining the demographic characteristics of the population covered is a prerequisite to understand the processes occurring there. Exposure is largely dependent upon the dynamic relationship between the population characteristics and their endurance thresholds.

The study area had a considerable number of migrants inhabiting different kinds of colonies at various surveyed locations. Migration was largely from National Capital Region and neighbouring states of Uttar Pradesh (contributing to 44% of the total in-migrants in Delhi between 1991-2001), Punjab (5%), Rajasthan (5%), Haryana (10%) and even from the further ones like Bihar (14%) and Bengal (3%), staying in Delhi from varying time periods[8] (GNCTD, 2008: 33). But for the present study, care was taken to only include households which have been staying in their present place of residence for more than a year to ensure they had been enduring the existing water and wastewater situation in the area for a considerable time period and was well informed about the existing situation.

The major demographic characteristics of the study area namely, population coverage, age-sex composition and average family size are discussed below.

5.3.1.1 Sex Composition

The total number of households taken into consideration for the present study is 696, covering a total surveyed population of 4358 persons including 2299 males and 2059 females residing in different types of settlement. The sex ratio of Delhi as a whole is amongst the low in the country at 821, which is below the national average of 933

[8] As per NSS 58th round survey conducted during July and December, 2002, about 33234 household had migrated to Delhi during the year 2002 of which 84.89% families moved permanently and15.11% on seasonal basis (GNCTD, 2008).

females. As reflected in the total surveyed population where number of males outnumbered females in all the colonies which is rightly reflected in the negative sex ratio (Table 5.1).

Table 5.1: Sex Ratio (No. of Females per 1000 Males)

Type of Settlement	Males	Females	Sex Ratio
India (2001)*	531,277,078	495,738,169	933
Delhi (2001)*	7,570,890	6,212,086	821
JJ Clusters	413	364	881
Unauthorised Colonies	418	340	934
Resettlement Colonies	564	507	898
Authorised Colonies	607	597	984
Urban Villages	297	251	845

Source: Own household survey 2005-2006 (N = 696)
* Census of India, 2001d - Provisional Population Totals: India, Paper 1 of 2001

The authorised colonies have a better sex ratio at 984 females per thousand males followed by the unauthorised at 934 females per thousand males, both higher than India's as well as Delhi's average. This can be explained because of the better socio-economic background of the population in these formal colonies. People in unauthorised colonies, although having resources for better education and cultural development (evident through slightly better sex ratio), are still spatially marginalised due to a general scarcity of infrastructural resources, housing, etc., in the urban area. Sex ratio of the population speaks a lot about the socio-cultural milieu too. The lowest sex ratio is in urban villages, which probably reflects the still existing social stigma attached to the female child.

Sex also influences the process of decision making as well as the attitude and perception. Males and females think differently and have different preferences; it may be consumption of an item or other usage habits (Gilligan, 1982; Statham, 1987; Betz, O'Connell and Skepard, 1989; Burke and Miller, 2005; Spring, 2008). Talking specifically about the wastewater and sewerage system of the study area, one would not disagree that it is the womenfolk in the household who feel the pressure of water and sewerage stress more than their male counterparts (also see Watts, 2004). The time spent by women in collecting water and managing wastes in the household is a factor to be considered for understanding the water system related stress among them. Moreover, it is the women who are responsible for household hygiene and sanitation. Females and children living more in their houses are supposedly more exposed to wastewater and sewerage hazards in the household.

In the context of the present study where we are trying to analyse household exposures to wastewater, it can be concluded that more females in a household means higher exposure if there are wastewater related risks in the area. Women in the household spend long hours in collecting water from various sources; additionally, they are also entrusted upon the task of maintaining household cleanliness with their limited resources (Fig.5.1).

Fig. 5.1: Females Involvement in Household Chores

Source: Own photos, 2006

Many times they also have to manually clean up the drains and raw sewage in settlements where such basic wastewater and sanitation infrastructural provision and maintenance facilities are non-existent. Thereby, females spending long hours in unhygienic conditions and getting in physical contact with contaminants are more exposed and vulnerable to wastewater hazard risks. On the contrary, males are more concerned about the outdoor activities, spend less time in the household and are less exposed to unhygienic conditions in the area emanating due to wastewater mismanagement, they can also avoid physical contact to raw sewage by not participating in the cleanliness chores of the household and neighbouring areas.

Thereby, for the present analysis households with more number of females are taken as most exposed and those with more male members are to be considered least exposed and equal number of males and females are kept at a moderately exposed range.

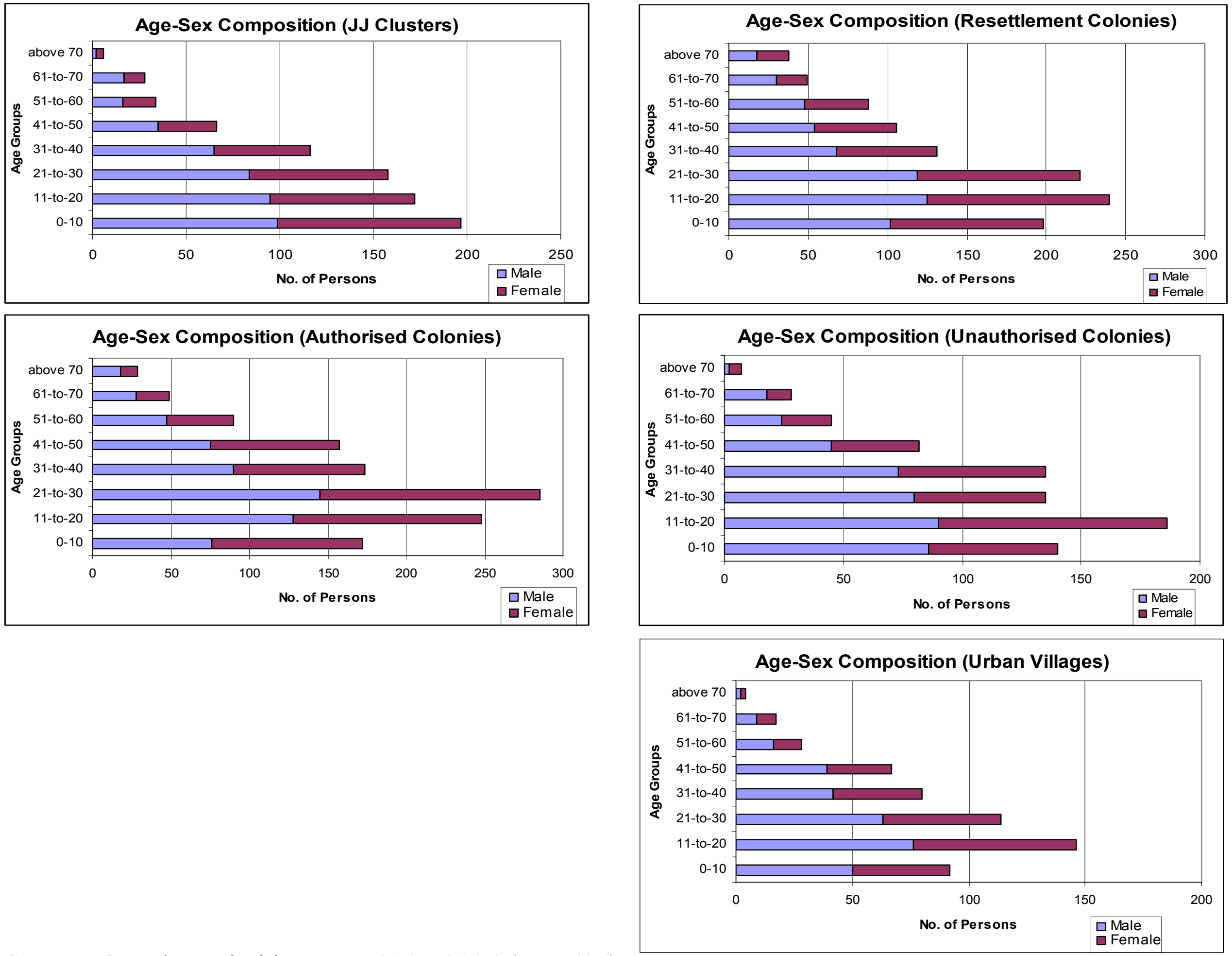
5.3.1.2 Age Composition

Age inherently affects the exposure and vulnerability of the population largely due to their nature of involvement in physical activity, endurance capacity and level of immunity. It is an important factor in particular to the households where the number of children and elderly are high. In the surveyed areas, children constituted a considerable share in the size of the family. At JJ clusters, the proportion of population among the age group of <10 years was highest constituting a major share of small children in the family. Similar trend emerges even in the resettlement colonies (Fig.5.2).

It can be noted that the inherent socio-cultural characteristics remains similar in JJ clusters and resettlement colonies. This may be because it is the families from JJ clusters who are resettled eventually in resettlement colonies; thereby, although they may have slightly better living condition in terms of housing and better access to other basic services but not much of an improvement is noticed in the socio-cultural, educational and preferential aspect among these groups.

Population within the active age group of 20-50 years was high in all the settlements. They constitute the most productive, economically active and spatially most mobile group. This age group was also conscious of the persistent wastewater and sanitation related problems and enthusiastic about sorting a solution. They were also active in forming Resident Welfare Associations (RWAs) and other types of social and political networking in order to take care of the existing problems. Although being spatially most mobile in the existing unhygienic environment, they took care in their everyday moving around so as to avoid contact with sewage as they were aware of the resulting hazards and health risks. This carefulness was obviously missing amongst the children which made them greater victims and more vulnerable to the hazards.

Fig. 5.2 Age-Sex Composition of the Surveyed Colonies



Source: Own household survey, 2005-2006 (N = 696)

Consequently, children were even reported falling in the open drains while playing. At Trilokpuri (a resettlement colony at E2), it was reported that within last one year, two children fell into the nearby open drain and lost their life. Open sewers and drains were major problems in this locality. In the absence of sufficient open space, children usually played in the lanes and thus getting in physical contact with raw sewage lying in the open pits was common. As observed during the field survey, young children below the age of 14 years come in the daily and direct contact with the site during the course of their playing.

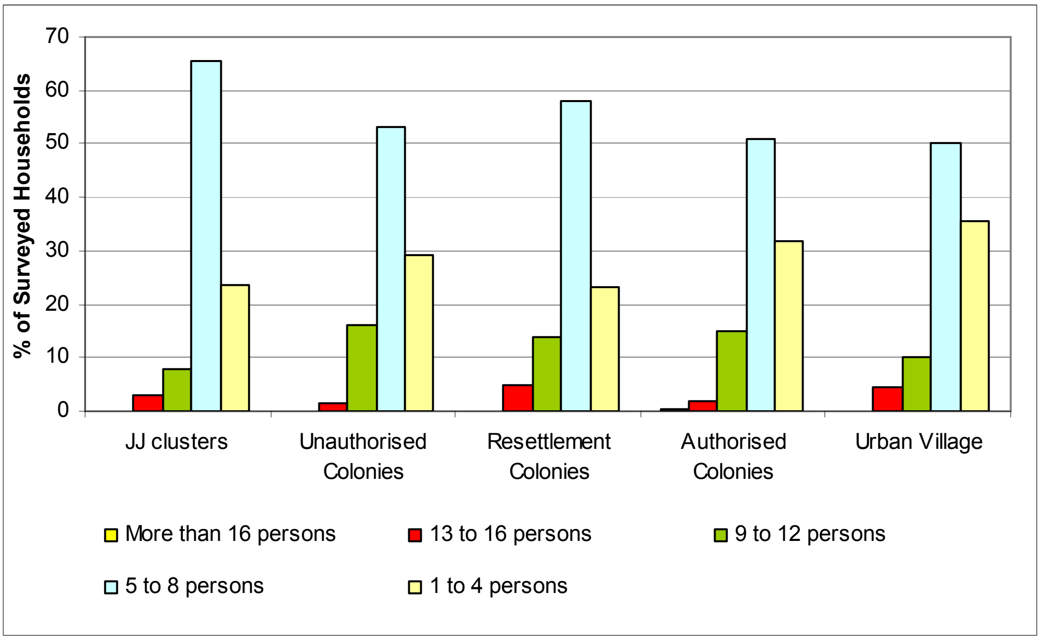
Children were also more susceptible to the water-related, water-born and water-washed diseases due to direct exposure to the contaminants in polluted water while the elderly, who spent long hours within the household and had reduced immunity level, were also the vulnerable group in terms of wastewater exposure. In the context of the present study, it is confidently assumed that people within the age group of 0-20 years and above 70 years were comparatively more exposed than the others. Usually the younger people, preferably women, managed the cleanliness chores.

Therefore, households with more family members within the age group of 0-20 and above 70 are considered to be at a greater wastewater exposure risk while households with family members within the age group 21-70 are comparatively less exposed and households with equal number of family members in both the categories were kept at a moderate exposure range.

5.3.1.3 Family Size

A large family size demands more water and generates more volume of wastewater; it further compounds the poverty syndrome and eventually more exposure to the harmful perturbations of wastewater nuisance in the immediate neighbourhood. Average family size in the study area was six members. About 56% of the total household in the surveyed areas are of 5-8 member family size. The proportion of households with small family size of 1-4 members was unusually high (36%) in the urban villages probably due to out-migration of members to other parts of the city. This was followed by the similar trend of small family size in the authorised colonies (31%). JJ clusters usually were inhabited by the new migrants to the city, who generally came with their nuclear family. This can be attested by the fact that in the surveyed colonies JJ cluster showed maximum proportion of households with average family size of 5-8 members (Fig. 5.3).

Fig. 5.3: Family Size in the Surveyed Colonies



Source: Own household survey, 2005-2006 (N = 696)

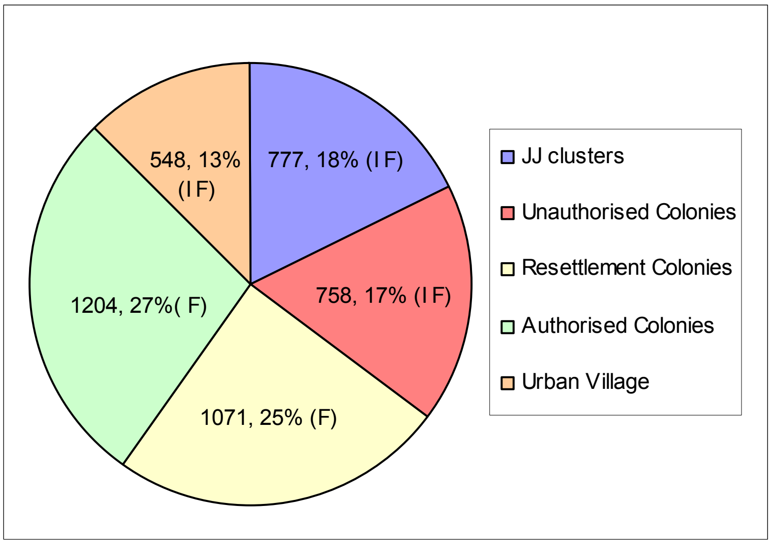
Larger family with numerous members had higher water demand and thereby generated more wastewater which needed to be disposed by already overburdened and mal functioning wastewater system. Thereby, households with small family size were comparatively less stressed due to wastewater disposal problem and in the context of the present study, are assumed to be at a lesser risk of wastewater exposure, while households with large family size are at a higher exposure and those households in between these two extremes are taken to be at moderate wastewater exposure risk.

5.3.2 Settlement and Infrastructure Status of the Communities

Settlement status is an important factor to be considered when talking about physical exposures to wastewater in the study area. There is a direct relation between the settlement status and the provided level of infrastructure. According to the government records, about 50% of total population are currently living in informal settings where by policy no basic infrastructure facilities can be provided, this primarily includes no sewer network and neither water supply pipe in the households. Although some provision of water supply is provided through community tap and tankers but these informal colonies lack proper outlet for the generated wastewater.

Formal or informal status of the colony reflects greatly the level of wastewater and sewerage facilities that can be legally provided there. According to the survey results 48% of surveyed population is living in some kind of informal settlements; this is also a right replica of the published secondary data. 27% of the population was residing in the authorised/planned colonies and 25% in resettlement colonies (Fig. 5.4).

Fig. 5.4: Population Distribution of the Surveyed Colonies



(F) Formal: Planned and having a legal status

(IF) Informal: Unplanned and largely illegal except the status of urban village [9]

Source: Own household survey, 2005-2006 (N = 696)

The households' settlement status further includes the kind of houses they reside in and their period of stay which are elaborated upon in relation to their level of wastewater exposure in the following section.

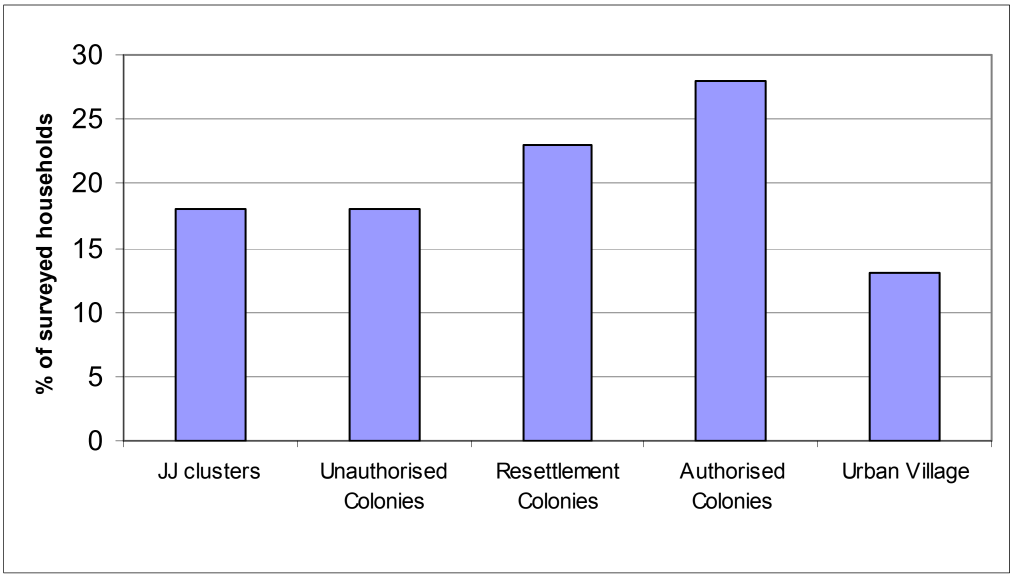
5.3.2.1 Kind of Colony

According to the household survey result on the household's colony type only about 28% of surveyed households were living in planned and authorised colonies where all the required infrastructure, namely, water, sewerage, electricity, paved lanes as well as standard public services were sufficiently provided; another 23% concentrated in the resettlement colonies which also had an acceptable level of wastewater and sanitation related infrastructure and the rest 18% of the total surveyed households

[9] For elaboration about types of settlement, legal status and sewer coverage please refer to chapter 3 section 3.4.2

were living in JJ clusters and about 18% in unauthorised colonies, where no provision of such infrastructure existed, while 13% were inhabitants of urban villages where the residents had made some kind of local arrangements for wastewater disposal (Fig. 5.5).

Fig. 5.5: Distribution of Surveyed Households Living in Different Surveyed Colonies



Source: Own household survey, 2005-2006 (N = 696)

JJ clusters were the most underprivileged in this regard, with almost no provision of any kind of basic services there. Although local political leader of the respective *ward* (smallest administrative unit), sometimes with his resources provided the *jhuggis* with a common water point and public toilets (Fig. 5.6), the status of collection and management of the generated wastewater from these informal residential units was environmentally risky posing serious health threats as heaps of solid waste and puddles of raw sewage was a common site at these informal colonies creating hazards.

Unauthorised colonies were at a slightly better state as the resident had made their own provision by illegally constructing the sanitation facility, mostly in their household. Some interviewees of these colonies had very frankly reported that they had privately laid a pipe joining the outlet of their household wastewater to the adjoining sewer line running along their colony; others had separate tanks collecting toilet and household wastewater which needed to be emptied and cleaned regularly.

Fig. 5.6: Public Water Point and Common Toilet provided by the Local Political Leader near a JJ Cluster (South Delhi)

Source: Own photos, 2006

Depending on the level of infrastructure provision and access by the residents of the different types of colonies they can be assumed to be at varying degree of exposure. The inhabitants of JJ clusters are taken to be at the highest level of wastewater exposure risks being the most underprivileged followed by those of the unauthorised colonies and urban villages who could manage some sort of alternatives, thereby being at a moderately high level of exposure risks. Resettlement colonies possessed some basic wastewater disposal facilities, which were highly substandard and functioning was below satisfactory. Thus, in the context of the present exposure analysis they are taken to be at a moderately low level of exposure while the households residing at authorised and planned colonies are considered to be at minimum risks of wastewater exposures at their household location.

5.3.2.2 Type of House

The attribute of a house type is importantly associated with the exposure factor. Depending upon the material of construction house types can be categorised into *pucca* and *kutcha*. The specific definition of different house type provided by the government of National Capital Territory of Delhi is stated in Box 5.1.

Box 5.1: Definition of House Types

Pucca House: is one, which has walls and roof made of the following material.

Wall material: Burnt bricks, stones (packed with lime or cement), cement concrete, timber, ekra etc.
Roof material: Tiles, GCI (Galvanised corrugated Iron) sheets, asbestos cement sheet, RBC (Reinforced Brick Concrete), RCC (Reinforced Cement Concrete), timber etc.
Kutcha House: is one, where the walls and/or roof are made of material other than those mentioned above, such as un-burnt bricks, bamboos, mud, grass, reeds, thatch, loosely packed stones, etc.

Source: Govt. of NCT of Delhi, 2005

The *kutcha* houses are those usually made up of thatch, scrap, plastic, tin and mud and are highly prone to the attacks of rodents, pests, flies and mosquitoes. These houses have less capacity to withstand heat, cold, wind and rain. Even slight flooding in the area can completely wash them away. Therefore, the severity and intensity of wastewater mismanagement and persisting nuisance is felt more in the *kutcha* to semi-*kutcha* houses. These houses are, moreover, inconvenient to clean. *Pucca* houses are referred to those built with concrete and burnt bricks and are protected from the natural and anthropogenic calamity and relatively less prone to pest and rodent attacks. Cleanliness can be easily maintained in such houses. The others referred as semi-*pucca* and semi-*kutcha* in the present study mean houses made with predominantly or with more proportion of *pucca* or *kutcha* materials as described (Fig. 5.7).

The financial status of the family is reflected in the type of house selected for residence. At JJ clusters, the households were mostly *kutcha* to semi-*pucca*. Considerable number of houses at the JJ clusters were also of *pucca* type but they were dilapidated and not of similar standard as the *pucca* households in other types of colonies. Almost all the households in other types of colonies were made of *pucca* construction materials.

Fig. 5.7: Examples of House Typology

Kutcha House

Semi-*kutcha* House

Semi-*pucca* House

Pucca House

Source: Own photo, 2006

In the context of wastewater exposure, *pucca* houses are considered at the least exposure risk due to greater protection at such dwellings whereas *kutcha* houses are considered to be at greater exposure level due to higher chances of being impacted by the wastewater hazards, while those falling in between these extremes such as semi-*pucca* or semi-*kutcha* are taken at varying moderation of exposure level depending upon their predominant housing material and type.

5.3.2.3 Connection to Sewer Network

Status of sewer connection has a direct influence on the level of wastewater exposures. Eligibility to get a sewer connection too depended upon the legal status of the residential colony. Primarily, the informal quarters and areas outside the jurisdiction of Municipal Corporation are devoid of the facilities of surface drainage system and sewerage. Higher proportions of households in the authorised and resettlement colonies (formal setting) were connected to the city sewer system.

Informal settlement areas completely lacked any provision of legal drainage and sewer facilities.

JJ clusters and unauthorized areas have higher proportions of households not connected to sewer network. The residents here usually connect privately to the nearby main drain (sometimes this provision is also done by the local leader). But such sewer arrangements were not satisfactory as they lacked maintenance. In the absence of proper drainage facilities, wastewater got accumulated at various places in the form of cess pools and muddy pits, which were breeding grounds for various disease-carrying vectors. Domestic wastewater from unsewered quarters usually flowed down along the line of gravity and flooded the narrow lanes. Sometimes the residents from these colonies as well as from urban villages use underground tank where the household wastewater gets drained and collected (5.8). These tanks needed to be emptied manually by the residents which were yet another addition to the household chores and means of direct contact.

In the context of the present study households which were formally connected and supposedly well maintained were taken to be at minimum wastewater exposure risk, whereas the underprivileged households devoid of sewer connections were obviously taken to be at higher level of exposure while those privately connected or using tanks for wastewater disposal were categorised under moderate wastewater exposure risk.

Fig. 5.8: Poorly Managed Wastewater at a Surveyed Area

Puddles of wastewater and raw sewage in an informal settlement at East Delhi

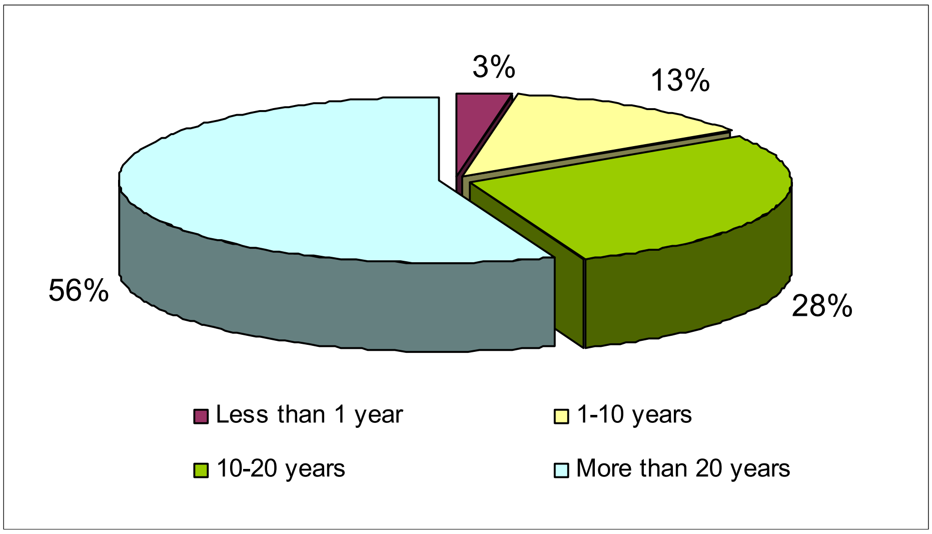
Tank at household collecting daily generated wastewater (Unauthorised Colony at East Delhi)

Source: Own photos, 2006

5.3.2.4 Period of Stay

Exposure to the wastewater contaminants for a prolonged period of time is bound to bring about environmental degradation/pollution and eventually show its effect in various forms of health impacts. Thereby, the period of stay is an important indicator of analyzing the level of household exposure to the contaminants of wastewater. The authorised colonies surveyed had existed there for decades, most of the resettlement had been formed during the late 1970s under the course of Indira Awas Yojna (A housing scheme for the poor) and the unauthorised colonies surveyed were also not very new (at least more than 10 years). Therefore, the period of stay for majority of respondents was long enough to be considered for exposure analysis 56% of the total households surveyed was living at their current location for more than 20 years; 28% had spent 10-20 years; 13% had spent 1-10 years; and only 3% households were newcomers and had been staying at their present household for less than 1 year (Fig. 5.9).

Fig. 5.9: Period of Stay for the Surveyed Households



Source: Own household survey, 2005-2006 (N = 696)

Living in unsafe conditions frequently prone to various types of wastewater nuisance undoubtedly directly and indirectly exposed humans to its contaminants through drinking water sources as well as direct physical contact with raw sewage. In the context of the present study, people living in their current households for more than 20 years were taken to be exposed to the unhygienic conditions for a prolonged time and were classed under most exposed, while the new comers in the location residing for less than 1 year during the time of the survey were considered to be less exposed and the rest of the households residing there for more than 1 but less than 20 years were subsequently considered at moderately low to high level of exposure.

5.3.3 Drinking Water Sources and Consumption Habits

Provision of safe water for drinking and other domestic consumption is an important objective to achieve for healthy and secured living conditions. Apart from the piped water supply, drinking water is accessed through various other sources in the surveyed colonies like hand and boring pumps, DJB tankers as well as water vendors. Consumption of raw water from unsafe water points, unchecked sewage contamination of the piped supply and other unsafe water usage habits undoubtedly determine the level of community exposure to various harmful pollutants via water routes. In this section, we will analyze the source of drinking water as well as the consumption habits of the surveyed population which in turn determine their level of exposure to wastewater.

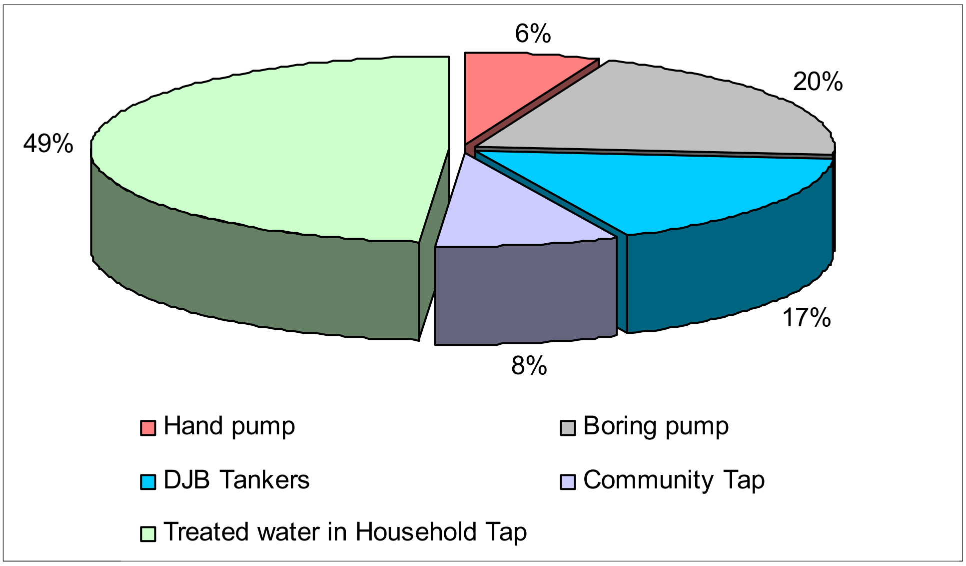
5.3.3.1 Source of Drinking Water

There were numerous sources of water in the different localities surveyed, but primarily they were through piped water supply in the households, community taps and water tankers supplied by DJB or private suppliers. Shortage of piped water was compensated by groundwater accessible via handpumps or boring pumps.

Usually the tap (piped) water is the formal means of water supply by the city water board and is supposed to be treated to acceptable and safe quality standards while the groundwater extracted by boring pumps either at the community level or household level are raw untreated water, which may be containing high levels of pollutants that are not checked by the residents.

According to the field survey results, about 26% of the households were relying exclusively on the groundwater via hand pumps and boring pumps. As high as 17% of the household are depended on the tanker water, 8% accessed the community tap and as high as 49% had water tap within their household premises (Fig. 5.10).

Fig. 5.10: Different Sources of Water Supply for the Surveyed Households



Source: Own household survey, 2005-2006 (N = 696)

Households were privileged if they could get regular water supply at their own premises tap as this water was supposedly treated and of safe standards. DJB provide water to the informal settlement colonies through their tanker supply (though they were incapable of providing sewerage due to policy limitations). Households also have access to community taps or hand pumps though the quantity of water supplied and timing was completely unreliable as residents reported. A respondent from unauthorised colony at South Delhi reported that:

"There is no fixed time for water supply, we have to get up very early in the morning and queue to fetch two buckets of water" (Open part of the household questionnaire).

The groundwater quality in various parts of the city is precarious too. DJB had also painted the hand pumps red in certain localities where the groundwater is of unsafe quality, but the continuous stress of piped water supply forced people to consume the unsafe hand pump water (Fig. 5.11).

Fig. 5.11: Alternate Water Supply Provision

Hand pumps painted red by the water authorities cautioning against its use. In the absence of sufficient water supply, the residents are forced to use contaminated handpump water for cooking, drinking and bathing (A Resettlement Colony at South Delhi).

Water supplied through DJB tanker. (A surveyed JJ cluster at South Delhi)

Source: Own photos, 2006

In the context of present exposure analysis such household supplied with treated tap water was considered to be at less risk while the household consuming raw and untreated groundwater drawn from hand pump and boring pumps were taken to be at a relatively higher exposure risks. The other households accessing community water points or water tankers were accordingly classed under moderate levels of exposures.

5.3.3.2 Sewage Mixing in Fresh Water (Sewer and/or Tap/Pipe Leakage)

Sewage mixing with the fresh water supply is commonly reported from the households having access to tap water. Fresh water pipelines usually ran along the sewer lines and so was the case with open canals or *nalas*; due to decrease in pressure, the sewage water got into the pipes through the leaking joints. This is a frequent problem during summer season when there is less water flowing in the pipe supply.

A second type of sewage pollution problem occurred through open and unlined drains: pollutants from these drains seeped down to contaminate the groundwater, which was extensively pumped up by the households for various domestic purposes (Fig. 5.12). Although they complained of this water being smelly and yellowish, still during crisis and non-access to alternate source they had to depend on it.

Fig. 5.12: Vulnerable Water Points

Water supply pipelines running through the open *nala* draining wastewater, the joints of these pipes are usually leaking points for wastewater to enter them during less flow pressure.

Stagnant raw sewage surrounding the handpump. High chances of pollutants seeping down to contaminate the groundwater, which is being pumped up.

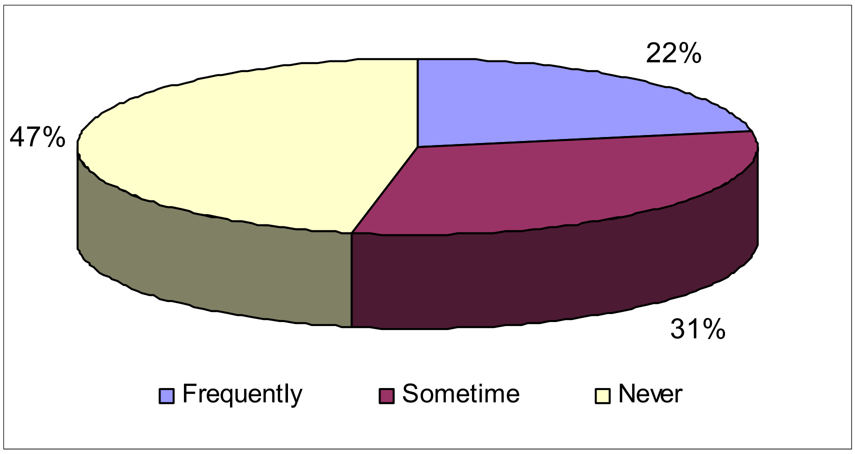
Source: Own Photos, 2006

Women interviewees were more sensitive to sewer related problems as it directly influenced the quality of water supply and consequently affected household activities. This can be easily gauged from the kind of grievances made by some of the women interviewees from Central and East Delhi, which have been quoted as follows:

"The area has been dug up for laying new sewer lines for many months now. With no alternative provisions, water stagnates everywhere and the place stinks, even the water from the taps is dark and foul-smelling"
"A DJB tanker comes to the neighbourhood around 11 am every morning. Someone always has to be at home for securing clean water from the tanker; if we miss the tanker, we don't get enough water for the whole day and then we have to buy bottled water for drinking" (Open part of the household questionnaire).

The residents also reported that the first few minutes of tap water supply was visibly dirty and fowl smelling; so they usually had to let the water run for some time before collecting it for use. Survey results shows that about 53% of the households were facing sewage pollution in fresh water supply at some point of time while 47% reportedly never faced this problem in their households (Fig.5.13).

Fig. 5.13: Frequency of Sewer Water Mixing Problem in the Surveyed Households



Source: Own household survey, 2005-2006 (N = 696)

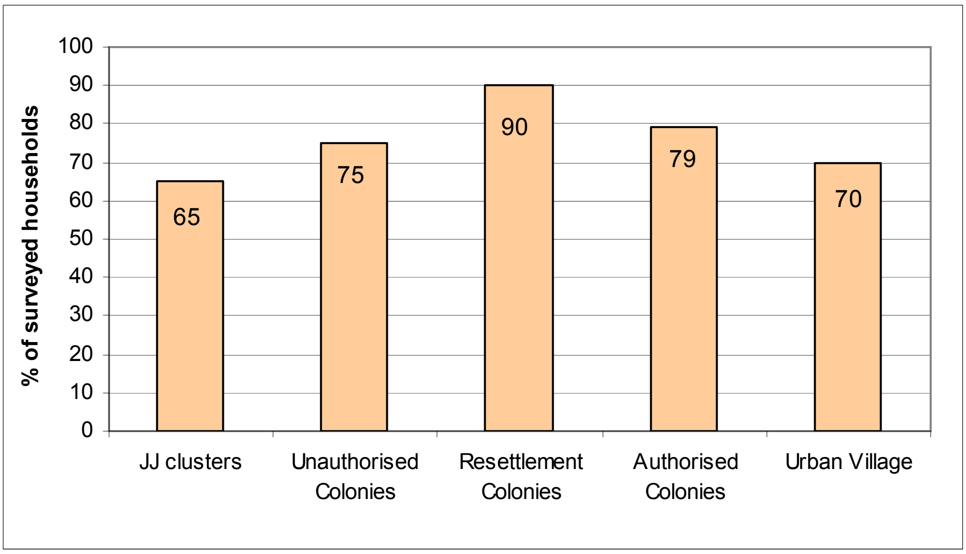
Since sewage mixing was primarily through the pipe supply, households having tap supply of water were the ones mostly experiencing sewage mixing problem and its implication was seen in terms of higher number of vomiting and diarrhea cases among them[10]. Therefore, households with sewage mixing as a frequent problem were considered to be at a greater exposure risk, while households never reporting such problems were taken to be at least exposure risks to wastewater contamination through water and the ones with sewage mixing problem in water supply once a while were taken to be at moderate exposure.

5.3.3.3 Drinking Water Purification Habit

The quality of drinking water was substandard in most of the surveyed localities. High proportions (77%) of households reportedly faced water quality problem that were required to take precautions atleast by adopting to suitable water purification habits. Interestingly, it can be seen that households in the formal setting of authorised as well as resettlement colonies where piped water supply was legally available were the ones reporting more water quality problem whereas the informal quarters; JJ clusters and unauthorised colonies and urban villages reportedly had 65%, 75% and 70% of households respectively experiencing water quality problems (Fig. 5.14).

[10] Health implication aspect is discussed in greater detail in Chapter 7 section 7.6

Fig. 5.14: Households Reporting Water Quality Problem in the Surveyed Colonies

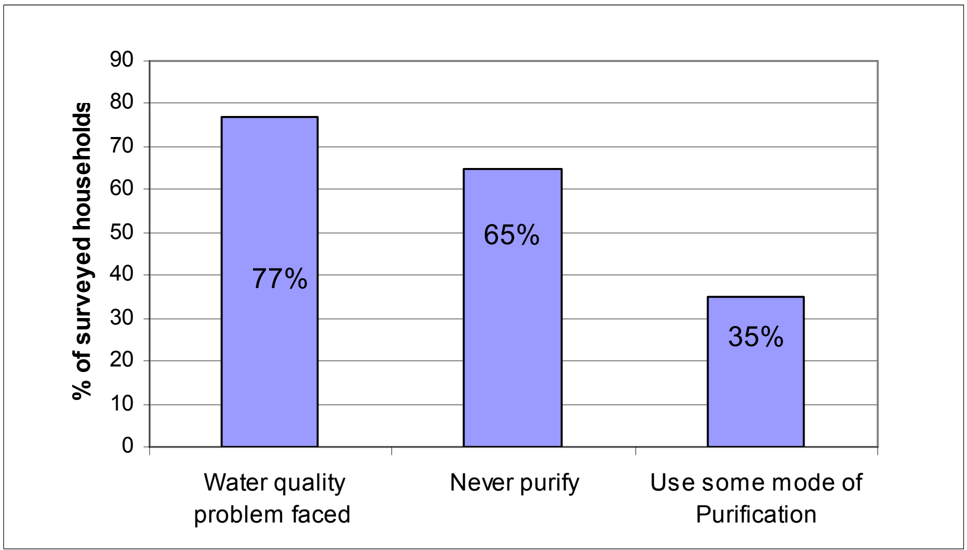


Source: Own household survey, 2005-2006 (N = 696)

This does not necessarily mean that the water quality of these comparatively poor colonies were of high standards; in fact here lays the differential perception. The residents of these undersupplied quarters were so much keen on getting their water need fulfilled that the quality of the water supply did not matter to them. They were satisfied as long as they could get their basic requirement of supply to the extent of quality compromise. Contrarily, since the supply of water was available to the residents of planned and formal quarters, they could better perceive the poor quality of supply as a problem. Against 77% of the households reporting water quality problem, only 35% were using some mode of purification like boiling water or using water filters and aqua purifiers, while remaining 65% households never purified water before consumption (Fig.5. 15).

Consequently, the habit of consuming water directly from source without any further purification led to greater risk of contacting water-borne diseases. Therefore, households which were consuming purified water were considered to be less exposed for the purpose of this study whereas the households consuming supply water directly were classed to be at greater and immediate exposure risks.

Fig. 5.15: Water Purification Habit of the Surveyed Households



Source: Own household survey, 2005-2006 (N = 696)

5.3.4 Direct Contact with Raw Sewage

Direct physical contact with raw sewage is yet another factor to be considered for better understanding of wastewater related exposure risk level. In the absence of proper collection and management wastewater from unsewered areas flowed to the open and storm water drains many times following the slope of gravity. Drains carrying this raw sewage mostly ran along the walls of the houses; they are primarily open channels; conscious residents sometimes covered these open drains with stone slabs but it hardly saved them from getting overflowed regularly.

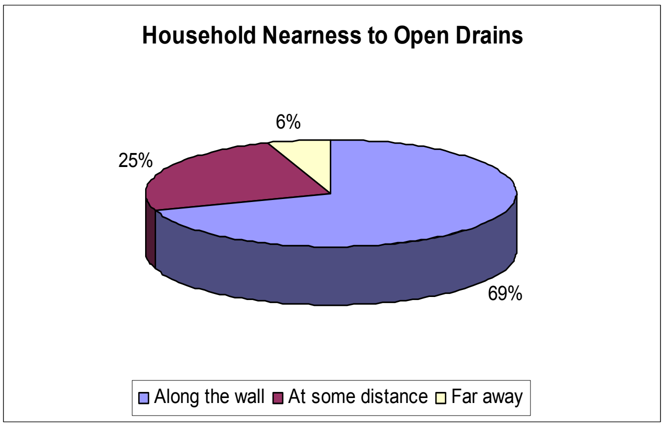
Open defecation and public washing was also commonly carried out by the marginalized groups of localities deprived of basic public facilities. In such case, puddles of wastewater lying in the open were unavoidable to be contacted during the course of everyday spatial mobility in and around the area. Nearness of open drains, frequency of drain overflow and taking to public washing and open defecation are all means of directly getting into physical contact with the wastewater.

5.3.4.1 Nearness to Open Drain/Canal

Open drains and channels carrying wastewater was a common sight at various residential locations. More than 60% of the drainage network was open surfaced and as high as 69% of the surveyed households reported to be having some type of sewer/drain in very close vicinity (Fig. 5.16). This included open channels along the houses of less than one meter width as well as bigger drains carrying effluents and raw sewage, which are not covered emanating fowl odour. These are a source of constant concern for the residents in the neighbourhood and a serious cause of mosquito infestation there. Such proximity to open drains and wastewater drainage channels was hazardous as they are not even properly maintained and neither cleaned regularly.

Fig. 5.16: Proximity of Households to Open Drains

Example of an open drain carrying raw sewage just along the wall of houses. (Source: Own Photo, 2006)



Source: Own household survey, 2005-2006 (N =696)

Though the maladies of open drain were not completely avoidable by some of the formal settlement colonies (e.g., surveyed authorised colonies at East Delhi) but the problem was more prominent and severe for the newly built unauthorised quarters as they completely lack any kind of sewerage or covered drainage facility. It can be, therefore, concluded that households living very close to the open drains are directly exposed to the wastewater risks while the exposure level was low for households living at a considerable distance from them.

5.3.4.2 Frequency of Drains Overflowing

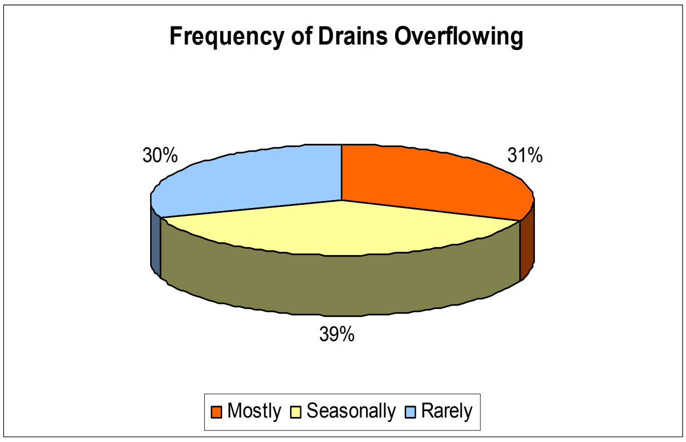
The existence of open drains also brought with itself the problem of frequent flooding, overflowing and constant odour. This was primarily due to the uncollected solid wastes and garbage entering drainage canals, which usually blocked the flow of wastewater. Apart from such human apathy, there were pre-existing structural problems in the drainage system which accentuated the problem of frequent flooding;

old and narrow drain pipes were not sufficient to carry the load of the increasing wastewater generation and the condition deteriorated due to increased siltation. Shallow drainage canals got easily flooded due to which overflowing even with little rainfall or during the non- monsoon was common.

Narrow and unmetalled lanes of surveyed unauthorised colonies and JJ clusters were in pathetic condition due to all time stagnation of flooded wastewater. According to the field survey results, about 70% of the households experienced overflowing and flooding problem in their household and immediate neighbourhood; among them, 31% reported to be facing drain overflowing problem most of the time were at greater exposure risk, while 39% said that it was a seasonal menace; the remaining 30% household were considered being at minimum exposure risks as they rarely experienced problem of chocked drain and sewage overflow in their households and neighbourhood (Fig. 5. 17).

Fig. 5.17: Problem of Drains Overflowing

Lanes of an unauthorised colony flooded by overflowing drains even during a non-monsoon period. (Source: Own Photo, 2006)



Source: Own household survey, 2005-2006 (N = 696)

5.3.4.3 Physical Contact with Wastewater

In the absence of proper wastewater disposal, infrastructure and irregular maintenance of the existing ones, direct physical contact with raw sewage was unavoidable. It was largely reported during the filed survey that the residents themselves had to clean the drains in their households and in the neighbourhood due to the general apathy of the concerned authority towards their maintenance. Due to frequent overflowing and wastewater flooding problems, residents even had to manually drain out the wastewater entering their houses (Fig. 5.18).

Fig. 5.18: Means of Physically Contacting Wastewater

Muck from the drain being manually removed by a member residents to clear the blockage and allow the water to drain out from his household. Resident usually had to clean them as the authorities were irregular in their maintenance.

A woman manually draining out the wastewater entering her household from the overflowing drains.

Source: Own Photos, 2006

At many surveyed locations due to all time stagnation of wastewater people usually contacted them in the course of their moving around, more so the children who played in such unhygienic vicinity. This coupled with the behaviour of poor personal hygiene further accentuated the risk of disease contact. Households with such direct proximity to wastewater and raw sewage were definitely at a greater exposure than the ones which could easily avoid it.

5.3.4.4 Open Defecation and Public Washing

Sanitation in low income households is almost lacking. Although there are provisions for paid toilets near JJ clusters and in other informal settlement quarters, it is still not accessible by the poor people due to various reasons. Firstly, because for most of the very poor people it is expensive, as each visit to the toilet costs 1 INR, and in that way if all the family members visit the public convenience at least once a day, it would cost them something between 5-8 INR for the whole household with an average size of 5-8 members. Secondly, there were no separate provisions for a women washing place in such public sanitation centres; therefore, young girls and women had to carry out washing in their household itself with limitations of improper water outlet. The menfolk used public water points also for bathing and washing. As children were not capable of using public toilets, they usually defecated in and around the open drains.

In the surveyed colonies, all the planned authorised and resettlement colonies had proper provision of sanitation in their own household, but the problem of improper sanitation facility was very prominent among the residents of informal settlement quarters. Improper access to sanitation facilities has an impact on the health of the exposed population too; partly explaining the predominance of gastro-enteritis among them. Therefore, households having proper access to sanitation and not taking to open defecation or washing in public are considered to be at a low exposure risk while the ones deprived of these facilities and forced to defecate openly are considered to be at a comparatively higher exposure risk.

5.4 Household Exposure Index

In the context of the present study household exposure assessment aims at systematically evaluating the exposure dimension of vulnerability at household level. Household Exposure Index is a composite of various parameters towards indication of the level of household's exposure to the wastewater or raw sewage. It is based on the similar approach used in the development of Human Development Index, where various elements measured in different units are aggregated together (UNDP, 1997). This method of constructing index involving normalization procedure of indicators had been successfully used in numerous earlier studies too (Briguglio, 1995; Nakamura and Hutton, 2001; van Dillen, 2002; Cutter, Boruff and Shirley, 2003; Pinto da Cunha *et al.*, 2005). Unlike the Human Development Index, all the indicators in this case are given the same importance by assigning equal weights.

Household Exposure Index is done with the specific focus on the relationship between the colonies/settlement status of the target households and wastewater implications faced due to enhanced direct exposure to the pollutants. The construction of Household Exposure Index is based on the idea that a combination of different advantageous and disadvantageous factors would help in determining the overall level of household exposure to wastewater implications. Therefore the selection of multiple indicators was necessary for identifying who is at greater exposure risk and where. It would further be helpful in tracing the causes for exposure and simultaneously can be used to identify preventive options and structural alternatives to enhance chances of protection against wastewater hazards. Moreover, it can also be helpful for planners and decision makers to identify areas of interventions, give them scope for reviewing prior actions and policies as well as make necessary rectifications.

The indicators to wastewater exposures were derived from the factors that causes an individual/household to be at greater wastewater exposure risks as discussed in the preceding section, though it must be mentioned here that the selecting of the indicators were based on personal judgement of the author on the grounds of knowledge and understanding of the problems gained during the course of intensive fieldwork. The selected indicators represent aspects of demographic and living conditions, colony status, house types, dependent water sources and hygiene habits etc. that are representative for the whole study area.

As mentioned earlier these indicators were categorized under four heads. Firstly, demographic characteristics of the surveyed population including information about the age, sex and the family size; the second category was the settlement status, which highlights information about the type of house, kind of colony and the period of stay there; the third category revolves around the drinking water source, sewage and fresh water mixing problem and water consumption habits of the households and final set of indicators are about physical exposure to raw sewage, gauging nearness to open drains/canal, frequency of drains overflowing, physical contact with wastewater, open defecation and public washing habits. These indicators were not completely independent; e.g. the legal status of colonies played a central role in influencing other exposure factors too; as legal colonies would presumably have sewer networks to carry the raw sewage away as well as piped water supply and thereby lesser chances of directly contacting wastewater for individuals there. Therefore, some of the indicators were also mutually inclusive.

On the basis of the 14 selected indicators outlined and discussed above, a **H**ousehold **E**xposure **I**ndex (HEI)[11] has been developed. Each indicator has been rated on a 5 scale score ranging between 1 and 5, where a lower score indicates a larger contribution to exposure and higher score indicates less exposure, thereby following an inverse relationship between the score and level of exposure.

[11] For examples of indices and indicator approach please see UNDP, 1997; Nakamura and Hutton, 2001; van Dillen, 2002; Cutter, Boruff and Shirley, 2003; Pinto da Cunha *et al.*, 2005.

All these indicators are assumed to have the same weight. Therefore, the HEI is defined as an average aggregate of all the indicator scores, which can be quantified as:

$$\textbf{HEI} = \frac{\textbf{Total Score}}{\textbf{Total number of indicators}}$$

The exposure index key (Table 5.2) so developed is in context of a specific empirical study related to wastewater hazards at selected residential colonies in Delhi and therefore it cannot be applied universally though it has the potential of applicability in similar settings only with careful modifications. The main aim of this index is to compare the surveyed households on the basis of their exposure levels to wastewater and raw sewage. It is also used for plotting an exposure-morbidity relationship later in the thesis (see Chapter 7 section 7.6.2).

The index of household exposure here is designed to show who is more exposed to the wastewater nuisance and is potentially at higher risk and where. These set of indicators reflect the core determinants of wastewater exposure which is the external dimension of vulnerability. Since the indicators are substitutable, it can only give a general picture of household exposure and therefore the result needs to be interpreted carefully. This index would later be analysed with the coping capabilities of households and together with people's perception and impact dimensions to asses the overall social vulnerability of the surveyed population in the city.

Table 5.2: Household Exposure Index Key

Sl. No.	Indicators \ Score	1	2	3	4	5
1	Age	More in age group 1-20 and above 70		Equal Numbers		More in age group 21-70
2	Sex	More Female members		Equal Male and Female members		More Male members
3	Family Size	more than 16	13-16	9 to 12	5 to 8	1 to 4
4	Period of Stay	More than 20yrs	10 to 20 yrs		1 to 10 yrs	less than 1 yr
5	Kind of Colony	JJ cluster	Unauthorised	Urban Villages	Resettlement	Authorised
6	Type of House	Kuttcha	Semi Kutcha	Semi Pucca	Pucca in JJ clusters	Pucca
7	Connection to Sewer	Not connected	Privately connected		Septic Tank	Connected
8	Source of Water	Hand pump	Boring pump	DJB Tankers	Community Tap	Treated water in Household Tap
9	Water Consumption Habit	Never purify				Use some mode of purification
10	Sewage Mixing	Frequently		Sometimes		Never
11	Nearness to Open Drain	Near (along the wall)		At some Distance		Far away
12	Frequency of Drain Overflow	Most of the time		Seasonally		Rarely
13	Open Defecation and Public Washing	Yes				No
14	Physical Contact with Sewage Often	Yes				No

Source: Own draft

Most Exposed	Moderately Exposed	Least Exposed

Exposure Index = Total Score/Number of Indicators (14)

Index value ranges between Minimum 1 to Maximum 5

0.1 – 2.3 Most Exposed

2.4 – 3.6 Moderately Exposed

3.6 – 5.0 Least Exposed

The Household Exposure Index so developed was further applied to the 696 surveyed households (Appendix IV). A combination of scores earned by individual households on the basis of their security and vulnerability to the harmful wastewater related exposure risks categorized them to relatively most exposed, moderately exposed and least exposed. However, as expected, the index is strongly associated with colony type and connection to sewer. Households in the formal settlement quarters with proper wastewater sewerage facility are concentrated at the least exposed end of the exposure scale whereas households without sewer facility, residing primarily in the informal quarters were more frequently exposed to wastewater hazards.

As mentioned earlier that the indicators are substitutable and therefore same total score can be earned by different combination representing different situational reason e.g. two households earning same score may fall in same exposure category but due to different reasons. Thus, a general idea about the household's exposure can be derived from the final scores but any further interpretation about individual reasons for exposure will need elaborate reference to the table in Appendix IV. Nonetheless, the index remains helpful in indicating the factors responsible for wastewater exposures that contribute towards the worsening of quality of life of the target population of the surveyed colonies.

Although the legal status of the colonies played important role in securing them sewerage facilities but it is not necessarily true that all the household inhabiting informal settlement quarters are highly exposed to the wastewater hazards; as even in the absence of proper sewerage, households could adopt hygiene behaviours and preventive measures against harmful exposures depending upon their awareness and action. This can be gauged from the set of indicators under drinking water sources and consumption habit. Moreover, the existence and nearness of open drains as well as the frequency of its overflowing, which depended upon the level of sewer maintenance (particularly true for the formal colonies where the sewer network existed) were important in influencing exposures. Keeping all these aspects in mind analysis of household exposure to wastewater was performed.

Elaborated exposure analysis shows that about 60% of the households surveyed were in the moderately exposed range, primarily because their disadvantage in terms of one exposure factor may have been replaced by their advantage in terms of another, thereby bringing their level of exposure within a moderate range. Households which were disadvantaged consistently in terms of numerous factors appeared to be most exposed which constituted of about 12% of the total surveyed households. This comprised of above 20% of the households in south location (64 out of 311), 7% (13 out of 178) in east and 2% (6 out of 207) households at central location respectively, whereas a composite 28% of the households were least exposed to wastewater due to their advantages primarily in terms of locational dwelling, sewer connectivity and avoidance of wastewater disposal problems (Table 5.3).

It is noteworthy that households at the central location were least exposed to wastewater related risks whereas the exposure risk was comparatively higher among the households at south location. This further attests better infrastructure facilities at the city centre than compared to the fringes due to multiple reasons such as its central location made it a prominent area of concern among the politicians and kept its development in the forefront; secondly, it is the oldest part of the city which was planned with primarily legal provisions making the residents easily access the water, wastewater and sanitation facilities provided by the administration, Drains in the central part of Delhi was largely covered and the dwelling units were primarily *pucca* providing more protection against wastewater. All these factors contribute to the comparatively lesser wastewater exposure risk at the central location while the absence or only precarious presence at other locations immensely contributed to greater wastewater exposure risks for the households.

Table 5.3: Distribution of Exposed Households

<table>
<tr><th>Location</th><th>Total No. of Surveyed HH</th><th colspan="2">Most Exposed</th><th colspan="2">Moderately Exposed</th><th colspan="2">Least Exposed</th></tr>
<tr><td rowspan="2">Central</td><td rowspan="2">207</td><td>C1 – 0</td><td rowspan="2">6</td><td>C1 - 58</td><td rowspan="2">100</td><td>C1 – 36</td><td rowspan="2">101</td></tr>
<tr><td>C2 – 6</td><td>C2 - 42</td><td>C2 – 65</td></tr>
<tr><td rowspan="2">East</td><td rowspan="2">178</td><td>E1 – 5</td><td rowspan="2">13</td><td>E1 – 52</td><td rowspan="2">138</td><td>E1 – 15</td><td rowspan="2">27</td></tr>
<tr><td>E2 - 8</td><td>E2 - 86</td><td>E2 – 12</td></tr>
<tr><td rowspan="3">South</td><td rowspan="3">311</td><td>S1 – 4</td><td rowspan="3">64</td><td>S1 – 55</td><td rowspan="3">180</td><td>S1 – 8</td><td rowspan="3">67</td></tr>
<tr><td>S2 – 29</td><td>S2 - 102</td><td>S2 – 17</td></tr>
<tr><td>S3 - 31</td><td>S3 - 23</td><td>S3 – 42</td></tr>
<tr><td>Total</td><td>696</td><td colspan="2">83 (12%)</td><td colspan="2">418 (60%)</td><td colspan="2">195 (28%)</td></tr>
</table>

Source: Own household survey, 2005-2006 (N = 696)

5.5 Concluding Remarks

Exploring the external side of vulnerability reveals that the locus of exposure to various wastewater related harmful perturbations in case of Delhi is embedded in the location, status of the residential quarter, general demographic characteristics, social profile and level of access to the wastewater and sanitation infrastructure by the households. Unsafe conditions as reflected in specific situations of various types of colonies in formal and informal settings and marginalization of social groups to the disadvantaged locations partly determined the cause of their vulnerability in the city's urban setting.

Although the type of colony and status of infrastructural facility is an important indicator for wastewater exposure, it is only in combination with other disadvantageous factors as the index also reveals that households at the same location and type of colony are differentially exposed to wastewater. It is rather difficult to strongly link exposure only to either spatial or social factors. It is not only the lack of sewerage in households but the general condition of the immediate neighbourhood, the activities and behavioural factors of individuals that determines their exposure to wastewater.

Nonetheless, it is primarily the status of settlement colonies which played an important role in influencing external exposures to wastewater hazards as many other indicators depended upon the factor of legality. In megacities like Delhi, which receives a huge number of immigrants, faces severe problem of slum proliferation and increasing informal settlement quarters, it is highly important to plan for the informal population as well. The city planners, policy makers and managers need to keep in mind the basic service requirements of the incoming population as the city is also benefiting from them in terms of labour force both in formal and informal sectors.

Apart from the mere provisions of infrastructure, it is also important to maintain them in functional state and both the management as well the civil society need to share this onus. A general attitude of public apathy towards maintenance of public good and provisions proves harmful in all respect e.g. maintenance of the drains was considered sole responsibility of the management whereas, the general public were unconcerned about it which was evident from the irresponsible behaviour of dumping solid wastes into the wastewater channels which blocked its flow leading to wastewater logging and flooding even during the non-monsoon periods. Therefore, it has been noticed that apart from the structural provisions, behavioural aspects of social community is equally important in determining their security and defenselessness.

In this chapter, the exposure side of vulnerability has been extensively explored, where we looked into the factors influencing exposure. In order to probe into the other facet and grasp a holistic view of defenselessness and insecurity of various social groups towards wastewater related hazards, we now shift on to analyse the internal aspect (coping side) of vulnerability in terms of household capital, social networking and resource capacity. At the same time, it is also equally important to understand people's perception about the existing condition, which influences and moulds their coping behaviour, thereby determining the extent of resultant implications.

Chapter 6

People's Perception and Management Capacity

6.1 Introduction

Vulnerability is conceptualized as being constituted by components other than exposure and sensitivity to perturbations or external stresses. This refers to the capacity to cope, adapt and move in the direction of negating the harmful effect. After analysing the exposure aspect related to wastewater we now explore the internal side of social vulnerability in terms of management capacity, social and economic capital as well as role of people's perception. This chapter further describes the factors that influence management capacity and people's perception which in turn influence their capability to act and moulds their responses itself. Appropriate indicators are selected which represent the household resource capacity and an index is worked out for its comparative analysis across different locations and colony types. They indicate that resource capacity and people's perception are associated predominantly with economic status, level of awareness as well as prevailing institutional and political ecology.

6.2 'Internal Side' of Social Vulnerability: People's Perception and Management Capacity

Coping capacity is a function of perception (of the risk and ability to cope), possibilities (e.g., options available for its prevention, mitigation and coping) as well as private and public actions (IPCC, 2001). In general it refers to "the means by which people or organisations use available resources and abilities to face adverse consequences, involving management of resources both in normal times as well as during crises or adverse conditions" (UN/ISDR, 2004: 16). In this study, the elements of internal side of vulnerability focus on people's perception of the hazard as well as their coping and management capabilities to overcome or at least mitigate the negative implications of adverse conditions created by wastewater.

While coping capacity is more directly related to an extreme event, adaptive capacity refers to a longer time-frame and implies that some learning either before or after an extreme event is happening (Peltonen, 2006). Coping capacity is viewed usually in the short term and adaptive capacity usually viewed as occurring over longer time-frames both in this case have been classed together as management capacity for a consistent understanding. Strengthening of management capacity lowers the vulnerability of a system, community or household through increased resilience.

Coping is a highly complex and dynamic issue, not only in times of acute crisis but also in coping with everyday or seasonal risks (Bohle, 2001). The concept of coping, adaptation and adaptive capacity in light of access to resource has been used both explicitly and implicitly in natural and social sciences, including natural hazards (Watts, 1983; Blaikie *et al*., 1994), environmental risks (Blaikie and Brookfield, 1987; Adger, 2000), climate change (Downing, 1991; Smit *et al*., 2000), political ecology[12] (Oliver-Smith, 1998), and entitlement to food security (Sen, 1981; Cannon, 2002).

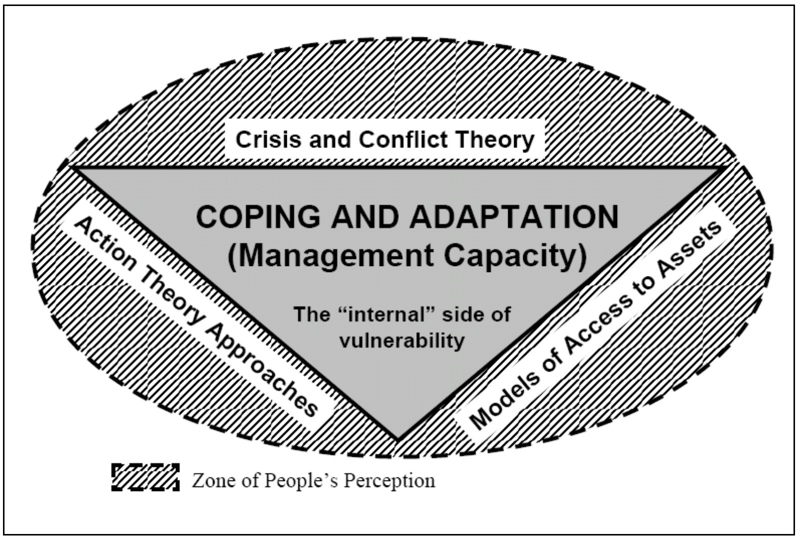
As elaborated by Bohle, three main strands of theoretical discussions namely, action theory (i.e., the means and ways used by people to act), model of access to assets (i.e., access to assets of different nature that allows people to mitigate their vulnerability) and the crisis and conflict theory (i.e., the capacity to manage crisis situations and the resolution of conflicts) seem to be most relevant to grasp the whole range of coping and adaptation capabilities (Bohle, 2001).

Naturally, all three approaches overlap in multiple ways, and they are also closely linked to the external/structural context in which they are embedded. But all these are influenced and would be triggered by people's perception of the situation. Human beings or social

[12] "Since the 1970s the growth of political ecological perspectives and hazard perspectives in the social sciences has led many scholars to consider disasters to be more as a function of social conditions…Political ecology is based on the premise that political, social and economic consideration mediates the dynamic interactions between humans and their environment. This perspective integrates political economy and human ecology by exploring the connections between the current and historical influences of the natural environment on human groups and the impact of larger political economic forces that characterize the society of which the people are members" (Ensor, Ensor and De Vries, 2003: 170-171). By adopting a political ecological approach to the study of disaster focus is on "the dynamic relationships between a human population, its socially generated and politically enforced productive and allocative patterns and its physical environment, all in the formation of patterns of vulnerability and response to disaster" (Oliver-Smith, 1998: 189). "…These social relations are maintained by dominant forms of production in a process that determines the patterns of resource allocation and other forms of social, political and economic differentiation. This differentiation, in turn privileges some individuals and groups with enhanced security while subjecting others to systemic risks and hazards" (Ensor, Ensor and De Vries, 2003: 71).

groups act and response only on the basis of the impression formed of the existing condition depending upon their level of understanding and prior experiences. Therefore, all these three strands are largely encompassed within the influence zone of people's perception (Fig. 6.1). It seeks to integrate these concepts into a comprehensive but simplistic model to serve as a framework for analysing the 'internal side' of vulnerability.

Fig. 6.1: Conceptual Model for Analysing the 'Internal Side' of Social Vulnerability



Source: Own draft after Bohle, 2001

The first dimension here focuses on action-oriented approaches, especially on the interaction and dialectic relationship between the external and internal side of vulnerability in terms of existing structure and agency. It refers to the means and ways used by the people to act, either by free will or as a result of external constraints. It is highly contextual and subjective to answer to what extent marginally located and underprivileged population have options to cope with prolonged exposure risks or to what extent their coping strategies are determined by structural/institutional limitations.

A second approach which is closely linked to action theory is the concept of access, to 'assets' especially to coping resources and strategies. This strand focuses on understanding the role that access to various assets (including personal, economic, socio-political, infrastructural assets) plays in providing security to the social group or individuals. The starting point of this strand of discussion is the observation that assets which people control contribute to mitigate their vulnerability and strengthen their resilience towards risks. The more assets they control, the less vulnerable they are and the greater are their capacities to successfully cope with risks, even in their everyday life. Social assets here play a particularly important role, for such assets are often the only form of 'coping' that a group is left with during a period of heightened risk.

The whole question of access to control over assets is closely linked with the political system of the region under consideration and in which way various groups of people are embedded in the basic structures and dynamics of society, economy, and polity. This leads, finally, to conflict and crisis theory approaches. Issues of access to control over resources occur usually in highly contested spaces and arena of risk and criticality, and the capacities to successfully manage risk situations will be a basic determinant for successful or less successful coping means (Bohle, 2001). Empowerments and rights that are exercised within a particular setting determine the access to resources (e.g., infrastructural resources in this particular case) and are therefore also a key dimension to analyse vulnerability. Analysing individual ability to reduce risk calls for identifying the accessibility of the infrastructural provision along age and gender lines.

Further aspects to be analysed within this framework of vulnerability are the challenges arising from the tension between objective and perceived elements of vulnerability and risk. Vulnerability may be differently perceived or experienced by the vulnerable themselves (Kasperson *et al.*, 2005a). The experiential or perceptual dimensions of vulnerability are not easily measured primarily because the impacts of environmental change that create perceptions of insecurity themselves may not be obvious (Adger, 2006). The coping capacity including awareness and willingness to act during time of external stress is widely influenced by differential perception by individuals and understanding of the available options as well as one's own status and ability to overcome the same. Thereby, it becomes clear that the opposing elements of vulnerability – coping capabilities and adaptive capacity – are extremely complex in the human system.

The pressure and release (PAR) model identifies the environmental stresses and progression in social vulnerability, including forces that relate to adaptive capacity (Blaikie *et al*., 1994; Wisner *et al*., 2004). In majority of past literature, treatment of coping dimension of vulnerability does not explicitly deal with the responses in terms of coping and adaptations methods itself but to the forces that facilitate the processes of management of risk and vulnerability. Capabilities (in terms of social and economic advantages) are often latent due to the circumstantial factors (Wisner, 2001) and only surface or get functional when the hazard strikes or during the time of exposure stresses. Such operationalisation of capacities is also highly influenced by people's perception of hazard risk and the sense of fear of being negatively impacted depending upon their knowledge of risk severity.

Yohe and Tol (2002: 26) analyse adaptive capacity of human system in terms of different determinants which include a variety of systems, sectors, and location-specific characteristics;

1. The range of available technological options for adaptation
2. The availability of resources and their distribution across the population
3. The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed
4. The stock of human capital including education and personal security
5. The stock of social capital including the definition of property rights
6. The system's access to risk spreading processes (e.g. insurance systems)
7. The ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers themselves and
8. The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

It, therefore, indicates that available options, awareness, ability of decision making and people's perception are all important determinates to analyse adaptive capacity of any studied system and it may be operational at different levels of management.

In this case study of wastewater-related vulnerability, some of the determinants of management capacity operate at the macro (national or state) level, which calls upon policy responses and outsource funding enhancements ones operating at meso (city) level depend upon structural enhancement for which institutional and organisational capabilities play significant roles whereas other determinants are operating at micro (community) level and are more influenced by the capabilities of households and individuals. Thus, successful management in terms of prevention, coping, adjustment and adaptation requires coordination across these scales.

6.3 Importance of Economic and Social Capital in Strengthening Capabilities and Decision Making

It has been recognised that a range of economic, social, political and cultural factors shape the coping capacity of population and also serve to shape their ability to make changes (Woodward and Scheraga, 2003; Smit and Wandel, 2006). Political, demographic and global economic processes have put coping strategies under great pressure and given rise to vulnerability and to reproduction of vulnerability over time which affect the allocation and distribution of resources between different groups of people (Blaikie *et al.*, 1994). In the 'disaster pressure model', Blaikie *et al*. (1994) extensively explained the progression of vulnerability from root causes through dynamic pressures resulting in local unsafe conditions. In this model, government policies and programs are considered the result of unequal power relations that create vulnerability and unsafe conditions at the local level. Although local people do not use the concept of vulnerability to describe their worsening situation, they feel the stress, face difficulties, talk about risks and make risk-taking or risk-avoiding decisions (Heijmans, 2001), which beside other factors are also primarily influenced by socio-economic status of the community groups.

Most poor people, moreover, choose a wide variety of options to try and increase their adaptability or minimize their risk to times of stress and shock (Chambers, 1989) and further try to diversify their interests (Swift, 1989), e.g. in the absence of proper wastewater infrastructure, households took to options like illegal connection or using septic tanks, but at the same time were of the intention to move to a better place of residence. All these options called for financial support. In case of impoverishment even a little amount of money which would be needed to cope is a lot to bear and is beyond financial capacity. Therefore, all the resorted options entirely depended upon the affordability of individual households.

Socio-economic factors are not only important in understanding the level of access to resources to undertake prevention, coping and adaptation (Pelling and High, 2005) but also in underpinning the behavioural context of social groups. The social context matters for collective action (Rudd, 2000), which is an important aspect of coping capabilities that helps in reduction of vulnerability and constitutes resources that individuals can undertake to increase their well being. Beyond instrumental benefits, social interaction and networking also lead to the development of trust, belief and cooperation within members, which again facilitate in strengthening their capabilities. This complex outcome of social relationships, interactions, social norms and institutions is referred to as 'social capital' (Coleman, 1987, 1990; Grootaert, 1998; Woolcock, 1998; Ostrom, 1999). It is a productive asset that enables individuals to better fulfil their aspirations through access to goods and services via their social network and collective actions (Castle, 1998; c.f Rudd, 2000: 135).

The limitations to choose from a range of accessible options, assets and risk reducing activities can often heighten vulnerability (Scoones, 1996). The poor amongst the poor were the worse effected, as they were economically weak and even lacked social assets, e.g. the engagement in economic activities left no time with them to organize themselves in active groups to be in a position to even communicate with the institutional members or the concerned authorities about their problem. They further lacked organised social interaction, flow of information and awareness building. Social interaction can influence the flow of information, which as a knowledge builder improves assessment, enhances coordination, reduces risks (Collier, 1998) and strengthens resilience by improving the capability to manage conditions of adverse implications.

It can be widely noted that incapability to manage crisis situation does not exist in isolation. It is rooted into the wider political economy of resource (physical as well as infrastructural) accessibility and use as well as the relationship among the community members as social capital helps in networked relationships and is produced through norms of trust and reciprocity among members (Dasgupta, 2003). Some coping and adaptation will occur autonomously through individual responses whereas other aspects will require greater foresights, planning and policy implementations on the part of government (Stern, 2007) as well as trust in the governance system and responsible behaviour on the part of social communities.

The most vulnerable populations who, usually, control very few economic, political, infrastructural, and personal assets rely upon social assets in the sense of being integrated into social networks of mutual trust, shared norms and reciprocity. Social networking of people in form of co-operative societies and Resident Welfare Associations (RWAs) are many times seen as the only support providers during crisis and period of adverse conditions. In this respect, the social capital offers a base for networking and collective action, thereby strengthening capabilities to act towards problems, further determining the speed and direction of adaptation and coping measures. Collective action is facilitated via trust and reciprocity.

Efficiency of social capital is further linked to the effectiveness of information dissemination among members and the level of assured trust and cooperation. This would further assist in community participation and developing a common vision for community development. As social capital also draws attention to the operation of power and flow of resources and information (Pelling and High, 2005) it can play an important role in decision making and collective actions. Apart from other factors and economic security, it is important for a conscious community to look into the adverse implications of the ongoing problems, evaluate its implications and discuss alternative for its solution through individual and collective actions. This would provide an efficient social base and strengthen their capabilities towards facing adverse situations during stress.

6.4 Factors Influencing People's Perception and Management Capacity in the Study Area

People's perception of environmental risk is largely influenced by the behavioural understanding of the harmful event or risky perturbation as seasonal phenomenon, rare event or something unexpected, which never happened before. Factors like household composition according to gender and age, educational and economic status as well as knowledge and awareness of the existing coping mechanisms determine the opportunities (resource capacity) people have to reduce risk. Under the influence of multiple factors, which may or may not be acting in a mutually inclusive manner, and depending upon varying ideas of risk occurrence and of its possible consequences, people can form very different opinion about the risk they are running and accordingly they make choice for mitigating the same.

The perception regarding reasons and implications of risks faces are also influenced by household's economic status, e.g. high income communities which may be well connected with the wastewater and sewerage infrastructures, and thereby at minimum physical exposure to wastewater nuisance but they consider themselves to be vulnerable due to wastewater mismanagement as it threatens their health security while the lower income group people living in informal settings were visibly more exposed to the wastewater nuisance in the study area had a different perception about the reasons of the problem and related risk. They considered themselves to be more threatened by other problems (such as poverty, unemployment, etc.) and not much by wastewater hazards. Outsiders label the people not provided by basic wastewater and sanitation facilities or those living in the unauthorised and informal settlements to be most vulnerable, while in reality people who face greater impoverishment and other economic problems do not consider wastewater hazard risk as a cause for prioritised concern.

Apart from economic status, perception of wastewater related risks, reasons, and suggestions for the alleviation of the same also differed across gender. Females in the household were more stressed and sensitised to the problems of wastewater nuisance in their immediate neighbourhood than compared to their male counterparts as it were the womenfolk who finally ended up with the task of maintaining household cleanliness.

People's perception about the adverse implications and about their own capabilities to face them is also greatly influenced by the implications they experienced in the past as well as the response of the local government officers and institutional agencies during the course of their past interactions with them, which in this case was largely reported unsatisfactory. The proper functioning of people's strategies, adoption and accessibility of the preventive measures depend upon the complex political economy as well as institutional sensitivity. If the responsible institutions are sensitive towards public grievances, quick and effective in their responses it helps greatly in enhancing their reliability and building up people's trust in them. Thereby, a community feels more confident about effectively dealing with the problems during the period of stress.

Urban system resilience is greatly enhanced by efficient institutional structure and beneficial relationship between municipal and national government (Solway, 1994 c.f Pelling, 2003: 81). Weak institutional organization coupled with poor urban governance has led to numerous obstacles which have directly hindered efficient management and adequate infrastructural access. Under such circumstances at city level, some social communities even if they have potentials to help themselves find it increasingly difficult to deal with the problem as they are faced with numerous economic, political and legal hindrances acting as limiting factors towards their developmental attempts.

While the government puts emphasis on universal coverage of wastewater network and relocates the impoverished, poor residents have been better off if the government provided them with alternate sanitation system and remove the constraints faced by the infrastructurally stressed population for self help or at least managed the existing infrastructures efficiently. Social communities, which were able and willing to help themselves (privately applying for sewer connection or construction of sewer tank) were faced with various constraints officially, e.g. the existing policies prohibits them from digging channels along their households for wastewater drainage; since they had no legal proof of land ownership, they could not apply for legal household sewer or water connection.

The existence of social capital in the form of people's group also plays an important role in strengthening the coping capacity of community groups through their combined effort towards common goal. Such social asset facilitates access to information, finance, state services, equipment, food and goods that raise the capacity of households to survive through adverse situations (Tudawe, 2002). In this sense social capital can be seen as an 'asset' which exists not in people but in relationships (Francis, 2002), e.g. existence of Residents Welfare Associations (RWAs), registered people's group formed to represent and look after residents' needs and rights, and work for the betterment of respective colony not necessarily with direct provision of amenities but by providing a common platform to represent people's voice before the state and communicate with the government agencies about their needs and problems.

Wastewater disposal related risks were understandable by people, more so the inhabitants of informal settlement quarters only in terms of health hazards. They perceived it as a problem only after serious disease outbreaks in the family although the disposal mismanagement overflows and chocking of canals was a regular phenomenon. Their understanding of wastewater risk was completely based upon health outcomes. Aesthetic degradation and long-term threats were not considered as a risk to their social well-being.

Individual factors that influence perception and operationalise resource capability cannot be identified and analysed independently or as separate entities. They frequently act in conjunction with each other and appear to be mutually inclusive. The entire gamut of factors, which influences people's perception and resource capacity and accordingly mould their choice of mitigation options are now taken up in details under following heads:

Socio-Economic Status

- Gender role
- Educational status
- Economic status

Knowledge and Awareness

- Nature of problem
- Earlier experience
- Knowledge of impact severity
- Available mitigation options

Role of Social Capital

- Existence of people's group
- Effectiveness of social networking
- Constraints to community participation

Institutional and Political Economy

- Level of institutional accessibility
- Institutional sensitivity
- Constraints upon self-help

6.4.1 Socio-Economic Status

Socio-economic factors such as gender, education and economic sufficiency are not only important in understanding the level of access to resources to undertake prevention, coping and adaptation but also in underpinning the behavioural context of social groups. Perception of risk, awareness of available options and management capabilities which operationalise responses and accordingly influence the choice of coping measures and adaptations differed across gender, educational and economic strata. These are dealt more in detail individually below.

6.4.1.1 Gender Role

The general development thinking confer secured water supply, wastewater and sanitation benefits the entire community but it has greater advantages for women than men as water and sewerage problems were more pressing on the womenfolk. There exists a general difference in the attitude towards the problem between the two genders. Numerous observations made in the field indicate the reasons and processes for women being more exposed to infrastructural stress and likewise led to perceive the related problems and its severity differently than men.

Firstly, the cultural setting in Indian context is such that the male's participation in everyday household work is minimal. Women of the house are supposed to look after the household, which in a wider sense encompass all the household maintenance and cleanliness work. In the absence of proper wastewater disposal infrastructure, females of the house had to clean the muck and overflowing wastewater manually, thus being at maximum exposure risk. Since women were more affected by blocked sewers and the problem of improper disposal, they avoided use of extra water during washing and cleaning in order to reduce wastewater generation.

Since the severity of wastewater infrastructural stress has led to compromised hygiene, resultantly exposure risk was highly perceived by females of the household than compared to the male members. Members of very poor households lacking sanitation facilities had to carry out washing and bathing at public water points. This was perceived as one of the major problems by female respondents as it was convenient for men to use public sanitation services and open washing and bathing whereas young girls and old women had to resort to other restrictive alternatives like carrying water into the household for bathing (the outlet of which was again creating havoc as it would take hours to get drained) or bathing only occasionally.

Though the male member of the household was aware of the sewer and wastewater problem they were sensitised about the severity of the issue by the womenfolk at home, who regularly indicated for solution to men. Men would then in turn approach the local authority or would hire private cleaners to clear the blocked sewer. It was surprisingly true that women were reluctant to officially lodge complains about the sanitation problem in their household and immediate neighbourhood themselves. Although, women were the ones who felt the stress of wastewater problems in household but they completely depended upon the males to lodge complain about the malfunctioning infrastructure.

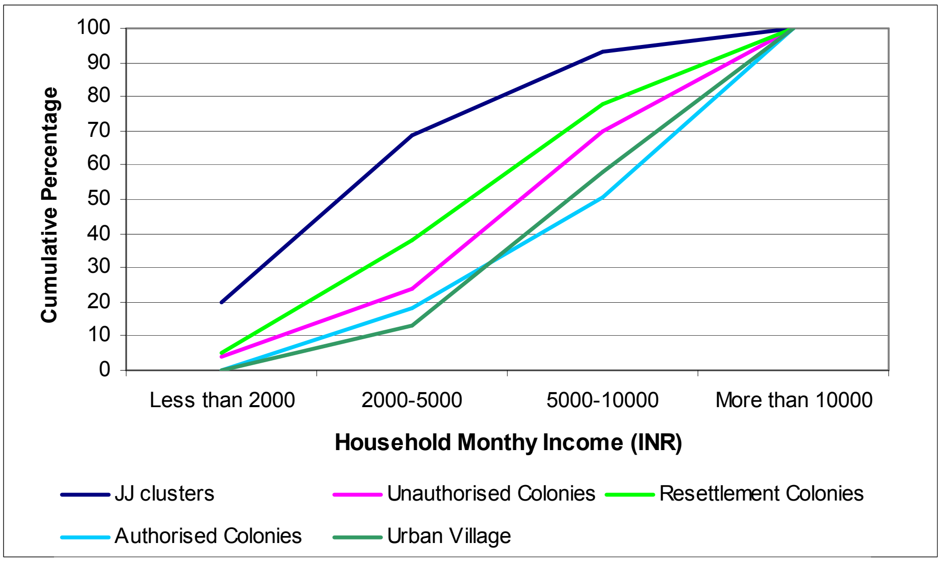
6.4.1.2 Economic Status

According to recent figures from the National Council of Applied Economic Research (NCAER), Delhi is the number one metro city in respect to average household income, expenditure, rich and very rich households. The average household income in Delhi is

23,250 INR ($ 583) per month (Economic Times Brand Equity, March 8, 2006). But according to the field survey majority of people living in the informal settlements, on an average, earned less than 2000 INR ($ 50) per month; they were either workers, in service jobs and daily wagers. About 75% of the workers were in temporary jobs and about 50% were unskilled. Total household income was taken into consideration here.[13]

Many households had more than one earning member to supplement family income. Data confirms the existence of inter- and intra-colony variations. About 80% of the respondents in JJ cluster had their household income between 2000-5000 INR[14] while the proportion of households in this income category got lowered with the improving status of colony. 30% of resettlement colony respondents were earning between 2000-5000 INR. The proportion of household in this lower income category further decreased to only 15% and 10% respectively for authorised colonies and urban villages (Fig. 6.2).

Fig. 6.2: Distribution of Household's Income per Settlement Colony



Source: Own household survey, 2005-2006 (N = 696)

[13] Respondents were asked to indicate the income category which their family were falling (including income of all the earning members of the family). This was done because the respondents were uncomfortable in revealing their exact household income. In some cases where no income category was indicated, average income category of that particular colony was assigned to that household.
[14] 1 USD = 39.88 INR (rates at 2008.02.28, 17:08:30 UTC).

One interesting point to be noticed here is the resettlement colony. Although it is infrastructurally well placed in comparison to the unauthorised colonies it has repeatedly appeared to be socio-economically lagging in comparison to the residents of unauthorised colonies. It is primarily because of the fact, that the very poor households residing in 'clusters' are resettled in these colonies. Thus, although the level of access to infrastructure improves with better housing, their educational and economic level remains the same.

Residents of the unauthorised colonies are not always necessarily poor. People belonging to the middle and also upper middle class economic strata and having better qualifications, too, were compelled to reside in informal settlements because of the scarcity of housing and comparatively cheaper land rent of the unauthorised areas. The major reason for choice of settlement for the JJ cluster was search of employment reported about 80%. This worker class had largely migrated to the city from the neighbouring states looking for jobs and in the absence of proper housing facility had to squatter. Over the period of time they were moved to resettlement colonies while the authorised colonies showed a mixed choice for their settlement (Fig. 6.3).

Fig. 6.3: Reasons for Settlement Choice

Source: Own household survey, 2005-2006 (N = 696)

The situation again reinforces the increasing infrastructural stress in the city in terms of housing and settlement. Infrastructure planning and policies in the city have clearly ignored the existence of this population residing in informal settings for over decades and has failed to adequately plan for the large, constantly increasing immigrants.

With sufficient economic assets to rely upon, people have a range of choice to choose the option during problem period, e.g. households which lacked sewer and sanitation facility but had comparatively higher income could have a private sewer connected to the main line (although the status of such connection remained illegal). This saved them from facing the wastewater disposal problem in everyday chores, while the population with limited income had no option than to endure the situation. Similar pattern of coping was observed with the connected population facing problem of improper maintenance. Even if the sewer lines were connected to households, they were predominantly substandard and ill-maintained more so in resettlement colonies. This was largely due to ageing infrastructure without proper renewals coupled with negligence of the local cleaners.

Depending upon the affordability, households could adopt prevention and coping measures of varying effectiveness. In this respect, financial affordability was a very important factor which enabled households to choose the options for solving their wastewater disposal problem at household or to endure the situation and continue to be exposed to the hazard risks. Moreover, economic security also influenced their perception to the problem and decreased complete dependence upon the government for actions towards solution of the problem as they could afford to act themselves.

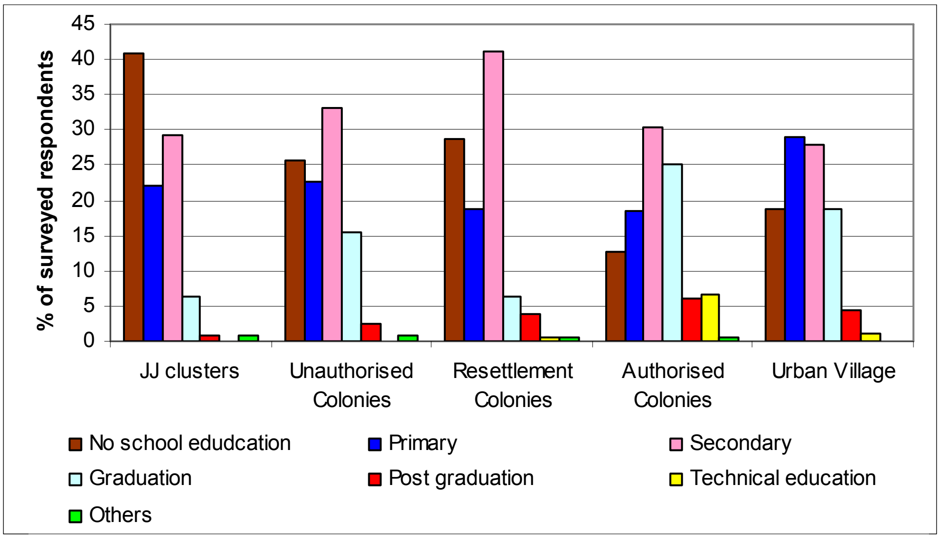
It was only with households with some financial security that the solution of wastewater exposure risk gained priority in attention. While the very poor households' wastewater problem though existing had less risk priority as they had other problems more pressing to face, e.g. getting at least sufficient water for domestic purpose, earning daily income for living etc. Although being the most exposed groups from physical and infrastructural point of view, wastewater risk was of a less priority for these groups further leading to aggravation of their overall vulnerability.

6.4.1.3 Educational Status

The level of education of the respondents has been interpreted as an indicator which can speak about the households understanding of the overall problem and capacity to work towards its mitigation as well as their awareness and keenness to act for risk prevention. The level of education only of the respondent cannot speak clearly about the whole household. Therefore, the other aspect like the type of occupational activity engaging most of the people was also taken into consideration.

The colony where the proportion of lower income households is highest, clearly in JJ cluster, is largely inhabited by wage labourers and migrant workers. Whereas the higher income households are in authorised colony followed by urban villages, and unauthorised and resettlement colonies. A similar trend is noticed for education status too. The overall level of education in almost all the colonies was primary and secondary (Fig. 6.4). Higher number of population with no school education was in the informal settlement and decreased with improving status of residential colonies. Poverty and caste segregation to a great extent explains the lower level of education among *Jhuggi* dwellers[15].

Fig. 6.4: Educational Status of the Respondents



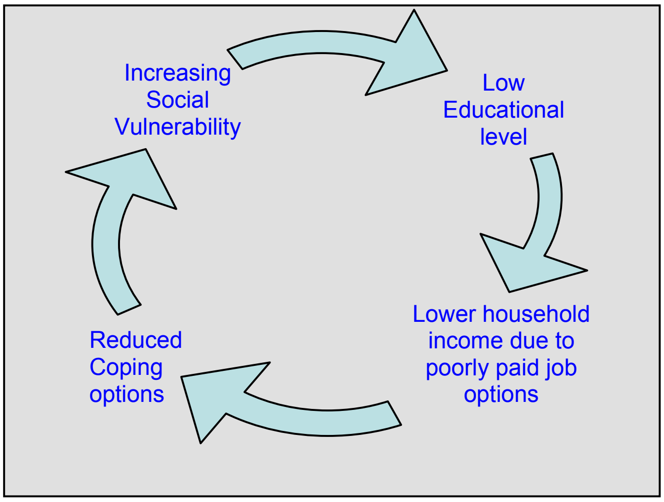
Source: Own household survey, 2005-2006 (N = 696)

[15] For further readings on socio-spatial segregation in Delhi see Nangia, 1976; Nagpaul, 1988 and Dupont 2004.

The graduates were more in the authorised and urban villages. Likewise for unauthorised colonies, the proportion of graduates was much higher than compared to those in the resettlement colonies, for similar reason explained in the earlier section further reinforcing that mere locational resettlement does not necessarily improve the economic and education status.

Relocation to a safer place may get better security to the household against exposure to the risky perturbations by better access to basic infrastructure but the internal capabilities towards mitigation in case of a hazard outbreak remain low for such groups. Poor education, low income and social vulnerability co-existed in the form of a vicious circle for poor and marginalized social groups (Fig. 6.5).

Fig: 6.5: Vicious Circle of Social Vulnerability



Source: Own draft

It was evident during the course of the social survey that with low education and skill, job options are limited, which only earned poor income to the family and with limited financial resources, infrastructural accessibility and coping options against water, wastewater and sanitation stress was increasingly restricted thereby placing the households at higher level of vulnerability.

6.4.2 Knowledge and Awareness

The way a person forms his or her opinion about the risk and its possible consequences depends upon the direct experience of the person involved and experience of others in near surroundings (Hauger *et al*., 2003). The internal capacity of individuals to cope with or face stress to a great extent also gets influenced by prior knowledge and awareness. The extent of preparedness of a community speaks not only of their adaptability but also of their knowledge and awareness of risk (Pantelic *et al*., 2005). This recalls the ideas about future impacts as well as lessons learnt from prior experiences which depend upon community's knowledge about the nature of risk, its impact severity and available mitigation options. Each of these factors is individually explained below:

6.4.2.1 Knowledge about the Nature of Risk

There always remains a considerable degree of uncertainty about the occurrence of serious outbreaks. Knowing the nature of risk and problem goes a long way in preparing for its prevention, thereby strengthening management capabilities. It is important to be aware about the possibility of its occurrence which can be deduced from the nature of the problem. Not all hazards or outbreaks that strike are always known. But people's idea about its nature influences their perception towards it and moulds their choice of prevention and coping strategies.

Risks of exposure to wastewater depended upon the frequency of problem occurrence, which also acted as an impetus for households to respond. Depending upon the nature of risk faced, coping and adaptation measures were chosen. When the occurrence of problem is unknown and irregular, preventive measures are difficult to adopt while adaptation was prominent in case of regular occurrences.

Nature of wastewater disposal related problem in Delhi differed across colony types. In JJ cluster and unauthorised colonies about 50% of the respondents reported that wastewater disposal problem resulting into flooding of raw sewage in and around the household was a frequent problem. Another 40% faced wastewater disposal havoc only seasonally (during the monsoon). In authorised colonies, due to better drainage and sewer infrastructure the problem related to wastewater disposal was primarily a rare phenomenon; therefore, not many preventive measures were in place, though these households possessed greater capabilities for its management in case they faced it.

Due to the occurrence of sewage and wastewater flooding problem frequently in the households and immediate neighbourhood, communities here in the informal settlements were better mentally prepared to face it and subsequently adopted preventive behaviours than compared to those residing in the authorised colonies. Interestingly, it was noticed that ignorance of the problem was also considered to be 'bliss'. A typical response from a female respondent of old Delhi authorised colony, brings us quite close to this point.

> *"People are just concerned of their household wastewater, the pipes of the upper floor draining water are leaking (because they are old) but they are not repaired, so the water sometimes flows on the road. But as we do not go out of the house we do not face this problem and so we are not much affected"* (Open part of the household questionnaire).

It clearly indicated that mere acknowledging the existence of wastewater hazard was not sufficient for people to respond. It was equally important for them to be aware of its nature and gauge its resultant ill implications as well as feel responsible for its alleviation instead of depending completely upon the government for every action.

6.4.2.2 Earlier Experience

People have a variety of modes of understanding risks and such perceptions will change considering the experience of the individual and the social and cultural setting in which these understandings are formed (Prowse, 2003). In this sense it should be recognised that risk perception and assessment are grounded in the cultural norms and values that govern a society and are embedded in the relationship that social communities have with their physical and social environment (Oliver-Smith, 1996). Understanding of risks occurrence pattern and finding means to prevent its next occurrence is to a large extent influenced by the individual's earlier encounter with the same or learning process by other's experience.

Prevention of an unexpected outbreak is not constrained solely by imperfect information but also by risk denial by the individual or social community. Field experience showed that the residents acknowledge the frequent nature of wastewater disposal related risks and their potential consequences, but often place the responsibility of the threat to a higher authority such as the government and other civic agencies. This takes us again to the structural approach to recognize the relationship between structure and agencies for a better understanding of, and response to, risk (Wisner, 1993).

Nonetheless, experiences of earlier implications strengthen adaptation through learning from the same and modifying measures accordingly. In this respect households which are in good setting for inter- and intra-community interaction and share knowledge about the problem and learn from experiences of each other are important and at higher level of awareness, which facilitate their timely response and strengthens their management capabilities.

6.4.2.3 Knowledge of Impact Severity

The alarm bell about a potential threat turning into a hazardous outbreak is triggered only if the social community or individual are aware about the severity of its impact on the life security and well being of themselves and their community. When the households were asked about their awareness of the health risks caused due to various wastewater nuisance, almost all the households said 'yes', they were aware of its health and environmental implications – prevalence of malaria, water pollution, etc. – but most of them added that although they are aware of such wastewater related hazards in their neighbourhood, they cannot do much in this regard as it was solely up to the government to look into this infrastructural deficit and maintenance problem.

Such awareness of the impact as well as the ignorance of civic agencies warns them to be precautious against the prolonged exposure of harmful wastewater nuisance and adopt preventive behaviours and measures in accordance to their capabilities. In this respect the households added that they had been keeping the area clean on their own but it is difficult to maintain cleanliness and solve the wastewater disposal problem in the immediate neighbourhood where raw sewage flood the by-lanes and alleys, which only dries up over the days leaving behind a slippery, stinking slush that becomes impossible to negotiate.

Households which had experienced the atrocities of sewage flooding had also considered improvement in their housing structure (e.g., raising the house entrance which could prevent the sewage water from entering houses). Moreover households with small children preferred to boil drinking water as prevention against water-related ailments. After facing numerous cases of stomach problems (dysentery and diarrhoea) in the households, avoiding consumption of raw water which was considered to be polluted by sewage leakages was common, household also switched to other sources of drinking water (e.g., buying water or using water purifiers).

In this manner knowledge of impact severity helps in being prepared and thereby helps getting the necessary action in place even before the event strikes and consequently enhances management capability.

6.4.2.4 Awareness about the Available Mitigation Options

People's coping capacity is also directly influenced by the available mitigation options within their reach and affordability. There may be a range of options to choose from, which would help to alleviate the current exposure situation of the vulnerable households but they need to be aware of its availability, accessibility and effectiveness.

During the study it was noticed that households which were infrastructurally deprived either took to private sewer and drainage connection (illegally), or tried to cover the open drains along their households with stone slabs (a local provision). The residents of JJ clusters were aware of their illegal colony status and thereby could not approach the authorities in case of sewage flooding, while the households of formal settlement colonies when faced with wastewater problem at their household or immediate neighbourhood had the option of complaining to the nearest office of concerned agency.

It was also frequently noticed that households were not aware where to approach for help in case of emergency. 58% of the surveyed households were not aware about the responsible authority to approach for such problems in their neighbourhood. They either did nothing to solve the problem and left it to the mercy of time or kept complaining to the person who would do least or was not in a position to help them effectively e.g. at certain surveyed lower income residential areas in Central Delhi, when there were problems of water logging or drain overflow the residents complained to the local political leader, who would listen to their problem but would not be very effective in managing it immediately as the sewer and sanitation was under direct control of Delhi Jal Board and managed by the zonal engineer in the respective area. Therefore, if the residents lodge complain directly to the concerned official, chances are that their problem could be solved sooner than going via local leaders. While residential areas of higher income group in the authorised colonies, particularly of south and east districts, when faced this type of problem could easily dial the management concerned and the pipe leakage or sewer problem was attended soon.

People surely could adopt the available local solution against wastewater problems (like hiring local sewer cleaners to remove the blockage in the drain) but the ones which are beyond household level solution (problem with the main sewer line) definitely call for immediate attention by the civic body. In this regard it is necessary to be made clear (especially to the women members) the place and person who can be approached for specific wastewater and sanitation related problem. Community groups also need to be educated about other options and strategies that could be adopted as solutions and preventive measures against wastewater related nuisance in order to strengthen their capabilities.

6.4.3 Role of Social Capital

There is much debate about what exactly is meant by the term 'social capital' (Putnam, 1998; Cox and Caldwell, 2000; Pawar, 2006). In the present context it is taken to mean the social resources, relationships and networking upon which people draw in pursuit of their objectives of securities and well being. Defining in Putnam's words, social capital means "features of social life – networks, norms and trust – that enable participants to act together more effectively to pursue shared objectives" (Putnam, 1995: 664-665). These are developed through networks and connectedness, membership of more formal groups and relationships of trust, reciprocity and exchanges that facilitate co-operation and may provide the basis for informal safety nets amongst the poor (DFID, 1999). But the term 'social network' itself adds no analytical value to the study of such phenomena (Devereux, 2001 and Moser, 1998).

Membership of associations can extend people's access to and influence over other institutions and also be forceful in influencing the political groups as well as governmental agencies to look into their needs e.g. through the action of people's group which are also attraction as a potential vote bank for political groups. But at the same time such association may not be really helpful in dealing with risks of larger dimensions. Tudawe (2002) further highlights how such 'forms of mutual assistance' for poor households are not adept at coping with major risks because such are poor-to-poor ties can often only provide a small amount of support for a limited time, or sometimes just emotionally.

The role and effectiveness of social capital in coping with the wastewater related hazard risk as observed in the surveyed areas differed across colony types and socio-economic status of the group, further attesting Tudawe's criticisms of only very limited benefits of social networking among the poor households. In the succeeding section existence of people's group, effectiveness of social networking and constrains to community participation is analysed to understand its importance in strengthening capabilities for management of wastewater problems, risks and hazards and who could benefit from it.

6.4.3.1 Existence of People's Group

Social networking in form of RWA (Residents Welfare Associations) were effective in solving day to day problems related to basic services including water, electricity, general hygiene in certain surveyed residential colonies. The level of such social networking varied according to settlement status too. It was largely noticed that places where people had made effort to form RWA and other social associations could look into the problems in their household and immediate neighbourhood more effectively than their deprived counterparts. This was primarily true for the formal settlements and co-operative societies.

Although such connections yielded limited results in their fight for basic services with the civic bodies, but nevertheless they succeeded in making a statement with the management where self-help was not possible. The marginalised and underprivileged inhabiting mostly the informal quarters were not even organised in active social groups for self-help or to raise their voice to the concerned authorities and negotiate with the government agencies for betterment of their settlement status and provision of basic services there.

Households when asked about the existence and possibility of forming any cooperating social groups, majority of the poor respondents in deprived settings answered not to be hopeful about the working of social groups, primarily claiming that there was no time for poor people to organise themselves effectively in such manner. This too affected people's perception about their own mitigation capability. They completely hoped and depended upon external intervention for the solution of their problems.

6.4.3.2 Effectiveness of Social Networking

Social networking, cooperation and interaction directly influence mutual bonding which is important and effective in encouraging 'community participation', which has proved to be an important tool in solving the community problems at local level. It can also be effective in improving the management of common resources (natural capital) and the maintenance of shared infrastructure (physical capital). Social networks facilitate innovation, the development of knowledge and sharing of that knowledge thus highlighting close relationship between social and human capital.

Social capital, like other types of capital, can also be valued as a good in itself. It can make a particularly important contribution to people's sense of well being through common identity, honour and belongingness (DFID, 1999). In order to secure a good social capital and networking it is important to have mutual trust and a common identity. Additionally the group needs to establish believe in one another and in the work they are attempting. The strength of social networking is in a direct relation with its effectiveness. 'Good' social networking (including social capital) can be effective in enhancing coping capabilities of people (Valdivia *et al.*, 2003; Lohnert, 2007) and at the same time it is considered 'good' and effective primarily if it is successful in facilitating coping and adaptation thereby strengthening security.

6.4.3.3 Constraints to Community Participation

Co-operating for a common solution is surely effective and it also holds true even in the present context of socio-structural deprivation. Field experience indicates that under the prevailing political and economic situations of insufficiency, community participation seems to be the effective instrument to alleviate the infrastructural stress condition of large number of population through united effort and effective management of water and sanitation at community level. Field survey results indicate that only about 20% of the total households surveyed was instrumental in implementing community participation for solutions to basic common problems while the remaining 80% were not attempting any sort of community participation due to various constraints.

Common constraints as reported by the respondents were lack of co-operation among the residents, time constraints, varying priority of diverse population and lack of knowledge and organisational skill to make community participation efficient and effective. Response to the question on possibility of community participation interestingly, yielded only 50% positive response. Another 50% of the surveyed households were not considering community participation to be a possible solution to their problems of basic services moreover adding that the residents were reluctant to act in a co-operating manner as it was a failed attempt in the past. While, the remaining 50% of the households differed in their opinion and considered the potentials of community participation to be a possible common solution towards self-help to strengthen their management capabilities.

External aid is needed in the line to focus on strengthening local institutions, either directly through capacity building, leadership training or injection of resources or indirectly through creating an open, democratic environment in which they flourish. This would make their operation effective, induce confidence in the membership to be fruitful and further contribute in encouraging and enhancing participation towards management of crisis at community level.

6.4.4 Institutional and Political Economy

Institutional and political economy encompass the working of organisations, both public and private that set and implement policy and legislation, look after the basic needs of the citizens, deliver services, and perform all manner of other functions that affect living, security of human health and environment and general well being of citizens. They draw their legitimacy from the basic governance framework and exist and operate at various levels with varying degrees of autonomy.

Analysis in the present context of study digs deeper into the roles and responsibilities of the concerned civic body, their accessibility by the common people and their level of sensitivity towards the prevailing problems of water and sewerage, more so for the poor communities of informal settlement quarters. Since large extent of informal settlements exists which are not having adequate infrastructure for basic amenities like water supply and wastewater disposal, it is a clear indication that the government fails to recognize the legitimate interests of the large marginalized social communities and plan adequately for large number of in-migrants.

One of the main problems faced by the disadvantaged poor in the study area was that the prevailing legalities that restricted them from benefiting out of the governmental plans e.g., lack of ration card and voter's identity card of poor in-migrants made them non eligible to avail the benefits offered by the state and thereby limits their rights. Respondent of a JJ cluster in Central Delhi convincingly expressed the need for such documents as:

> *"We should get a ration card, if there is a card then we can be eligible for resettlement to by the government"* (Open part of the household questionnaire).

Thereby lack of rights to the poor systematically restricts them and their opportunities for advancement (Yaro, 2004). In this manner management capabilities of households are conditioned by the legal and political settings of the region. Level of institutional accessibility by the community groups, responsiveness of civic agencies towards pro-poor improvements and various constrains faced by the community to help themselves influence their overall capability to face risks and manage adverse conditions.

6.4.4.1 Level of Institutional Accessibility

Level of institutional accessibility in the present context of study refers to the ease and availability of the various institutions in getting instrumental for solving the prevailing problems related to wastewater and sanitation services. Water availability is somehow looked into even unofficially by the public institutions through tanker supply to the undersupplied areas of informal status too, but due to various technical difficulties and legal hindrances the demand for wastewater and sewerage infrastructures was not negotiable compelling continuation of living in unhygienic local environment.

Residents found the local level of administration and officials concerned with dealing with the wastewater, sewerage and sanitation problem to be not easily accessible. 42% of the households could actually approach the local water and sanitation department with their problem to be fixed. This largely constituted of the households who were aware of the function and responsibility of these institutions as well as knew how to approach them. RWA proved effective in exerting pressure on these departments for fixing the day to day water and sewer problems of the colony while majority of others were poorly equipped for solution.

Thus, awareness about the services offered by the concerned institutional agencies and means to easily access them during time of stress could enhance the management capabilities of social groups.

6.4.4.2 Institutional Sensitivity

Increasing the responsiveness of various levels of organizations to the urban poor and needy is an important objective of good urban governance. The increasing infrastructural stress and inability on the part of civic body to provide minimum level of basic services to all the urban citizens is badly ailing Delhi. The perpetual existence of infrastructural inadequacies even in the present period of growing economy reflects week governance as well as the level of institutional sensitivity and eagerness to alleviate the ongoing problems.

The civic body clearly appeared to be less sensitive to the issues of deprived populations which were evident through the continued deprivation of infrastructural access and poor living condition of these social groups. Enquiring about the role and responsiveness of the local authorities in solving the wastewater and sanitation problem in the area yielded disappointing results. Higher proportions (69%) of the households, largely comprising of lower and middle income groups reported that the wastewater problems when reported to the concerned Department are not attended properly. The responsible officials and workers (*safai karmacharis)* are reluctant to act which discourages the residents to approach them again. Only about 31% of the surveyed households attested the responsiveness of the management to be good and quick in attending to the reported problems. These households were largely the privileged upper class inhabiting planned colonies of formal status.

The above discussion clearly shows the institutional insensitivity and biasness in responding to the problems pertaining to basic services to the majority of social groups primarily in the informal settlement quarters. This led to loss of trust in the civic body, consequently adversely affecting the perception of the people about their own capabilities of citizen's right to basic amenities and safe environment.

6.4.4.3 Constraints upon Self-Help

Households in the informal sectors were not privileged to be severed by all the basic amenities of acceptably safe standards by the city government. Dependence on the government to provide for water and sewer was also well justified as these involved infrastructural solution; nonetheless, it increased the pressure on the city government. Incapability of the civic body to fulfil the demand for solution of sewer and water problem has long been discussed. It is equally true that people although informally located possessed willingness and ability to make provision for themselves. But there were various constraints to self-help.

Large proportions of unauthorised areas cannot be provided with individual piped water supply and sanitation because of the problem of legality pertaining to their land ownership rights. Attempts to make any private or community provisions with respect to water, wastewater and sanitation infrastructure involved going through complex official processes. Such processes questioned their identity and legal status on paper which was a major constraint for residents of informal settlements and acted as impediment in their attempt to self-help.

A clear indication to one such constraint is evident from the response of one of the interviewee of an urban village located in the south district of Delhi.

> *"This locality is called "Bahari Delhi" (outer Delhi), approx. 95% household has water motors while rest (5%) don't have motors, only unauthorized connection of water and (too many formalities in getting water supply and sewer connection legally so people bribe / corruption start in order to get connection in an easy way); sewer must be started so somehow water logging and other water and drain problem cannot be solved, water table is almost below 800 feet, hand pump are not working either"* (Open part of the household questionnaire).

People's group like resident's welfare associations too which were 'unregistered' remained neglected in terms of official and financial support from the city government and ineffective in terms of their effort which further discouraged people to organise themselves for common action. These bureaucratic constraints to self-help, which are rooted in the political capital and determined by norms, laws and action of the state, can be removed by wilful effort from the administration. This can eventually result in easing the dependence upon the government and strengthening the capabilities of the community groups for finding effective solutions during period of crisis or threat.

6.5 Household Management Capacity Analysis

The capacity of a household to cope with wastewater exposure risks depends to a great degree on the environment of the community, and their adaptive capacity which is reflective of the economic resources, social capital and political processes of the region. Hence analysis of household capability to endure wastewater infrastructural stress incorporates a significant range of parameters in building quantitative and qualitative pictures of the underlying processes and outcomes. These relate to ideas of resilience by identifying key elements of the system that represent adaptive capacity in terms of social capital and other assets and the impact of extreme event thresholds on creating vulnerabilities within systems (Pelling and High, 2005; Adger, 2003).

Some indicators for the household income, level of education and social capital were selected from the questionnaires administered during the field survey to work out a household management capacity index so as to facilitate a comparative analysis across colony types and location. It needs to be mentioned here that all the factors discussed above were not included for indexing because not all of them were quantifiable and thereby could not be hierarchically categorised. But, nevertheless, the selected factors are expected to reflect household management capacity in a generalised manner.

Keeping in parity with the scaling of indicators done in the preceding chapter of exposure analysis, each of the selected indicators were rated on a 5-scale score ranging between 1 and 5, where a lower score indicates lower resource capacity and vice versa thereby following an inverse relationship between the score and level of household resource capacity. The Household Management Capacity Index Key constructed on the basis of some identified parameters discussed above is specific for the surveyed area (Table 6.1).

Aspects related to the level of socio-economic status, knowledge and awareness of the residents about the nature of problems and mitigation options, the level of social networking and role of social capital were the main descriptors that determined the household's management capacity. Equally important were the institutional and political factors, which further influenced community's resilience. The main aim of Household Management Capacity Index is to compare the surveyed households on the basis of their coping and management capacity that enables them to endure the wastewater exposures and sanitation related stress. The Index key so developed was further applied to the 696 surveyed household to get a composite picture of all the households status (Appendix V).

Table 6.1: Household Management Capacity Index Key

Sl. No.	Indicators \ Scores	1	2	3	4	5
1.	Income Level	Less than 2000 INR	2000-5000 INR		5000-10,000 INR	More than 10,000 INR
2.	Educational Level	No School Education	Primary	Secondary	Graduate	Post Graduate
3.	Existence of Resident Welfare Association or other Unions or Organisations	No				Yes
4.	Awareness of Responsible Authority	No				Yes
5.	Response to the Reporting	Bad				Good
6.	Possibility of Community Participation	No				Yes

Source: Own draft

Low Capacity	Moderate Capacity	High Capacity

All the indicators are assumed to have the same weight, therefore the HMCI is defined as an average aggregate of all the indicator score, which can be quantified as:

Household **M**anagement **C**apacity **I**ndex (HMCI) = $\dfrac{\text{Total Score}}{\text{Number of Indicators (6)}}$

Index value ranges between Minimum 1 to Maximum 5

1.0 – 2.3 Low Management Capacity

2.4 – 3.6 Moderate Management Capacity

3.7 – 5.0 High Management Capacity

A combination of scores were earned by individual households on the basis of their level of educational, economic and social capital which were aggregated, standardised and classed under high, medium and low resource capacity categories for making comparative analysis of 696 households easier to handle. Since the indicators here too are substitutable and thereby the same total score and index can be derived through the combination of different situations, e.g. both, a poor and a rich household can get same score by gaining or losing on other aspects like education, social networking or institutional accessibility. Therefore, it is important to be careful while interpreting the index on household basis and factors about its individual management capacity. Furthermore, the indicators considered for this indexing is relative rather than absolute, which limits its comparison with other colonies or areas.

Broadly speaking, the management capacity showed a more even distribution of households into low and medium levels with 45% and 32% of surveyed households respectively. Only 13% of the total households surveyed could be classed as possessing a high resource capacity (Table 6.2).

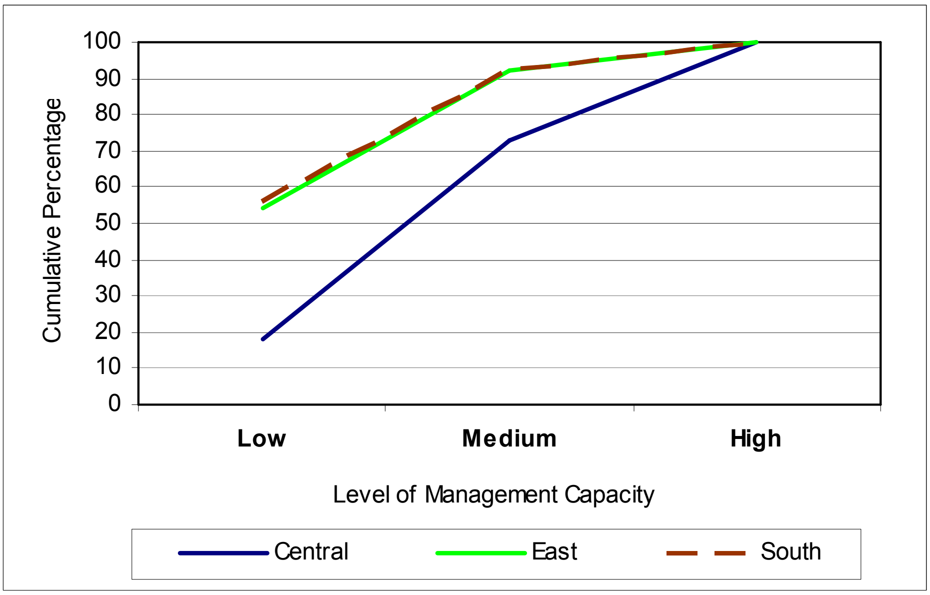
Table 6.2: Distribution of Household by Management Capacity

	Total No. of surveyed HH	**Low Resource Capacity**		**Medium Resource Capacity**		**High Resource Capacity**	
Central	207	C1 – 15	38	C1 - 46	114	C1 – 33	55
		C2 – 23		C2 - 68		C2 – 22	
East	178	E1 – 39	97	E1 – 32	67	E1 – 1	14
		E2 – 58		E2 – 35		E2 – 13	
South	311	S1 – 46	174	S1 – 21	113	S1 – 0	24
		S2 – 80		S2 – 60		S2 – 8	
		S3 – 48		S3 – 32		S3 – 16	
Total	**696**	**309 (45%)**		**294 (42%)**		**93 (13%)**	

Source: Own household survey, 2005-2006 (N = 696)

Households with good economic assets to support were not necessarily in a conducive socio-political environment which reduced their capabilities to cope with prevailing infrastructural stress and resultant exposures. Higher proportions of households in the East (54%) and South (56%) districts were having low coping and management capacity, while in the central district this figure was reduced to only 18%. On the contrary, households with high level of capabilities to cope with wastewater and sanitation infrastructural stress were highest at central district (27%) and were as low as 8% in each of East and South district. The East and South districts of the city followed a similar pattern of household distribution with more than 90% of the households in both districts clubbing in medium to low resource capacity category while this figure remained only about 73% for the central district (Fig. 6.6).

Fig. 6.6: Household Management Capacity Status



Source: Own household survey, 2005-2006 (N = 696)

Apart from the supporting economic factors, prevailing political economy, knowledge and awareness of people were helpful in contributing to the higher coping capabilities at the central district. The central status of this district earned them special aids from the local government and was helpful in keeping them always on priority of the political parties. The higher density of people living in the central district acted as potential vote bank, which facilitated their involvement in the political process of atleast exerting pressure on the higher levels of administration to solve the prevailing problem of infrastructure there. Whereas, the South and East district were lacking political involvement of the local people; they were also less informed about the processes and lacked ability to participate in a cooperative manner.

Household's management capacity is influenced to a large extent by the socio-economic and awareness level descriptors. The socio-economic characteristics explain quite directly about the reason why a person or a community is more socially vulnerable to the prevailing environmental condition. It was only with households of better educational and economic background which were better informed about the available preventive and mitigating options. Moreover, they could also build up a social capital in the form of community participation and Resident Welfare Associations, which eventually facilitated enhancing their coping capacities. Thereby, the required conducive factors for strengthening management capabilities were more or less collectively skewed towards a few socio-economically privileged households placing them under high management capacity; this was only 13% of the total surveyed households while majority of the households remained with medium to low resource capabilities to support them during the period of increased impacts of infrastructural stress. It is difficult to ascertain one particular reason for the varying degree of resource capacity by different social groups, but what emerged from the analysis confirms a combination of all the discussed factors to a large extent was responsible for determining the existing coping and management capability status of the surveyed households.

6.6 Concluding Remarks

In this procedure, the internal side of social vulnerability is expressed according to the present condition of management capabilities and social networking of the social groups (including capabilities to adopt preventive as well as post-problem responses). An important aspect which was considered is how the wastewater problem is perceived by households and how it influences their choice of responses. The selected indicators analysed display in a direct manner the reasons for defencelessness cum response of the households. They however do not show the dependence and variations according to the magnitude of the problem faced by the different households and neither are complete representative of all intricacies.

Nevertheless, the household level analysis shows that the low income households in informal settings possess low capabilities to manage the stress; even within these households the burden of water, sewerage and sanitation infrastructural stress fall especially on the womenfolk who typically end up doing most of the cleaning and wastewater managing and children who suffer most from the diseases associated with improper water supply and sanitation.

This analysis identifies options to enhance the degree of management capacity, but has been constructed for specific areas. Its application to other locations will need careful adaptations as per the need of the target population and the prevailing problems faced. There is a general assumption that economic assets would increase the resource capacity of the households. But one of the important observations of this study is that the prevailing political environment of the area is important in indirectly influencing the overall management capabilities of the social community.

It is quite clearly evident that dependence upon the city government is very high and at the same time the management organisations are not efficiently equipped to provide even the basic amenities of acceptable standards to the fast increasing city population. Arrangement of management organisations to be able to provide these basic services is often a political issue, especially if it requires changes in the distribution of power, authority, resources between different levels of government and changes in the quality of governance in terms of its responsiveness, accountability, transparency and engagement with civil society.

The social groups were marginalised and deprived with respect to basic infrastructure, and also due to lack of social capital and effective networking. The socio-structural dysfunction, over-dependence upon government and anticipation of only external aid has limited their chances of improvement and management capabilities, further contributing to their socio-structural deprivation. On the other hand, households possessing the capacity to pay for the services were unable to do so either due to the unavailability of standard service provisions by the civic authorities at certain locations within the city or due to the institutional constraints. In such a situation, services of the private providers were sorted, that added to the economic burden of the households.

Although the socio-economic attributes of households remain a supportive factor, it is not the only requirement for strengthening management capabilities. Households though possessing economic security but lacking knowledge and awareness about the ways and means of solution to their wastewater and sanitation related problems remained socially vulnerable to the prevailing infrastructural stress. Ignorance and lack of any clear direction regarding responsible authorities and ways of getting the problems (ones beyond household capacity to solve) reported and solved by the right Department was a hindrance too.

Having analysed the varying degree of exposures and levels of management capabilities to cope with the prevailing wastewater and sanitation problems at various settlement locations, we now move on to learn more about the implications which the wastewater and sanitation infrastructural stress have on the environment and public health securities and how far the households at the prevailing exposure levels, with their own level of risk perception and with the given resources at their disposal are able to adapt preventive measures or cope with the faced wastewater and sanitation problems at their households and immediate neighbourhood.

Chapter 7

Implications of Wastewater Problems on Environment and Public Health in Delhi

7.1 Introduction

Urban areas are not only concentrations of people and enterprises but also concentrations of their wastes; in domestic sector human excreta and raw sewage are particularly dangerous. But in many urban areas basic services of sewerage and sanitation are either non-existent or difficult to access. If existent, many times it does not fulfill its primary task of ensuring safe water supply and disposal of wastewater due to various reasons like ageing and poor maintenance. The influences of these water and sewerage inadequacies are finally reflected as health burden and other allied costs to people in terms of time and effort involved for managing their own wastes and protecting themselves against hazardous exposures.

World Health Organization has recognized that lacking and inadequate basic infrastructure and services make urban areas the world's most threatening human environments. Many diseases are associated with inadequate disposal of wastewater, including a group of diseases for which water or wastewater provides a habitat for disease vectors or host (UN-Habitat, 2003). Proper hygiene and sanitation can reduce the incidence of infectious diseases by 20% to 80% by inhibiting disease generation and interrupting disease transmission (WHO, 1998).

This chapter explains the wastewater and sanitation threats to environmental and public health in Delhi. In particular, it discusses the implications of wastewater and sewerage inadequacies in the form of water quality degradation and other harmful influences on environment and public health. It further explores who is most affected and in what way? Finally, it presents a health profile of the study area and tries to analyse exposure-morbidity relationship aiming to understand the extent of influence wastewater exposure has on prevailing health hazards.

7.2 Underlying Causes for Wastewater and Sanitation Inadequacies

Delhi has been expanding in a haphazard manner: planning has not been very successful for the city; frequent violation of developmental norms has left large areas still poor and unserviced by basic amenities. Continued population growth, immigration and scarcity of suitable habitation compel people to settle in unfavourable areas and unresponsive utilities combine to create wastewater disposal and sanitation deficiencies.

Moreover, conventional way of piped supply and sewers are neither affordable to poor communities nor easily accessible without high government subsidies and support. Thereby, lack of access to safe water supply and sewerage can be indirectly related to poor governance reflected through inability of the government to invest in water system and sanitation improvement.

Common explanation for the wastewater and sanitation infrastructural inadequacies in Delhi is very rapid population growth, which overwhelms the capacity of local authority to improve and extend provision. But many rapidly growing cities in Latin America and Europe have nonetheless managed to develop the institutions to improve water and sanitation provision, in part because it is easier to do so with an expanding economy and also with efficiency in management system (UN-Habitat, 2003).

When the city economy is developing at a good rate (12.6%), higher than the national economic growth (GNCTD, 2006), it should be rather easy to expand the basic infrastructure facilities and maintain them in good shape. But rapid population growth, planning lacunas and various administrative and governance problems act as hindrances in equal infrastructural access. The responsibilities and mandates between various concerning Departments and managing bodies are fragmented and unclear. Mismatching of planning and administrative zones, water and sewerage zones also hinder development and pose institutional and managerial problems, further accentuating the inadequacies in provision and maintenance of basic services for all.

Realizing the need for urban sector development, the Union Government launched the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) in December 2005 aiming at developing and expanding physical infrastructure, attaching high priority to its access by urban poor. Cities depend on the central government for provision of such special funds for infrastructural and other developments. But these are very limited and, therefore, not all cities can avail of it.

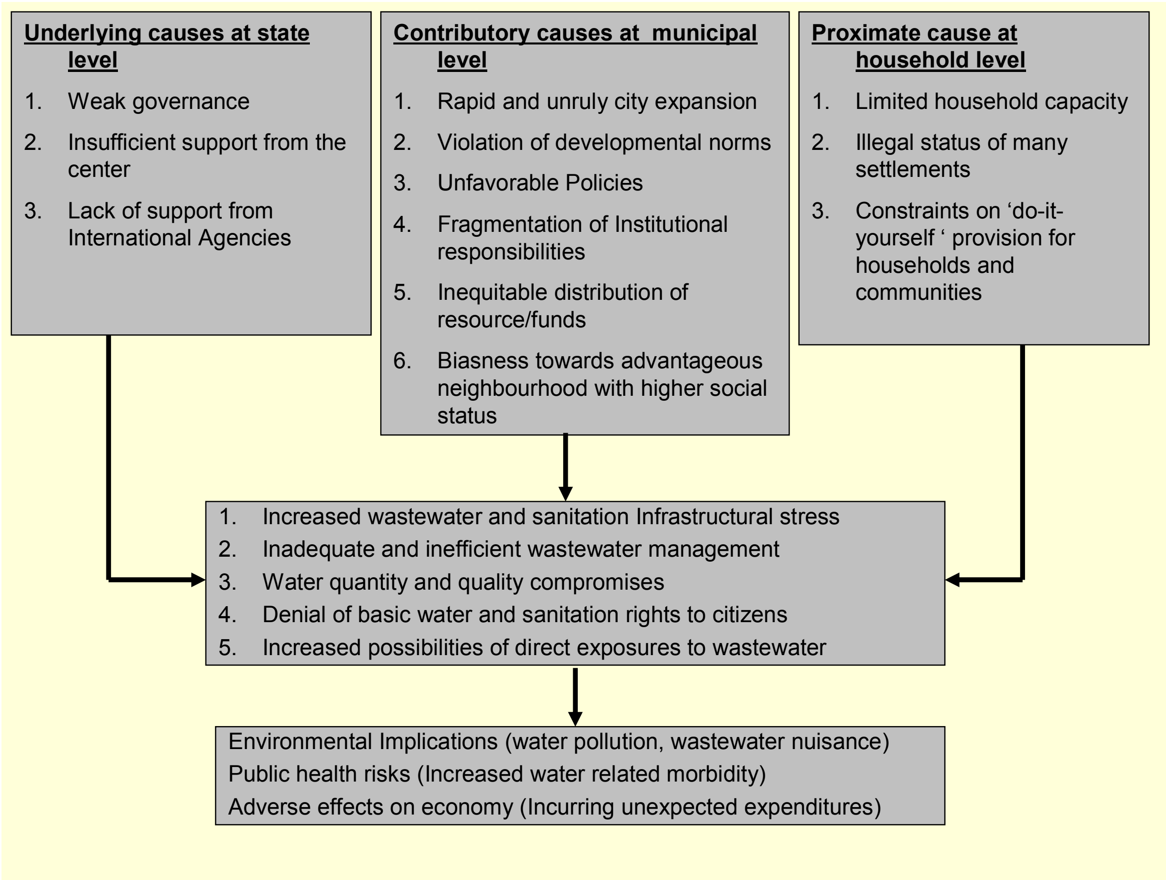
Delhi as the capital of India does enjoy a better position with respect to fund allocation for infrastructural development by the central government, but in reality much percolation of such developmental funds is seen or rather it is not sufficient to cope with the increasing infrastructural demands. There is also lack of international funding for investment in water and sanitation in urban areas. International funds are primarily channeled to selected section of the world and mostly to rural area development while the urban centres are not attractive for investment into wastewater and sanitation infrastructure by international agencies (UN-Habitat, 2003).

Status of the settlements has considerable importance for water and sanitation provision too. Present policies do not outline any scope for provisions of sewers in illegal settlement quarters. Large proportion of unauthorised areas cannot be provided with legal sanitation because the municipal provides individual sanitation connection only where households can provide proof of ownership of property and a receipt for payment of property tax. Further problems in networking the unsewered areas are the distance between informal settlements and existing sewer networks and high costs of new connecting construction (Comptroller and Auditor General of India, 2004).

High degree of biasness exists in grants of developmental funds giving rise to inequitable infrastructural provision and maintenance depending upon the legal and social status of the locality (Kundu, 1993; Comptroller and Auditor General of India, 2004). In disadvantaged informal residential setting, deficiency of sanitation and wastewater disposal infrastructure provision by the civic bodies leave households and communities in an almost ‘do-it-yourself’ situation, which is highly constrained by various economic and political issues. Moreover, poor households with limited resources cannot avail of private arrangements for sewers. Additionally, their participation in the political processes is less and consequently political leaders of the area may be ignorant about their local problems or only highlighting the problems on their agendas during the time of elections.

A range of causes for inadequacies in provision of wastewater and sanitation infrastructure exits at various levels of organization: the proximate causes that act in the settlement itself, i.e., at household level, the contributory causes that act at municipal level and the underlying causes acting at the state level (Fig. 7.1).

Fig. 7.1: Causes and Implications of Inadequate Water System in Urban Areas



Source: Own draft adapted from UN-Habitat, 2003

Increasingly inadequate sanitation and water systems have polluted the environmental resource base, contaminated surface and ground water, while diseases like gastroenteritis, dysentery, diarrhea and malaria are occurring frequently and showing devastating impacts on public health (Chute, Smith and Baron, 1987; Chambers *et al*., 1989; Georges-Courbot *et al*., 1990). Thereby, coupled with the inadequacies relating to the provision and management of sewerage and sanitation are the problems pertaining to adoption and implementation of standards for safe disposal of wastewater in order to safeguard the receiving water bodies so as to secure quality of water supply in future.

7.3 Standards for Safe Potable Water Supply and Effluent Discharges

The impact of the discharges of urban wastewater into rivers, lakes, estuaries and other water bodies has always been a matter of great concern. An important point in these circumstances is the establishment of an adequate legislation for the protection of the resource base, environment and development of public health (Von Sperling and de Lemos Chernicharo, 2002). This is commonly done by setting up and implementing standards for safe potable water supply and wastewater discharges.

With the objective to safeguard water from degradation and to establish a basis for improvement in water quality, certain standards have been laid down by various agencies in different countries. But there always remain problems related to conversion and adaptation of standards and numeric values of general guidelines set by international agencies like WHO and the World Bank to those set by these agencies in individual country (Johnstone and Horan, 1994, 1996; Von Sperling and de Lemos Chernicharo, 2002).

In India drinking water falls under the purview of Union Ministry of Urban Development and Poverty Alleviation (MoUDPA). The Central Public Health and Environmental Engineering Organization (CPHEEO) under this Ministry set guidelines for drinking water quality. Local bodies such as municipalities and public health engineering Departments in urban areas are expected to follow these guidelines. But water is a state subject. The role of MoUDPA is therefore merely recommendatory in nature. It is the state government that must adopt standards and enforce them (CSE, 2003).

CPHEEO (1999) has recommended drinking water quality standards in its *Manual on Water Supply and Treatment.* The prescribed standards exist in two forms, or criteria: 'acceptable' and 'cause for rejection' (Table 7.1). Notably all the standards for safe water supply and effluent discharges presently existing are mere recommendations and not legal enforcement.

Table 7.1: Range of Various Parameters in Drinking Water Guidelines

Parameters	Bureau of Indian Standards (IS:10500:1991)[1]		Central Public Health and Environmental Engineering Organization (CHPEEO)[2]		
	Requirement (Desirable limit)	Undesirable effects outside the desirable limits	Acceptable	Cause of rejection	Range between guidelines
Total Hardness (as $CaCO_3$)	300	Encrustation in water supply structure and adverse effect on domestic use. Extendable to 600 in the absence of alternate source	200	600	3 times
Chlorides (as Cl), mg/l, Max.	250	Beyond this limit, taste and appearance are affected. Extendable to 1000 in absence of alternate source	200	1000	5 times
Total dissolved solids, mg/l, Max.	500	Beyond this, palatability may cause gastro-intestinal irritation. Extendable to 2000 in absence of alternate source	500	2000	4 times
Copper (as Cu), mg/l, Max.	0.05	Astringent taste, discoloration and corrosion of pipes and fittings will be caused beyond this. Extendable to 1.5 in the absence of alternate source	0.05	1.5	30 times
Manganese (as Mn), mg/l, Max.	0.1	Beyond this limit taste/appearance are affected. Have adverse effects on domestic use and water supply structures. Extended to 0.3 in absence of alternate source	0.05	0.5	10 times
Arsenic (as As), mg/l, Max.	0.05	Beyond this the water becomes toxic. No relaxation is allowed	0.01	0.05	5 times
Zinc (as Zn), mg/l, Max.	5	Beyond this limit, it can cause astringent taste and opalescence in water. Extended to 15 in the absence of alternate source	5.0	15.0	3 times
Anionic detergents (as MBAS), mg/l, Max.	0.2	Beyond this limit, it can cause a light froth in water. Extended to 1 in the absence of alternate source	0.2	1.0	5 times
Aluminium (as Al), mg/l, Max.	0.03	Cumulative effect is reported to cause dementia. Extended to 0.2 in the absence of alternate source	0.03	0.2	6.7 times
Source: 1. Bureau of Indian Standards, 1991 2. Ministry of Urban Development, 1999: 14-15					

Source: CSE, 2003

'Acceptable' defines the limits up to which water is generally acceptable to the consumers. 'Cause for rejection' means there are substances in the water in excess of the limit defined as 'acceptable', thus rendering the water not acceptable. Still, the water may be tolerated in the absence of an alternative and better source. The standards assume no responsibility on the part of the provider to provide 'clean' water; thus water not matching one set of standards may be easily passed off as 'tolerable' but only up to the limits set for this criterion. Above this, water source has to be rejected.

Similar is the case with the effluents discharged into the river. Against an estimated 3267 million liter per day (MLD) of total sewage generation in Delhi, installed treatment capacity is 2330 MLD (71%). However, owing to 63% utilization of the installed treatment capacity, only 45% of total sewage is being treated. The remaining joins the river untreated. The effluent discharges are indeed not even meeting the required standards. The influent and effluent quality of composite samples with respect to pH, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) is presented in Table 7.2.

It is revealed from the table that after treatment the pollution load in terms of TSS, COD and BOD at all the STPs is reduced by 92%, 81% & 87% respectively (CPCB, 2006). The standard of effluent being discharged from the sewage treatment plants as prescribed by CPCB is of 20 mg/l for BOD, 100 mg/l for COD and 30 mg/l for TSS. But in most cases this standard is not met before discharging the effluent out. Additionally, there is no prescribed and legally binding standard for reducing the total suspended solids and faecal coliform in outgoing effluents.

According to a study conducted by the Central Pollution Control Board (CPCB), the level of total coliform upstream of Delhi is twice the standard value already; after it passes through Delhi, the pollution level goes up 24 times – the maximum allowable limit after treatment (CPCB, 1999b). Since the procedure to remove them is difficult and expensive, consistently high level of pollution in the river has totally disturbed the marine eco-system; most of the exotic fish are already extinct and most fish depending on fauna are no more seen in Yamuna (Kumar, 2002).

Table 7.2: Influent and Effluent Quality of Wastewater in Sewage Treatment Plants in Delhi: (Nov-Dec 2006)

Sl. No.	Name of the STP	Designed Capacity (Mld)	Actual Flow (Mld)	Performance Evaluation of Sewage Treatment Plants (24 hrs composite sampling of three hourly samples) All values are in mg/l except pH							
				Influent Quality				Effluent Quality			
				pH	TSS	COD	BOD	pH	TSS	COD	BOD
1	Cor. Pillar (I)	45.46	40.87	7.2	179	317	112	7.4	35	61	18
2	Cor. Pillar (II)	136.38	120.01	6.44	342	172	48	6.9	93	48	15
3	Keshopur (I)	54.55	46.55	-	-	-	-	-	-	-	-
4	Keshopur (II)	90.92	95.1	7.3	404	404	282	7.6	78	149	45
5	Keshopur (III)	181.84	106.46	7.3	404	404	282	7.8	21	55	10
6	Okhla (I)	54.55	39.09	7.3	498	498	204	7.8	21	54	10
7	Okhla (II)	72.73	40.91	7.4	291	291	207	7.7	83	108	48
8	Okhla (III)	136.38	136.98	7.4	647	647	222	7.6	76	153	45
9	Okhla (IV)	168.2	159.11	7.3	480	480	249	7.8	32	62	12
10	Okhla (V)	204.57	181.84	7.3	480	480	249	7.7	27	51	19
11	Narela	45.46	2.5	7.4	426	426	100	8	38	72	8
12	Y.Vihar (I)	45.46	27.27	7.1	391	391	174	7.7	44	84	17
13	Y.Vihar (II)	45.46	14.77	7.2	405	405	199	7.5	39	44	20
14	Timarpur	27.27	4.79	6.7	412	412	106	7.3	11	26	4
15	Najafgarh	22.73	2.27	7.4	165	165	54	7.7	29	38	1
16	Niloti	181.84	15.0	7.7	432	432	90	7.8	21	26	4
17	Dr. Sen.N.H	10.00	10.00	7.5	370	370	236	7.4	36	46	16
18	Delhi Gate	10.00	10.00	7.5	263	263	147	7.3	26	62	20
19	Papankalan	90.92	37.73	7.6	142	142	103	7.9	39	46	10
20	Kondli (1)	45.46	56.55	7.3	363	363	241	7.8	68	140	27
21	Kondli (II)	113.65	57.96	7.3	604	604	261	7.6	45	50	34
22	Kondli (III)	45.46	28.36	7.3	519	519	237	7.8	16	50	14
23	Mehrauli	22.73	4.95	7.8	251	251	126	8.1	12	35	7
24	Rithala (old)	181.84	46.28	7.2	330	330	205	7.5	75	54	14
25	Rithala (new)	181.84	185.07	7.2	330	330	205	7.3	47	151	55
26	Vasant kunj I	10.00	3.18	7.5	379	379	323	7.8	23	43	7
27	Vasant Kunj II	13.63	4.36	7.4	479	479	306	7.9	49	80	20
28	Rohini	68.19	Nil	-	-	-	-	-	-	-	-
29	Ghitorni	22.73	Nil	-	-	-	-	-	-	-	-

Source: CPCB, 2006: 6 of 11

Total Suspended Solids (TSS)
Chemical Oxygen Demand (COD)
Biological Oxygen Demand (BOD)

The above information indicates that broadly the set standard is not met by most of the Sewage Treatment Plants owing to various technical and economic hindrances. On the basis of interview with the engineers of sewerage treatment plants in Delhi and by looking at the informations provided in the civil reports by Comptroller and Auditor

General of India on Delhi infrastructure (particularly water and sewerage)[16] of the last three to four years, as well as the Central Pollution Control Board (2004) sewerage report on Delhi, various reasons for the improper management of wastewater that can be concluded are outlined below:

- Under-utilized treatment capacity of the Sewage Treatment Plants (STPs).
- Lack of adequate sewerage system in the catchments area of the STPs.
- Massive silting of the existing sewer lines.
- Large extent of unsewered areas; wastewater from all un-sewered areas finally discharges into open drains.
- The operation and maintenance of interception of sewage from sewer lines and pumping stations is the weakest part in sewage management in Delhi.
- The operation and management staff of the sewage treatment plants are not professionally qualified and trained.
- Unfavorable locations of the sewage treatment plants (The treatment plants should ideally be located near the sewage generating areas to avoid long transportation involving high construction cost and regular maintenance).
- Lack of efficient machineries and equipped laboratory facilities at the STPs.
- Absence of legal enforcement for prescribed/recommended quality standards.
- Improper monitoring and lack of accountability.

Consequently, the influences of such inadequacies and wastewater mismanagement are reflected on the environment and inhabiting social communities as health burdens and other allied costs in terms of time and effort involved for managing their own water needs and waste disposal and protecting themselves against hazardous environmental exposures. In the present study implication of inadequate sewerage facilities and

[16] http://www.cag.gov.in/html/cag_reports/delhi/rep_2004/civil_overview.pdf
http://www.cag.gov.in/html/cag_reports/delhi/rep_2004/civilvolII_yamu_rev.pdf
http://www.cag.gov.in/html/cag_reports/delhi/rep_2004/civil_ch4.pdf
http://www.cag.gov.in/html/cag_reports/delhi/rep_2005/civilvolII_chapter_2.pdf
http://www.cag.gov.in/html/cag_reports/delhi/rep_2006/chap4.pdf
http://www.cag.gov.in/html/cag_reports/delhi/rep_2007/vol_2_chap3.pdf
(All last accessed on 21.07.2008)

sanitation inadequacies are analysed as potential risks to the environment, public health and household economy in terms of:

1. Water pollution (water quality problem)
2. Air pollution (fowl odour)
3. Aesthetic degradation (eyesore)
4. Kind of health problems reported (illnesses/diseases)
5. Number of reported cases (morbidity)
6. Burden of additional expenditure on household

7.4 Water and Sanitation Risk to Environment and Public Health

Risk in human terms is "a situation in which human values (including human themselves) are at stake and where the outcome is uncertain" (Jaeger *et al*., 2001: 17). Today many risks are eco-centric i.e. they are linked to environmental problems or related to environmental conditions (Jaeger *et al*., 2001: 9). "…to be at risk is to be under threat of harm" (Pelling, 2003: 5) by unfavourable consequences. Improper management of wastewater creates hazardous conditions, water pollution and environmental degradation, exposure to which is regarded as a matter of risk that threatens the ecosystem and human health security.

Human immediate neighbourhood and his behaviour in the surrounding influence the health of individual residents in different ways: via the social and physical environmental stress, neighbourhood networks and norms, as well as through facilities and services available (Ellaway and Macintyre, 1998; Campbell, Wood and Kelly, 1999; Ellen, Mijanovich and Dillman, 2001; Parkes and Kearns, 2006). There exists considerable variation within infrastructural resources shaping neighbourhood services, social beliefs as well as the social practices prevalent there, which all directly or indirectly influences health in the area (Macintyre, Ellaway and Cummins, 2002).

Geographic inequalities of infrastructural provision and basic services too show its effects on environmental and public health. Even if the water and sanitation services are not officially provided by state, under whose jurisdiction one is residing, still everybody alive somehow obtains drinking water and also disposes off their wastewater (Solo, 1999). Though, not in environmentally safe and hygienic manner this may backfire in terms of serious environmental and public health implications. In this context health is influenced through stress produced by the physical socio-political and environmental influences and through neighbourhood networks and norms (Ellen, Mijanovich and Dillman, 2001).

The public health gains and household security are derived from provisions of qualitatively safe and quantitatively sufficient volumes of water and access of adequate sewerage to all. Further health improvements may also occur at higher levels of service, associated with drinking water quality control and improved sanitation at the household level. Where the basic access service level has not been achieved, hygiene cannot be assured and health may be at risk. Therefore, providing a basic level of access is the highest priority for the water, sanitation and health sectors (Howard and Bartram, 2003).

In the present case study of Delhi mismanagement of domestic wastewater is the main cause for surface and ground water pollution, which further reduces the availability of usable water for future supply. Freshwater lines, which often run close to drains, are contaminated by the intake of wastewater into the freshwater system due to frequent change in pressure and pipe leakages. Inadequate wastewater management has polluted the resource base, degraded environmental aesthetic and negatively impacted quality of life, while water-borne and water-related diseases like dysentery, diarrhea, typhoid, dengue and malaria are occurring frequently and showing devastating impacts on public health.

Improper management of wastewater also involved considerable economic risks in terms of increased household expenditure for treating the water-borne and water-related diseases, loss of work days and expenses involved in managing their own wastes privately. Such expenditures which could be largely avoidable add to the impoverishment of already poor community. In this respect various kind environmental, health and economic risks exist cumulatively (Table 7.3).

Table 7.3: Risks Associated with Inadequate Management of Wastewater[17]

Type of risks	Description
Environmental Risk	▪ Pollution of ground water through unlined drains. ▪ Septic tanks contribute high rates of pollutant infiltration. ▪ Open drains are source of bad odor and air pollution. ▪ Unmanaged wastewater accumulating in pot holes and muddy pits serve as breeding grounds for disease carrying vectors. ▪ Unhygienic sights and degradation of environmental aesthetic.
Health Risk	▪ Drinking water supplies gets contaminated with harmful chemicals and pathogens from wastewater as a result of contamination. ▪ Illnesses that are contracted from consumption of contaminated water include Cholera, Typhoid, Gastroenteritis, Dysentery and Diarrhea. A significant risk of illness like ear, eye and skin infections exists if people come into physical contact with raw sewage. ▪ Stagnant wastewater creates conducive habitats for disease vectors making the region infested with illnesses like malaria and dengue. ▪ Open drains and uncovered manholes are death traps for people especially children, who fall into it and die of suffocation if not rescued on time.
Economic Risk	▪ Expansion of infrastructure and rehabilitation and maintenance of the existing ones involves considerable funding. ▪ Increased expenditure of family income on treatment of member suffering from water borne or water related diseases. ▪ Additional economic expenditure on hiring private cleaners for desilting and cleaning of local drains.

Source: Own draft after Smith *et al.*, 2002

The level of basic water and sanitation services provided has a direct influence on urban health. Apart from improved hygiene behaviour, public health gains and security is derived from use of increased volumes of water and provision of sewerage and sanitation, which typically occur by overcoming lack of basic access, increased sanitation and sewer coverage and largely when sewerage and sanitation is available at household level. Further incremental improvements may also occur at higher levels of service, associated

[17] This table is reproduced from Singh (2008): Wastewater Related Risks and Social Vulnerability: A Case Study of Delhi. In: Bohle, H.G and Warner, K (eds) Megacities: resilience and social vulnerability. SOURCE 10/2008, publication series of UNU-EHS, Bonn, pp. 125.

with household sanitation facility and drinking water quality control which can also be linked to improved socio-economic status, better social capital and good city governance.

Health is significantly compromised at lower levels of these basic water and sewerage services. There exists an inverse relation between the levels of sewerage and sanitation services and level of health risks (Table 7.4).

Table 7.4: Levels of Sewerage and Health Risks

Sewerage access	**Means of access**	**Frequency of wastewater exposure**	**Health risk**
No access (No sewer or drain provided).	Wastewater disposing into ditches, yards and open spaces. Use of public toilet or take to open defecation.	Always (unavoidable)	Very High
Insufficient access (illegal connection made to the waterways or to the nearby open drain)	Wastewater disposed into the open gutter. Manually dug ditches or tanks for onsite disposal of wastewater and sanitation. Lacks regular cleaning.	Most of the time	High
Basic access (Open drains for surface drainage provided).	Open drains and channels for wastewater removal. Shared toilets. Surface drains and channels are cleaned on daily basis.	Occasionally/Seasonally (when the main sewer lines are blocked or during monsoon due to additional load of wastewater)	Moderate
Optimal access (Covered drains, underground sewers provided).	Piped outlet for wastewater. Toilet facility provided in household.	Rarely	Low

Source: Own draft

With optimal level of sewerage and sanitation services where piped outlet of wastewater and toilet facility exists in the household, health risks was observed to be low due to least chances of wastewater exposure. When the level of access is insufficient i.e., only to the very basic ones and no proper maintenance is done, exposure to wastewater takes place most of the time and thus keeps the community at high health risks. Even basic access to sewerage and sanitation facilities with regular maintenance reduces the chances of wastewater exposure (exposure taking place occasionally when the sewer lines are blocked or during monsoon when the wastewater loads is increased); it consequently reduces the health risk to moderate level. Low health risk is only attained at optimal access to sewerage and sanitation facilities in households.

Estimates of present level of sewer coverage and sanitation services in different surveyed colonies establishes that the level of health concern is very high in JJ clusters, high in unauthorised colonies and moderate in resettlement colonies and urban villages. It reduces to low only in the authorised planned residential areas where the service level of water as well as sewerage and sanitation is optimal. Thereby, evidence from the field study suggest that provision of environmental health services are highly skewed towards authorised colonies and high income residential areas whereas the poor neighbourhood is more exposed to negative implications of wastewater.

It therefore seems imperative to understand how wastewater implications affect various communities inhabiting different colonies. Thus, it is attempted to study influences of wastewater on environment at city and household levels and examine the adverse impacts on the health of exposed households without aiming to establish causal linkages between the factors and any particular disease. Subsequently, in the succeeding sections environmental, health and economic implications of wastewater are explored and further supported by field experiences and survey results.

7.5 Environmental Implications of Wastewater

In the earlier section of the thesis it has been well established that sewerage has lagged far behind water supply. Wastewater disposal and sewerage system in large part of the city is overloaded or defunct. Badly managed sewers have become a serious environmental and health hazard. The pathways to environmental degradation due to wastewater nuisance are varied having far-reaching effects like water quality problem, unhygienic site, prevalence of fowl odour, mosquitoes, flies and rodents due to the inadequate management of sewage and solid wastes contributing immensely to loss of environmental aesthetic, degrading the living environment and in turn showing its implications with varying severity on the health and general quality of life of different social groups.

7.5.1 Pollution of Freshwater Sources

Domestic as well as commercial activities taking place within the residential areas result in large amount of wastewater loaded with contaminants like salts, nutrients, organics, micro-organisms, soaps, detergents and other chemicals to flow as sullage to other water bodies through storm drains and sewer channels with or without receiving sufficient prior treatment. Additional bulk remains on land to percolate, leach or get washed off to streams or groundwater. Even in case wastewater is primarily treated, the resulting effluent still contains bacteria and chemicals that will contaminate the environment and may contaminate other freshwater sources. (Smith *et al*., 2002; Lee, 1993; LaGro, 1996).

Surface water pollution because of sewage outfalls, groundwater contamination due to sewage percolation and via unlined drains, contamination of piped water supply systems because of leaky sewer lines leading to infiltration of pathogens into drinking water pipelines are all means of wastewater contaminating freshwater sources. Chemical pollutants can leach into groundwater from variety of sources in including irrigation, septic tanks, sewage, injection wells, solid waste disposal and accumulation of industrial wastewater on land.

The river Yamuna, apart from being the main source of raw water for the city also carries away wastewater from the city including sewered as well as unsewered areas. Untapped as well as insufficiently treated sewerage joining the river Yamuna led to higher quantity of ammonia in the water which was declared to be beyond treatable limits (Times News Network, 2007). Since the river forms drinking water source for downstream population, the water quality criteria of the river needs to be maintained at high priority. But the extent of environmental imbalance is so severe that the water quality of Yamuna that should ideally be fit for bathing, swimming and recreation actually is unfit even for agricultural purpose[18] (SulabhEnvis, 2003).

[18] Central Pollution Control Board has recommends 6 classes of water (as A, B, C, D and E) suited for various uses (Appendix VI). The water quality of Yamuna River that should ideally lie in the category 'B' actually falls under category 'E'.

In Delhi, sewer lines overflow most of the time due to numerous reasons discussed earlier in Chapter 3. According to the field survey about 55-89 % of the households, depending on different colony types, complained of seasonal or permanent water logging due to overflowing sewage drains. In such situation sewer leakages into the freshwater pipes and groundwater contamination due to seepages and infiltration of the stagnant sewage or through unlined drains and tanks are simply unavoidable. Observation during field survey brought to notice various compulsive practices at community level which pave the way for sewage contaminants to pollute groundwater e.g. collection of domestic wastewater in ditches and tanks in the absence of sewer disposal structure (Fig. 7.2). Moreover, practices like open washing and defecation around sources of drinking water all lead to high risk of unsafe water supply.

Yet another type of sewage pollution occurred through open and unlined drains, pollutants from these drains seeped down to contaminate the ground water, which is extensively pumped up by the households for various domestic purposes. Additionally, stagnant wastewater around water taps and close alignment of freshwater pipelines and wastewater drains and channels contribute towards intake of contaminated wastewater into the freshwater system. Moreover, frequent changes in water pressure within the supply network further enhance sewage backflow and further mixing wastewater with the fresh water resulting in contaminated water supply for end users.

Since the ground water quality in various parts of the city is precarious residents were continuously warned by the Delhi Jal Board (DJB) not to consume groundwater by painting the hand pumps red in areas where the water authority had diagnosed the water to be of unsafe quality.

Fig. 7.2: Means of Water Pollution by Raw Sewage

Sewage contamination of ground water

Domestic wastewater is collected in a ditch or diverted to a covered tank which is emptied manually when filled up. These serve as open unlined wastewater disposal point onsite. The bacterial leachates and other contaminates easily percolates down to contaminate the groundwater. These are also source for fowl odour, mosquitoes and flies.

The unlined bed, porous subsurface under the open drains provide continuous area for sewage pollutants to infiltrate down to the ground water level.

Sewage mixing with piped water supply

Freshwater pipelines often running close to wastewater drains and channels are affected by the intake of contaminated wastewater into the freshwater system due to frequent change in pressure and over pumping causing numerous leakages and further mixing wastewater with the fresh water resulting in contaminated water supply to the end users.

Source: Own photos

7.5.2 Groundwater Status in the Study Area

The groundwater availability is controlled by hydro-geological conditions. In Delhi it is characterized by occurrence of alluvial formations and quartzite hard rocks. The hydro-geological set-up and the distinct physiographic units which further influence the ground water occurrence are older alluvial plain on the eastern and western side of the ridge, Yamuna Flood Plain deposits, isolated and nearly closed Chattarpur alluvial basin and the NNE-SSW trending quartzite ridge, which serves as the watershed. Shallow aquifers occur in weathered part and deep aquifers are found in the fractured joints of these rocks (Augustin, 2006).

The groundwater is fresh at all depths in the areas around the ridge in the Central, New Delhi, South and Southwest districts and also Chattarpur basin. In the areas west of the ridge, groundwater is generally brackish with freshwater existing down to 25-30 mts only. In the flood plains of Yamuna, in general, freshwater aquifers exist down to 30-45 mts. But during the last years there has been tremendous depletion and deterioration of groundwater resources due to over-exploitation and pollution by unsafe human activities. The pollutants which percolate down get trapped in the aquifer; they further tend to form plumes of polluted water and move in accordance to the hydraulic gradient. The size of the pores, their relative permeability and the character of the pollutant present determine the rate of infiltration. In this respect the area with sandy soil would be more vulnerable to the percolating contaminants (CPCB, 2003).

Pollution by disease-causing pathogens occurs when human and animal waste containing virus, bacteria and parasites come into contact with groundwater. Moreover, in most cases where groundwater is observed polluted, the area is densely populated and wastewater and sanitation infrastructure is alarmingly inadequate which further adds to the potential risk of sewerage pollution. Numerous studies attest and quantify the risks involved in the failure to recognize the close interrelation of sewerage and groundwater management (Chadha, Kirk and Watkins, 1997; Misstear and Bishop, 1997; Eiswirth and Hotzl, 1997). However, this awareness has not been widely incorporated into practice (Pokrajac, 1999). Like in the sewage pollution of surface water, chances of bacterial, fungal and viral contamination of groundwater due to raw sewage and human wastewater is more too, but due to lack of data this cannot be adequately ascertained which leaves enormous scope for further investigating the influence of sewage pathogen on wastewater.

A general groundwater quality assessment was done for the test locations in and around the surveyed areas. All the surveyed test sites fall in three blocks of Delhi namely, City Block including test sites of Central district and some of South district, Mehrauli Block covering surveyed localities of South Delhi and Shahdara Block encompassing localities of East district or Trans-Yamuna region. The present analysis of groundwater quality is completely dependent upon the data from secondary sources primarily provided by the Central Pollution Control Board for Delhi. Relevant sample points for the surveyed areas were selected and analysed for some physio-chemical parameters. These parameters were evaluated on the basis of the drinking water standards as prescribed by the Bureau of Indian Standards (BIS). The recorded values for various chemicals presents in the groundwater at these selected locations were compared against the desirable limits as recommended by BIS. A summary result of this analysis is presented in Table 7.5.

The values of the below analysed parameters clearly indicate the following:

- Groundwater quality in and around these test sites are having pollutants above the desirable level for usage.
- Total dissolved solids (TDS) and total hardness in form of $CaCO_3$ is high at almost all the sample locations.
- The pH value is also mostly towards the higher scale.
- Concentration of total hardness, suspended solid, calcium and magnesium are beyond the desirable limits in all the three blocks.
- In the City Block concentration of nitrate is almost double the desirable limit and the fluoride concentration is 2.8 mg/l which exceeds the WHO norm of 1.5 mg/l.

Table 7.5: Water Quality at Sample Locations in and around Surveyed Test Sites

	DESIRABLE LIMITS (mg/l)				6.5 – 8.5	500	250	200	45	1.0	75	30	300
Test Area	**Sample location within Test Sites**	**Block**	**Source**	**Depth**	**pH**	**TDS**	**Cl**	**SO4**	**NO3**	**F**	**Ca**	**Mg**	**CaCO3**
South	Tuglakabad	Mehrauli Block	HP	40	7.91	566	118	40	9	0.51	83	13	260
South	Kanpur	Mehrauli Block	HP	60	8.06	490	42	10	29	0.51	65	9.6	201
South	Dakhinpuri	Mehrauli Block	HP	40	7.41	800	240	32	59	0.39	134	40	500
South	Hamdard Nagar	Mehrauli Block	HP	30	8.04	846	226	60	95	0.53	149	29	490
South	Moti Bagh Colony	City Block	HP	13	7.62	735	134	87	41	2.11	65	46	354
South	Greater Kailash	City Block	HP	20	7.68	725	120	48	35	0.51	104	22	350
South	Kalkaji Extension	City Block	TW	70	7.62	680	170	121	62	1.2	88	28	335
Central	Old Delhi	City Block	DW	4	7.6	660	92	75	79	1.29	86	53	433
Central	Abdul Fazal	City Block	HP	10	7.3	570	42	55	2.3	0.39	98	49	445
Central	Ashram	City Block	HP	25	7.26	1270	222	290	74	2.3	106	106	700
Central	Jalsadan	City Block	DTW	100	8.15	165	11	39	3.5	0.41	37	7.9	126
East	Okhla	City Block	HP	10	7.46	768	59	60	3.9	1.2	24	88	420
East	Okhla Ind. Phase-I	City Block	HP	63	7.39	1105	300	97	110	0.9	132	45	515
East	Trilokpuri-1	Shahdara Block	TW	50	7.55	678	93	180	1.16	0.9	80	24	300
East	Kalyanpuri	Shahdara Block	HP	40	7.3	1408	580	166	1.22	0.7	184	53	68
East	Trilokpuri-2	Shahdara Block	HP	12	7.32	957	186	216	33	0.48	132	32	460
East	Ashok Nagar	Shahdara Block	HP	12	7.57	508	46	110	3	0.5	96	12	290
Average for the entire Block in which the test areas are located													
Mehrauli Block (South Delhi)					7.72	762	123	81	78	0.72	84	36	350
City Block (Central Delhi)					7.65	1098	223	161	88	2.83	93	59	421
Shahdara Block (East Delhi)					7.47	945	222	155	19	0.58	106	40	410

Based upon data provided by Central Pollution Control Board

<u>INDEX</u>

HP- Hand Pump — TDS – Total Dissolved Solids — Cl – Chloride
TW- Tube Well — SO4 – Sulphate — NO3- Nitrate
DTW- Deep Tube Well — F – Fluoride — Ca – Calcium
Beyond Desirable Limits — Mg – Magnesium — CaCO3 – Total Hardness in form of Calcium Carbonate

The dissolved solids mainly consist of carbonates, chlorides, nitrates and sulphates of minerals. The amount of dissolved solid is important consideration in determining its suitability for usage. In general water with TDS <500 mg/l is most suitable for drinking. Higher dissolved solids may lead to impairment in physiological processes in the human body, if used for irrigation can lead to salinization of soil, thus rendering the agricultural land non productive over a period of time and for industrial use it can accelerate corrosion and interfere with colour and tastes of finished products (CPCB, 2005). Inorganic substances like salts, nitrate, phosphorus or heavy metals can lead to health problems if consumed in high doses (FAO, 1993).

Groundwater is not stationary; it flows in accordance to the slope and direction affecting a larger area in its slope gradient. An average for the whole block has been calculated for a comparative analysis for the blocks which would be helpful in giving a broader picture.

In the City Block the quality of groundwater is originally potable in nature. But human activity has deteriorated it. TDS is much above the desirable limit; calcium and magnesium content is also higher, which can lead to stomach and kidney disorders. Fluoride content is as high as 2.83, whereas the desirable limit is 1.0 and permissible upto1.5 mg/l. An excessive amount of fluoride causes mottled or discolored teeth, a condition called dental fluorisis. Concentration of nitrate in City Block is almost double the desirable limit. This increase in the nitrate content is primarily due to discharge from cess pools or due to leakage of sewage pipes, agricultural run-off and run-off from unsewered residential areas.

The Mehrauli Block largely consists of alluvial formation and quartzite ridge. In this block apart from the ridge area where the hard rock occurs at surface and shallow depth, in other areas the bedrock occurs at less than 50m below ground level in many places (CSE, date not mentioned)[19]. The groundwater quality is generally potable in nature. Apart from high levels of TDS and hardness of water which has evidences of leading to health problems like urinary and stomach disorder and kidney problems, calcium,

[19] Available online http://www.rainwaterharvesting.org/index_files/geology.htm (last accessed on 25.02.2008).

magnesium and nitrates were also found to be above the desirable limits in this block too. High levels of nitrate can be attributed to leachates from all time stagnation of raw sewage on land. Groundwater decline of more than 20 m has been observed in Mehrauli Block due to excessive extraction by bored tube-wells; in this case the effluent farmhouses located in this area are the major culprits.

The Shahdara Block consists of alluvial formation. The basement or hard rock occurs at greater depth around 100 below ground level (CSE, date not mentioned). The porous sandy soil of this area is highly conducive for infiltration due to which the contaminants can very easily and fast percolate down. Here too the TDS and hardness of groundwater were above the desirable limits, while unlike other blocks nitrate content was low. But calcium and magnesium levels were still higher than desired. Specifically speaking of Trilokpuri (a resettlement colony in East Delhi), sulphate content was high; this was primarily due to inadequately managed and leaking sewer in the area, which is contaminating the groundwater resource.

The data which stand out of the general trend is from the sample located at Jalsadan. Only at this location all the chemical parameters were within the desirable limit. This is because here the water sample was collected from deep aquifer, showing that while the contaminated of groundwater has occurred it has its worse effects on the shallow aquifers while the water at a depth is still safe from contaminants. Indiscriminate extraction of water has exhausted the shallow aquifers. People are now digging deeper to get to the water table which will soon deplete if the present rate of extraction continues.

7.5.3 Wastewater as Nuisance to Environmental Aesthetic

Implications due to the inadequacies of sewers and sanitation have created a situation of socio-environmental havoc for the residents, particularly of the informal residential colonies; worst hit amongst them are the slum dwellers. Besides surface and ground water pollution, the indiscriminate disposal of wastewater and sewerage has also led to degradation of environmental aesthetic. Flooded narrow lanes, rotting garbage in stagnant water, emanation of foul odour, breeding of mosquitoes, flies and rodents are some of the common wastewater nuisance.

Stagnant and stinking sewage lying in the open emanate fowl odour. The decomposing sewage and solid wastes in the narrow lanes of various residential areas give rise to pungent and smelling ambience. These are also breeding ground for mosquitoes, flies and other disease vectors. The gas emitted by rotting sewage is methane, which is poisonous as well as highly inflammable[20] and risky too. Some of the respondents at south location reported that the emission of gas is so strong that it is difficult to breathe comfortably.

The presence of rodents in large number was also due to dumping of wastes and left-over food items in open. Rodent infestation was so serious in some of the residential areas especially reported from the Old Delhi area (due to very high congestion of households and local eateries in the area), that humans more so the small children during nights were also bitten by big rats. These rodents also damaged the joints of sewer and water supply pipelines, further adding to the leakage problems.

These are some of the very apparent problems faced by the residents. The severity of these problems varied according to the colony type (Fig. 7.3). High proportions of households in low income neighbourhood – from JJ clusters, unauthorised and resettlement colonies were strongly affected by sewage nuisance like foul odour, harassment by flies, mosquitoes and rodents in the household and neighbourhood. These problems were severe enough to make life difficult for the residents.

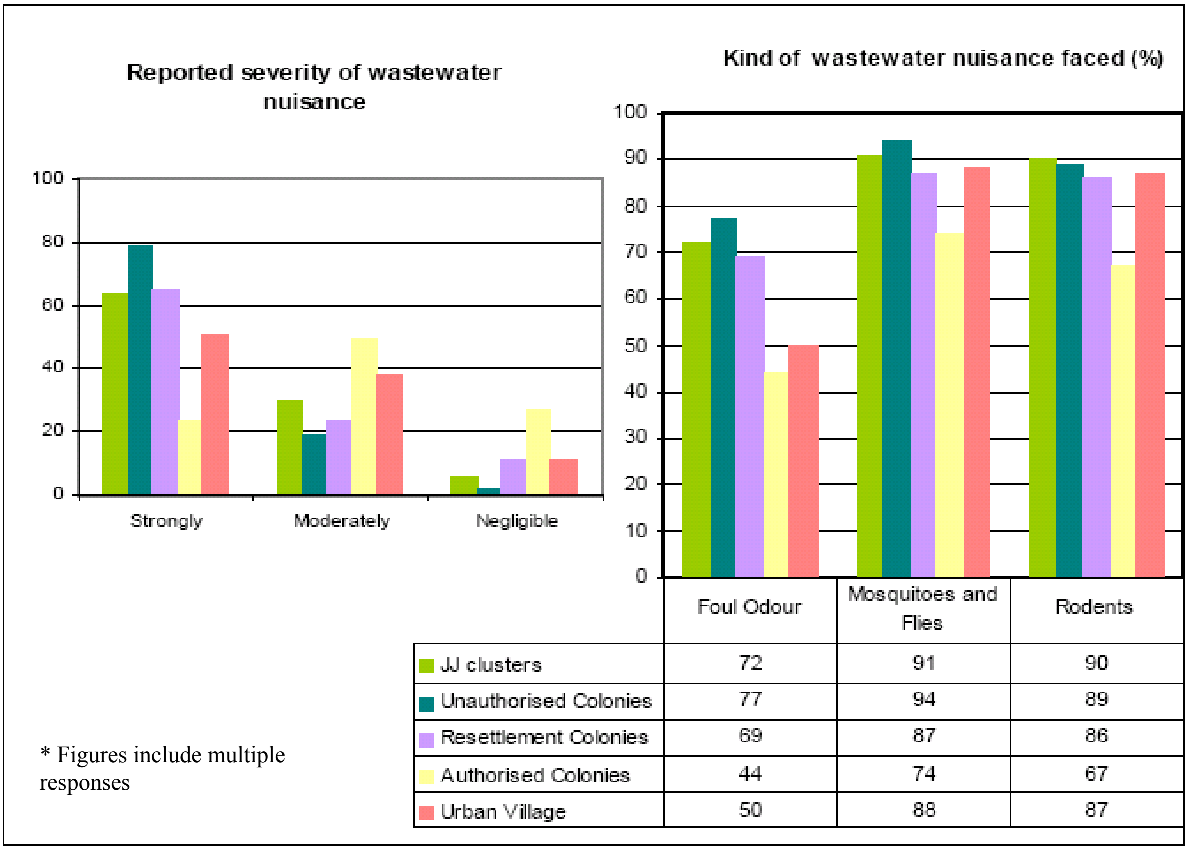
The residential areas have become increasingly infested by mosquitoes and flies in recent years as reported by the respondents. These problems are more aggravated during summers and pre-monsoon periods. The flies and mosquitoes easily infect food, especially the ones sold by local vendors. In a city like Delhi where outside eating is so common, there remain high chances for spread of diseases.

As high as 90% (N=127) of poor households like in JJ clusters reportedly faced nuisance of mosquitoes, flies and rodents. These were primarily households without piped water supply and wastewater outlet; they disposed their wastewater in the yard or open space.

[20] It was reported during the household survey that the local boys of the residential area sometimes played by lightening fire in the dry manholes which emitted gas and it could easily be put off by putting back the cap of the manholes.

Presence of mosquitoes and flies were comparatively less among the households in authorised colonies, 74% (N = 195) of which had wastewater outlet in the household. In fact, flies were a nagging problem for households in lanes where solid waste and garbage was not regularly removed but lay in the open and decayed under high tropical temperature. Presence of flies always in the toilet was highly reported by households using communal or shared toilet.

Fig.7.3: Distribution of Wastewater Nuisance and Severity by Colony Types



	Foul Odour	Mosquitoes and Flies	Rodents
JJ clusters	72	91	90
Unauthorised Colonies	77	94	89
Resettlement Colonies	69	87	86
Authorised Colonies	44	74	67
Urban Village	50	88	87

* Figures include multiple responses

Source: Own household survey, 2005-2006 (N = 696)

Usually the authorised areas were comparatively less affected by wastewater nuisance, but exceptionally in east district big open drains running very close to the middle to high income co-operative colonies (e.g., Vasundhara Enclave) posed problems of objectionable odour and mosquito infestation, costing upon environmental aesthetic. Although these apartments were inhabited by people belonging to the middle to higher economic strata, enjoying other benefits of good living surrounding but the problem of open drain has degraded the effort of co-operative society and it remains a nagging concern to be looked into by the Irrigation and Flood Control Department and DJB.

The problems which were heard and understood closely during field survey were also commonly reported from other parts of the city. Sewage flowing in the tap, clogged and overflowing drains, stinking muck breeding mosquitoes, etc. made common headlines in the city's daily newspapers (Fig. 7. 4).

Fig. 7.4: Commonly Reported Sewer Malady in Delhi


Clogged drains, mounds of silt, broken roads worry RWAs

'Monsoon may arrive next week'

Dwarka woes overflow, but drains missing

By S Shanthi/TNN

Drain water from pocket-9 in Nasirpur of Dwarka Phase-I overflows into a nearby park at Nasirpur

Sewage flows from Lajpat Nagar taps

By Kunal Doley

TIMES CITY

Drain turns death pit for 5-year-old

Girl's 2 Siblings Also Fell In Overflowing Drain But Were Saved

Rain pours cold water on MCD desilting plan

Malaria, dengue risk rising as city turns mosquito-breeding ground

By Ambika Pandit/TNN

MCD, MOSQUITOES AND SOME MATHEMATICS

Two girls die after falling into pit at E Delhi

The pit is at an engineering college's construction site

City's slum clusters are worst hit

Source: Selected newspaper clips collected from Times of India-Delhi[21], 2005-2007

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[21] http://epaper.timesofindia.com/archive/skins/pastissues2/navigator.asp?

During the monsoon months, problems related to sewerage are aggravated by additional storm water entering the drainage channels, which are not desilted adequately to cope with storm. Flooding of wastewater rises up to knee level in the narrow lanes and remains for a considerable period of time before draining away. The small channels and drains in the locality are not regularly cleaned as reported by the respondents. Their desilting is done only on continuous complaining; even after the mucks are removed they are deposited along the drains itself which remain there for many days before being taken away. These muck stinks and stray animals dismantle them to other areas bringing them very close to the households. Children while playing often ran into sewage muck and their careless preventive behaviour increases their risk of contacting diseases.

7.6 Public Health Implications

Wastewater is still the root cause of much environmental degradation and water-related morbidity and death around the world (Pipeline*,* 1996). Influence of wastewater pathogen is seen as a medium of transmitting diseases through the ingestion of contaminated water in which pathogens occur or by eating contaminated agricultural products grown with unregulated sewage irrigation, through direct skin contact with the raw sewage and muck containing pathogens (Shuval, Fattal and Yekutiel, 1986; Mara and Cairncross, 1989; Armon *et al.*, 1994; Lerman, Slepon and Cohen, 1994; Blumenthal *et al.*, 1994; 1995) or through contact with other animal and insect carriers.

Additionally, the improper disposal of wastewater create conducive habitat for disease-carrying vectors. Malaria is unquestionably the most important of this class of diseases. Over 40% of the world population lives in areas with malaria risk. Some 1.1 to 2.7 million people die of malaria each year (DFID, 2004). Dengue is also transmitted by mosquitoes; the incidence of dengue has increased due to urbanization growth (Porto, 2004).

Diarrhea due to unsafe water, sanitation and hygiene is placed as the sixth highest burden of disease on a global scale, a health burden that is largely preventable. It accounts for 1.73 million deaths each year and a total equivalent to 3.7% of the global burden of disease (WHO, 2002). Other water-related and water-washed diseases related to poor water, sanitation and hygiene are dysenteries, trachoma, schistosomiasis, conjunctivitis, hookworm disease, malaria and Japanese encephalitis contributing to an additional burden of disease on the already vulnerable groups (Howard and Bartram, 2003).

Health of people is directly related to the prevailing environmental conditions, hygiene behaviour as well as their level of economic and social prosperity. People with low income are more likely to be malnourished and develop a low immune system against diseases (Chambers, Longhurst and Pacey, 1981). This coupled with low capabilities to adopt preventive measures and access health care system makes them perceivably more vulnerable.

Vulnerable social groups bear the greatest health burden associated with poor water and sanitation facilities. It is well documented that social group exposed to wastewater and under safe water supply stress has increased relative risk (RR) of water related diseases including hepatitis and gastrointestinal symptoms (Heller, 1999; Hansen *et al.*, 2003; Jeggli *et al*., 2005; Boadi and Kuitunen, 2005). “Relative risk (RR) is an epidemiological risk measure. The relative risk of a given disease as a result of exposure is defined as the ratio between the incidence rate of the disease among an exposed group and the incidence rate among an unexposed group. It represents how many times more likely it is that the disease will occur in the exposed group compared with the unexposed. If the 95 per cent confidence interval excludes the unity, then the study factor is significantly associated with the risk of disease at a statistical level of 95 per cent. For RR>1, the exposure is a risk factor; for RR<1, the exposure is a protective factor” (Heller, 1999: 139).

Since health is an important component in the achievement of the quality of life, some negative influences of the existing wastewater problem have been analyzed in the subsequent section in terms of commonly prevalent diseases among the social communities residing in various kinds of residential colonies.

7.6.1 Health Profile of the Study Area

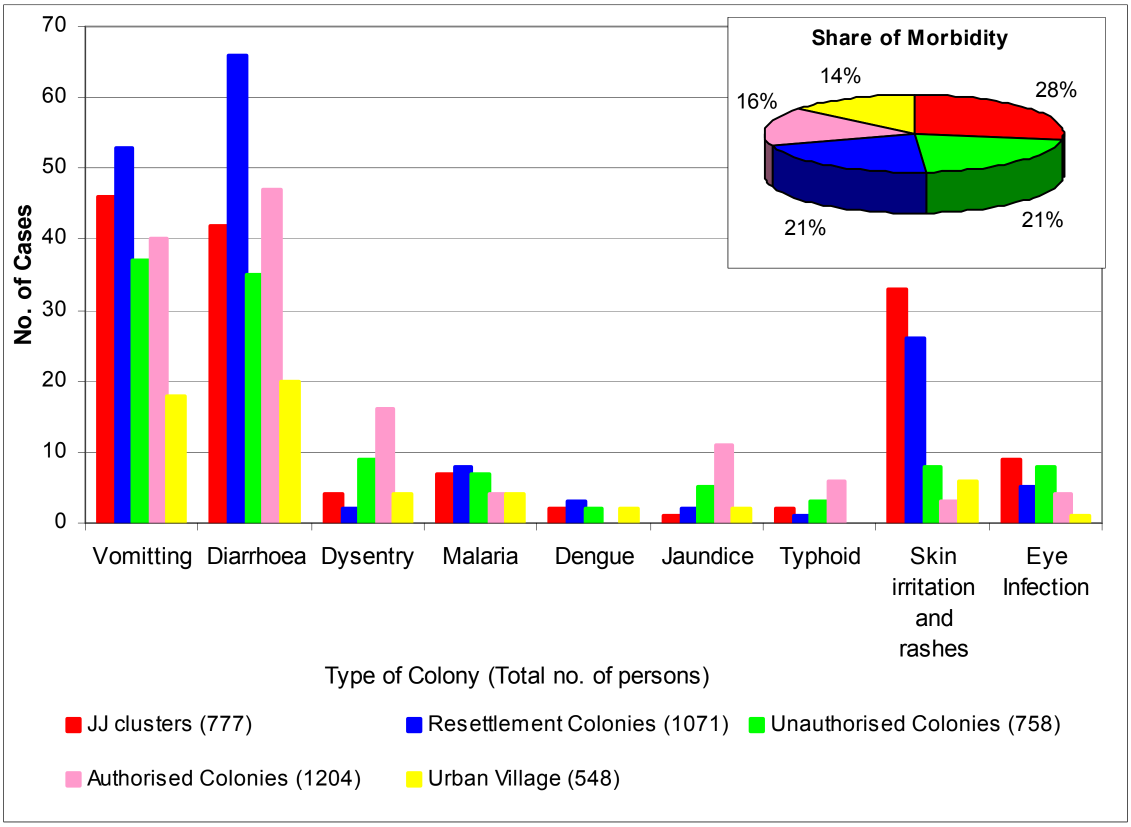
A small section of the surveyed questionnaire was also devoted to investigate about the kind of diseases which were common among different social groups in the studied localities. This was done because health effect in terms of water-related illnesses is seen as a major implication of wastewater exposure which took place via consumption of contaminated water as well as by direct physical contact. Although it has to be underlined that not primarily an epidemiological study was conducted and therefore no attempt was made to establish a relation between the kind of diseases and wastewater nuisance. But the field experience showed some causal relationship between the water and sanitation conditions of the different localities, and commonly reported illnesses in some places which need to be highlighted.

Apart from fever and cold, which were extensively reported from all kinds of localities as a regular phenomenon, diarrhea, vomiting, dysentery, malaria, dengue, jaundice, as well as skin and eye infections were also common diseases prevalent among the surveyed communities. However, the number of cases differed across the colony types and the level of vulnerability. JJ clusters, unauthorised and resettlement colonies report about 75% of the total morbidity whereas, authorised colonies and urban villages uphold only one-forth of the total (Fig. 7.5).

Skin irritation and rashes were also highly reported from those localities where exposure to raw sewage was more prominent and unavoidable. Highest number of cases for skin irritation was from the JJ clusters and resettlement colonies, particularly among the children. This can probably be attributed to their frequent physical exposure to sewage and mucks, unsafe hygiene behaviour as well as their incapability to take preventive measures. Nevertheless, other reasons like exposure to poisonous substances within their household or at other places cannot be completely ruled out.

A comparatively higher proportion of malaria cases was reported from the informal settlement quarters (although mosquito problems are prominent and ubiquitous), affecting even the posh residential locations but poor people of the JJ clusters were usually lacking preventive measures and therefore were more prone to its impact. Mosquito infestation was also reported as a major problem from the authorized colony of East Delhi due to the existence of open drains running along the boundary wall of the colonies. But the higher socio-economic status of the residential groups there strengthened their internal capability to take precautions against the problem (e.g., getting mosquito-resistant window and door net, usage of mosquito repellants in the households and regularly cleaning and spraying the colony with anti-mosquito chemicals).

Fig. 7.5: Distribution of Water-Related Diseases in Different Surveyed Colonies



Source: Own household survey, 2005-2006 (N = 696)

Interestingly, but in line with the above finding, cases of jaundice and typhoid were comparatively higher in the authorised colonies. This can again be attributed to the unsafe quality of piped water supply. Although water is officially supplied to these colonies through proper pipelines after considerable treatment, it is taken to be sufficiently safe and suitable for direct consumption, in which case people were reluctant to use any purification measures. But sewage leaking into the pipelines led to contamination of water before it reached the endpoint thereby confirming that even the formal settlement was not safe from sewage impact although the nature of problem was different from those prevailing in informal settlements.

Skin irritation, rashes and eye infections like allergic and infectious conjunctivitis which is caused due to direct contact with infectious pathogens (viral or bacterial) were also highly reported from those localities where exposure to raw sewage was more prominent and unavoidable; like in informal JJ clusters about 34 cases of skin irritation and 9 cases of eye allergies were reported.

Water-related diseases showed distinct occurrence almost in all the households which has a neglected or compromised hygiene behaviour including drinking water purification habit. Although the households were grappling with the problem of water quality but the habit of purifying water before drinking was not much prevalent among them. When asked about drinking water purification, only 35% of the total households surveyed reported to be using some mode of purification though 77% reported water quality problem in their household. More households in the authorised colonies than in the resettlement colonies adopted preventive measures (e.g., using filters and aqua-guard for purifying water). Respondents from urban villages said their water is supplied directly through pumps which are underground water and therefore it is safe to drink. Only when the water is perceivably dirty they cleaned it before drinking either through filter or boiling but this was not done on daily basis.

It was interestingly reported that even in low income households, water fed to very young children was boiled while it was not a usual habit to drink boiled water. Boiling of water for sick children in the households was generally a curative measure adopted on doctor's recommendation. This indicates that, although the respondents were aware of the kind of health implications of exposures to unsafe water, sanitation and hygiene system but they were relatively ignorant about this issue and only adopted preventive measures after the occurrence of any illness in the family.

7.6.2 Exposure-Morbidity Relationship

The socio-economic attribute of a community influences their level of exposure to harmful environmental perturbations. Continued and prolonged exposure to unhygienic and unsafe environmental conditions as created by improper management of water and sanitation system make the communities vulnerable to various kinds of water-related diseases. Water-related diseases can be divided into five categories: water-borne microbiological diseases, water hygiene diseases, water contact diseases, water vector habitat diseases and water-borne chemical diseases (McJunkin, 1983). The basis of this classification and the correspondent preventive strategy is described in Appendix VII.

It has already been discussed extensively in Chapter 5 that the level of exposure depend upon factors like period of stay, income levels, house types, direct contact with sewage sources of drinking water as well as their preventive and hygiene behaviour in their household. Interplay of various exposure factors leads to occurrences of various illnesses. An individual is vulnerable living in risky sites or unsafe places where health is threatened. Due to the infrastructural inadequacies and improper management of the existing ones, there is a profound adverse effect on the environment which finally comes back to people in the form of health impacts. This study is a prospective attempt towards analysis of resultant implications of wastewater nuisance; thus, there remains a general limitation to find out the extent of the health impacts due to wastewater exposures.

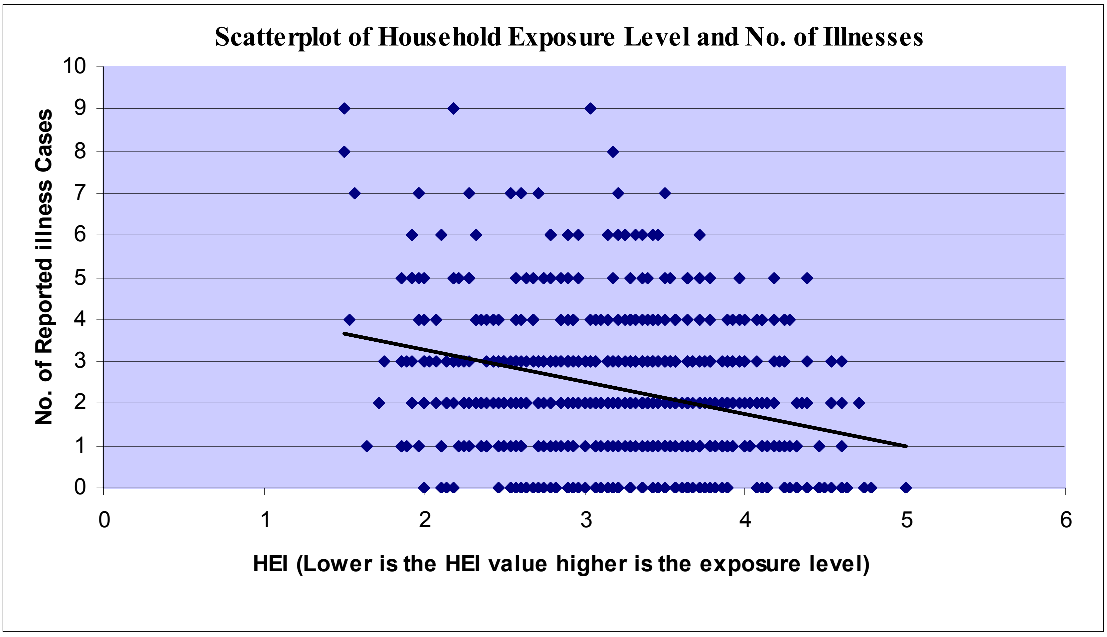
Nevertheless the study has brought forth the fact that the number of diseases occurring in the studied locations increased with the increasing level of exposures. A sketch statistical analysis was done to study the relationship between household exposure level and reported cases of illnesses. A scatter diagram was plotted with values of elaborately calculated HEI (Household Exposure Index[22]) and number of reported cases of illnesses in the households (Fig. 7.6).

Applying the Pearson's correlation method (r) was calculated to be -0.30 which is significant at the 95% and 99% level. There clearly appears to be a direct exposure-disease relationship between levels of household exposure and morbidity. It can be concluded that with increasing level of exposure (indicated by lower value of Household Exposure Index) the number of illness cases in the household increases and vice versa. The scatter plot and fitted trend line does not establish a very strong relation between exposure and morbidity above but it is showing a positive relation in 95% cases.

[22] Refer to Chapter 5 for elaborate explanation about Household Exposure Index as calculated from the questionnaire results for the surveyed households.

However, at the level of 99% it may not be strongly significant probably because a deteriorating health and increasing morbidity in megacities is due to multiple factors and stresses and not only due to exposure to water and wastewater related hazards which is the focus of this study.

Fig.7.6: Scatter Diagram Showing Household Exposure-Morbidity Relationship



Source: Based on household questionnaire results (N=696)

$y = mx + b$
$y = -0.7545x + 4.7794$
$R^2 = 0.0892$
Pearson's (r) = -0.29 ($\alpha = 5\%$)

The equation $y = mx + b$ algebraically describes a straight line for a set of data with one independent variable where x is the independent variable, y is the dependent variable, m represents the slope of the line, and b represents the y-intercept.

In order to further establish the exposure morbidity relationship more clearly a contingency analysis was performed where the household exposure and morbidity was classed into three equal categories within the available highest and lowest data range (following the same classification as done in the preceding sections). When the exposure was high, significantly over proportions of high morbidity in the households were noticed and vice-versa. The contingency coefficient was calculated to be 0.207 (N=696), which reveals a highly significant relationship even at 99% confidence level. Detailed cross tabulation of the exposure and disease categories can be seen in Appendix VIII.

Figure 7.6 represents situation of different settings in an aggregate manner. In order to re-establish that there exist multiple stressors responsible for morbidity apart from mere exposure to harmful environmental perturbations due to wastewater mismanagement, it was necessary to analyse exposure-morbidity across different types of colonies individually. With this idea in mind, similar scatter for exposure-disease relationship was plotted for different types of colonies and its result is presented in Table 7.6.

Table 7.6: Household Exposure-Morbidity Relationship across Colony Types

Type of Colony	Relation	Pearson's (r)	Significant	
			95%	99%
JJ Cluster	Positive	-0.16	Yes	No
Unauthorised Colonies	Positive	-0.40	Yes	Yes
Resettlement Colonies	Positive	-0.29	Yes	Yes
Authorised Colonies	Positive	-0.20	Yes	Yes
Urban Villages	Positive	-0.54	Yes	Yes

Source: Based on household questionnaire results

Varying degree of correlation was seen in different settings and all of them showed a positive trend significant at the 95% level. The relation is weakest in the JJ clusters with (r = -0.16) significant at 95% level and not significant at 99% level whereas strongest relation emerged in urban villages (r = -0.54) which was significant at 95% as well as 99% levels. It still remains difficult to confidently blame increasing morbidity entirely on wastewater exposure. Nevertheless, it can be concluded that the inhabitants of JJ clusters in the dense urban areas although are highly exposed to wastewater nuisance but simultaneously are also at various different other stresses of low income, poor education, water scarcity, lower level of awareness and reduced options to cope.

The relation between wastewater exposure and morbidity was comparatively more strongly represented in urban village settings probably because the fringe setting of these colonies kept them in a lower density and the other factors of stress were comparatively less there. In this respect, the relationship between the variables represented in urban village case emerged stronger. Looking at the situation in planned colonies, where the exposure level was lower due to different factors discussed earlier in the Chapter 5, and a weak exposure-disease relationship emerged.

7.7 Economic Implications

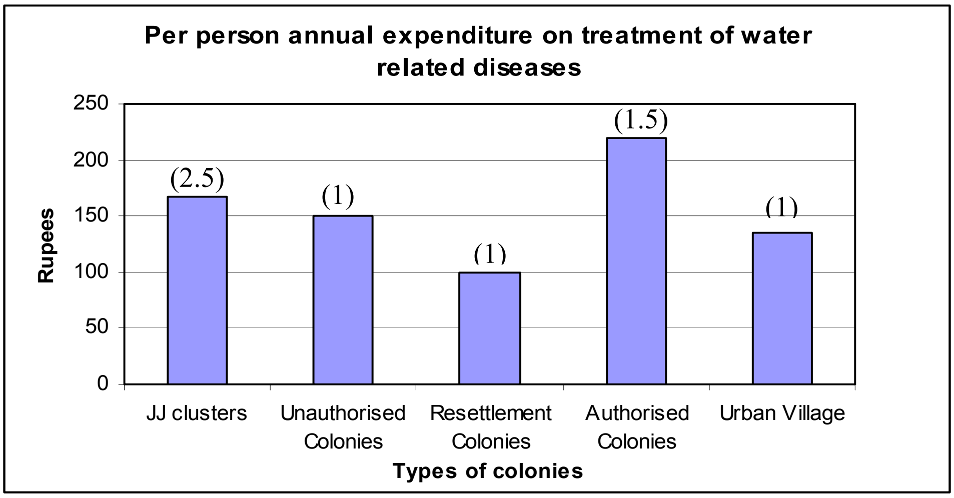
Adverse economic impact of environmental degradation is an important aspect to ascertain the success of the existing water and sewerage system efficiency in delivering its goal. In case when the existing sewerage and sanitation infrastructure is not efficient enough, resultant implication costs on the economy dearly as trying to alleviate years of environmental contamination can be expensive and involves overcoming a host of practical issues (Smith *et al.*, 2002).

In case of ground and surface water contamination, there is the additional cost of advising the residents, visitors and tourists to the area of the risk, managing community anxiety and the indirect costs associated with the perception that the area is unsafe (Smith *et al.*, 2002). Additionally, there is increased economic burden on people created due to sewerage mismanagement via health costs and expenditures on hiring private cleaners for desilting and cleaning the drains. This could be easily avoided through improved management and extended coverage of safe water supply and sanitation to all (Augustin, 2003).

In India, the cost of water pollution (seen on health implications), especially with diarrhea diseases is ranging between $3076-8344, which accounts for about 59% of the total annual environmental costs (Brandon and Hommann, 1995). Apart from avoidance of additional expenditure, reduced environmental degradation can augment income by saving working day lost. An interesting study was conducted by the All India Institute of Hygiene and Public Health, which concluded an average of five working days saved yearly per family due to the positive health impact of Ganga Action Plan (AIIH&PH, 1997).

Field results reveal that infectious water-borne and water-related diseases manifest Delhi all time of the year, but there was a considerable rise by the onset of monsoon. Direct economic burden due to water, sanitation and hygiene related health implications acts as a decrementing factor on household finances in numerous manners. Per capita expenditure on treatment of water-related diseases like jaundice, diarrhea, dysentery, cholera, worms, malaria, conjunctivitis and skin infections[23] was considerable (Fig. 7.7).

Fig. 7.7: Annual Expenditure on Water-Related Diseases (INR/Person)



Source: Own household survey, 2005-2006 (N = 696)

* Figures in the parenthesis indicate the percentage to household income

On an average it ranged between 160-180 INR annually for each person, which could be largely avoided by households. In case of households having large family size, the percentage of household income spent on treatment would increase enormously. Residents of the authorised colonies spent the maximum of about 220 INR, which was largely because they had the preference and financial capability to avail of private practitioners whereas residents of resettled colonies preferred to go to the public health clinics for these ailments and had to spend on medicines only as the consultancy was free. Nevertheless, water and sanitation related health implications were posing an increasing economic risk to the urban citizens.

[23] This calculation only includes minor treatments and doctor's consultancy which were largely reported by most of the houses. Serious cases of hospitalization and prolonged medical treatment was not taken into consideration since the data was not reliable due to discrete reporting.

When families are impoverished, e.g. residents of JJ clusters who were largely daily wage laborers or domestic help and their household earning was less than 2000 INR monthly, even a marginal unexpected increase in household expenditure would be a pressure on the family. Taking an average family size of six members, households annual expenditure on water-related minor health ailments and managing their wastes for lower income families (earning < 2000 INR) was ranging between 5-8% of household income and only about 0.5-1.5% of household income for higher income families (earning > 10000 INR).

Additionally, there was a loss of working days when suffering from various ailments as mentioned earlier which indirectly led to economic loss for the family, particularly if the earning member of the family falls sick. The pressure of economic burden was even more severe for the daily workers who need to find job everyday. A respondent from one of the surveyed JJ cluster at Central Delhi reportedly said;

> *"If I cannot go to the work contractor early morning, I cannot find work for the whole day or even for weeks. Therefore, if I fall sick, cannot get work and so my family will have nothing to eat"* (Open part of the household questionnaire).

The intention here is to hint at the additional economic burden which is largely avoidable by (1) combating environmental degradation (2) extending efficient water and sewerage system, and (3) achieving reduction in water-related morbidity.

7.8 Concluding Remarks

The above discussion supports the view that wastewater management in Delhi is astonishingly inadequate exposing environment as well as social communities to greater risks. Irregular cleaning and maintenance are the primary reasons why the existing wastewater structure is associated with environmental and public health problems. Solutions are urgently needed to effectively increase coverage and maintenance of water, sewer and sanitation infrastructure and make their access equitable and easy for people of different economic strata residing in urban areas.

Numerous physical, technical and institutional drawbacks caused unsafe disposal of wastewater leading to environmental degradation, which shows its effect on humans in form of health impacts. The relative risk of diseases indicates that population connected to public services is not necessarily safe from wastewater nuisance. The means of exposure to wastewater is different for a formal and informal setting varying from perfectly direct to indirect contacts with harmful occurrences and so is the level of related health hazards.

Inadequate water and wastewater infrastructure was showing detrimental implications on the environment in form of continuously increasing pollution level in surface and ground water and causing aesthetic degradation. Implications were seen on public health in the form of increasing prevalence of water-related mortality in the city all year round. There was additional economic burden on the households to deal with the implications of wastewater and sanitation infrastructure stress.

Although the social groups were aware of the wastewater hazards in terms of health implications not all were taking serious preventive measures against it. Households with capabilities to respond effectively and still not doing so were probably reluctant as the severity of implication was not yet detrimental for them. On the other hand households who were willing to take actions were sometimes restrained by economic hindrances or lacked awareness regarding the available options to do so. Therefore, in both cases there was lack of effective response either due to reluctance and unawareness.

It can clearly be derived – even though not astonishingly – from the findings that the risk of diseases is higher among the social groups living in JJ clusters and informal settings due to the lack of proper water supply and sewage disposal facilities and a poor socio-economic level to cope with such infrastructural stress. Nonetheless, the threat remains even for the residents in formal settlements but their coping capability is higher; thereby the disease risk is comparatively reduced.

The exposure-morbidity analysis establishes a trend of positive relation between household exposure levels and disease occurrences significantly in 95% cases in all the colony types. But in certain cases the result is not significant at 99% confidence which also indicates that wastewater exposure is not the only reason for the existing disease burden. It thereby attest that megacity inhabitants are exposed to multiple stresses which cannot be grasped clearly by only considering physical exposures to harmful environmental perturbations and stresses in the form of water and sanitation.

Apart from multiple exposures to various stresses in an urban setting, poor social status of marginalized population further suppresses their capabilities to effective responses. In this regard, it is important to identify critical areas for priority action and means to remove impediments to self-help. Although sanitation and hygiene are a household decision, availability of basic infrastructure and existence of favourable socio-economic settings is important to deal with the 'informal challenge'.

Since the cost of alleviating accumulated water contamination would be costly, management should focus more on checking further deterioration of the water resources by adopting prevention measures. One such measure could be strengthening and extending the sewer coverage as well as improving the management efficiency so that the contaminant outfall into fresh water bodies is controlled. It also calls for determining alternative environmental sanitation services, which is sustainable, price competitive and effective in result.

Residents, depending upon their level of awareness, management capabilities and willingness to respond have adopted certain preventive as well as recovery measures to deal with sewerage and sanitation problems in their household and immediate neighbourhood. In the next chapter, a summary of various such measures on the basis of field experience have been analysed as well as the gaps between responses of local people and administration has been identified.

Chapter 8

Households and Institutional Responses

8.1 Introduction

Response and adaptation as well as mitigation efforts are all important coping measures to achieve human, environmental, livelihood and health security. People faced with risk use their own capabilities, skills, talents, knowledge and technologies to deal with the crisis situation or protect themselves against adversities, which might not necessarily be sudden extreme events. Even in everyday life, people's knowledge and their level of understanding play an important role in perceiving risks and in turn it moulds their decision making and responses (Hauger *et al.*, 2003).

One-sided treatment of coping and adaptations with particular focus on so called 'vulnerable groups' perceives human beings as passive recipients and individuals without relationships (Wisner, 2001) and reduces the scope of analysing the process which prevented the other counterpart from being impacted by external stressors. The poorest and underprivileged citizens of any country are faced with unfavourable circumstances and find it difficult to devote sufficient resources to protect themselves against hazards (Yohe and Tol, 2002). Thus, "more emphasis needs to be given to understand the capabilities of people and groups labelled 'vulnerable' or 'marginal' and the power of history and global political economy must be taken into account as conditioning the circumstances in which situations come and go" (Wisner, 2001: 4) thereby comprehending their incapability to adopt strategies for protecting themselves.

This should proceed with the pragmatic approach of seeing everyone as having capacities for self-protection and group action (Wisner, 2001) against external stresses. Such approach can therefore go beyond capacities of coping, adjustment and adaptations to also capture aspects of coherence and resilience in a system which would facilitate a holistic understanding of management capacities as well as strategies in action opposing exposures to harmful perturbations and external stresses. Awareness, learning and communication are all requirements for effective responses and strengthening resilience. A framework is presented in this chapter to show interaction between various components for a resilient megacity system.

Present research has seen that in the absence of adequate wastewater and sewer facilities, which forces social groups to chose various adaptation and coping strategies (to defend themselves against the harmful implication) - depending on their capabilities, perception and available options. Their responses range from emotion-driven ‘doing nothing’ to adoption of action-oriented preventive, adaptive and coping measures for dealing with water, wastewater and sanitation problems depending on family particularities and available resources at the household level.

This chapter begins with the discussion about the importance of effective responses and adaptation in strengthening resilience of a megacity system towards stresses and emphasising why it is critical to understand them. Responses in the form of prevention, adaptation, coping and mitigation measures undertaken by the individual households or a group of households as well as institutional strategies adopted by the management are analysed. Further, the obstacles faced by social communities and institutions towards protecting humans and effectively defending against wastewater are elaborated with the aim to identify gaps in responses which need to be closed. Finally, wastewater reuse as a remedial measure for wastewater management is discussed.

8.2 Responses and Adaptation as Components of a Resilient Megacity System

Human societies are in a constant process of responding and adapting to their changing environment surrounding as well as influencing them. Adaptation in the context of human dimension refers to the actions which human community (at different scale) take in order to better cope with, manage or adjust to changing conditions, stress, hazard, risk or opportunity (Smith and Wandel, 2006: 282). At a higher scale, a city itself is a complex adaptive system (Batty, Barros and Alves, 2004) wherein the system is responding to the constant changes taking place. This also demands the system to pose high capacity for frequent adaptation and adjustments to ongoing events.

Adaptation capacity is seen as capacity of the system to restructure in responses to certain events, shock or ongoing stress, more for long-term and more sustainable adjustments whereas coping is more immediate response to certain events or surprises more on short-term basis (Turner *et al*., 2003). It is also necessary to distinguish adjustments and adaptation. However, adjustments are “system responses to perturbations or stress that do not fundamentally alter the system itself; they are commonly (but not necessarily) short-term and involve relatively minor system modifications” whereas adaptations are seen as “system responses to perturbations or stress that are sufficiently fundamental to alter the system itself, sometimes shifting the system to a new state” (Kasperson *et al*., 2005b: 253).

Studies on various aspects of social vulnerability have shown that ‘living with risk’ needs to be based on coping responses and adaptation techniques and any vulnerability assessment needs to serve as a means of improving human capacities to respond and actively manage the risks (Bohle, 2006: 189). These aspects clearly indicate the importance of effective responses towards strengthening defences against risks of varying nature (sudden events as well as continuous stresses) and in doing so moves in the direction of resilience building. Apart from other things like good governance, diverse option availability and accessibility, awareness, education and communication at city level, local coping strategies are considered to be key factors in determining a community’s resilience (Davis, Haghebaert and Peppiatt, 2004).

Resilience is surely not just absence of vulnerability. It refers directly to the ability to function with the spectrum of uncertainties associated with the dynamics of megacity system and indirectly to the capacity of people, communities, agencies, infrastructure “in the first place to prevent and mitigate losses and then secondly, if damage does occur to maintain normal living conditions as far as possible and manage recovery from the impact” (Buckle, Mars and Smale, 2000: 13). The relation between vulnerability and resilience is rightly expressed in the terms “vulnerability comes from loss of resilience” (Holling, 1995: 24). In this respect residents of a megacity system become more vulnerable if the prevailing socio-political structure restricts their capability to respond effectively towards risks.

Therefore, “resilience depends on, among other things, the effectiveness of the risk response and the capability to respond in the future” (Alwang, Siegel and Jørgensen, 2001: 10). Although the capacity to response is clearly an attribute of the system as a whole that exists prior to the event (sudden shocks as well as continuous stresses), it gets operational or functional only when the event strikes or the stress exceeds tolerance. Responses then are needed for coping with the contingencies and improving the condition itself (Gallopin, 2006) as well as for enhancing their capacity to respond in future. Good governance, positive social networking, commonly shared values, sustainable economy are all elements to enhance capabilities and thereby strengthen resilience.

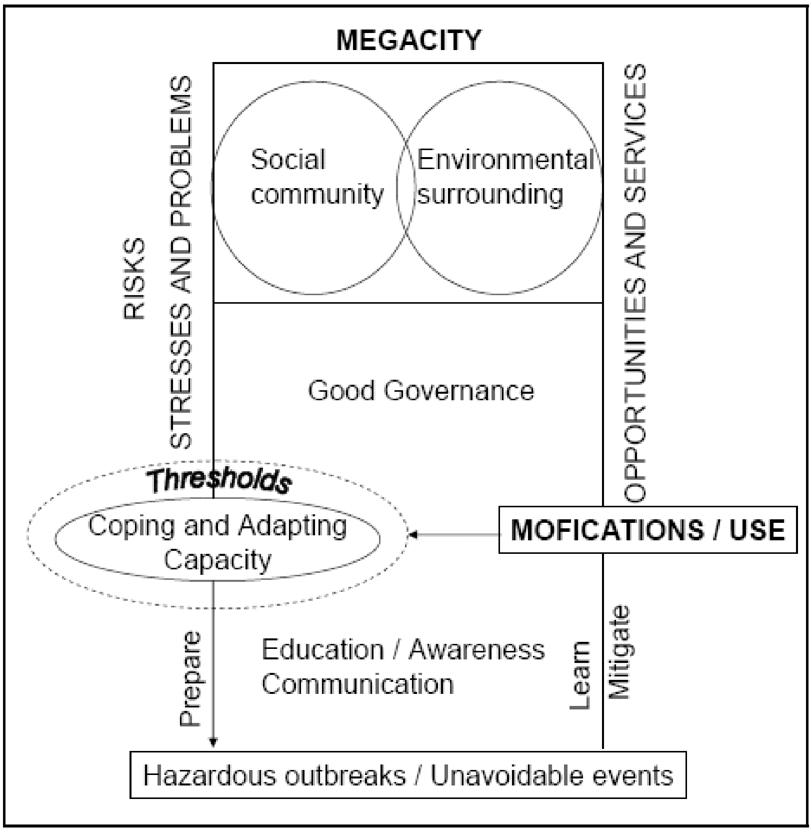
The above discussion reasserts that coping responses, adjustments, adaptations and capabilities to respond effectively are all interrelated and require components for strengthening the resilience of a system and thereby it emphasise the importance to understand various forms of human and institutional responses towards changes of potentially negative implications posing risks and threatening securities in megacities.

Slow changes over time get absorbed within the coping thresholds[24] in case of human society and get rectified to some extent by the self-correcting mechanisms for the environment. Since humans are constantly exposed to environmental changes and stresses they are continuously coping and adapting to them, but once the threshold of coping and adaptation capacity is crossed, hazardous outbreak strikes, calls for further responses and again the process of coping and adaptation restarts. Although there are limits to the thresholds, "they are not necessarily fixed" (Yohe and Tol, 2002: 26).

After analyzing the definitions and views relating to coping, adaptation, thresholds etc., it seems important to put them into a framework which would facilitate understanding of responses and its relation to resilience, which in this case is a characteristic in terms of flexibility to adapt to change, ability absorb the stresses, mitigate impacts and maintain normal conditions as far as possible. Thresholds, coping responses, preparedness, education, learning, adaptation and adaptive capacities, are all necessary components and mutually complementary for a resilient megacity (Fig. 8.1).

[24] A threshold is defined as a point between alternate regimes in ecological or social-ecological systems (Resilience Alliance and SFI, 2004:1).

Fig. 8.1: A Resilient Megacity System



Source: Own draft

In this respect a megacity is viewed as a complex social and environmental system[25]. Social communities and environmental surroundings are in constant interaction with each other within the superstructure of a megacity. A megacity system can be interpreted as a more complex reflection of socio-environmental interaction which is not linear or unidirectional. It also seems difficult to clearly indicate whether the social and environmental interaction is within the megacity or whether the megacity itself is part of the socio-environmental system. They can be considered as major components of a megacity system which acts on as well as influences each other in a complex manner.

[25] Similar to this is Socio-Ecological system (SES) which is defined as a system that includes societal (human) and ecological (biophysical) subsystems in mutual interaction and can be specified for any scale – from local community to global system (Gallopín, 1991; 2006). It is also called social–ecological system (Berkes and Folke, 1998) and coupled human-environmental system (Turner et *al*., 2003).

The megacity provides opportunities and services on one hand and simultaneously is region of infrastructural deficits and supply crisis, which threatens environmental and human health securities. Within the system society and the environment endure stresses as well as make use of the opportunities and services to strengthen their capabilities against potential threats. They constantly cope with the stresses and problems in various forms of responding behaviour, depending upon their social status and capabilities. In this respect some parts of the society have to suffer more and thereby require to cope much more than others (e.g., inhabitants of the JJ clusters in Delhi were the group most exposed to water stress and wastewater nuisance; they needed to cope more than the residents of other colonies where sewerage and water was somewhat secured).

Adaptation and coping capacity also prepare the system for future risks and stresses but in cases when stresses exceed the thresholds of endurance capacity, hazardous outbreaks or unavoidable events strike (e.g., an outbreak of dengue fever or diarrhoea). These are occasions which again call for the coping capacity to get operational; the system needs to adapt and learn from the experience, modify their preventive as well as coping responses and strengthen their capabilities, which would presumably increase the threshold to a higher level. Good governance, education awareness and communication are required elements for directly enhancing effective responses and indirectly strengthening resilience of a megacity system.

8.3 Responses to Wastewater Hazards

Human response to hazard encompasses all the ways in which the negative effects of an event, outbreak, risk or threat can be reduced. It exists even before the occurrence of an event (as preventive strategies) and operates after the event (as coping and adaptation strategies). Responses and adaptation strategies are imperative part to be understood within the megacity system where social communities are constantly adjusting, adapting and responding to multiple stresses. Learning from the success of past responses and preventing adoption of failed strategies would strengthen the effectiveness of response towards future anticipated events and help in being better prepared for the unknown ones.

Human responses depend on the prior experience, awareness about the severity of resulted consequences, their perception of problem as well as their social and material capabilities to cope with the situation. Responses can be towards completely known events to sudden surprises and can range from properly organized or completely chaotic. Not all responses of human towards harmful environmental perturbations/events or stresses are unexpected; human societies are also capable of anticipating outcomes, at least the most probable ones (Stern, Young and Druckman, 1992). Therefore, apart from coping, adaptation and adjustment, responses can be preventive and preparative in nature.

Anticipation of certain implications can be on the basis of their own prior experience or experience of others which might have been communicated to them within their social network, e.g. if there is heavy rainfall, it is expected that the narrow lanes gets easily flooded to the extent that water may enter the household. In this situation the residents usually try to barricade the entrance with stone block or raise the level of the door (structural adjustment), thereby preventing water from entering the houses.

Respondents in the localities more prone to wastewater problems showed a moderately higher degree of awareness about the wastewater hazard. Since the frequency of wastewater flooding and other allied nuisance was higher in certain locations and colony type, households there were somehow responding to the frequent wastewater problems in various forms including short-term as well as long-term actions. On the basis of field experience, particularly dealing with wastewater and sanitation problems some of the general response categories in this regard are elaborated below:

8.3.1 Preventive Responses

Social community and institutions, based on their previous experience may start responding to anticipated events even before they occur. Adoption of preventive measures, precautions and similar strategies to minimize the impact are categorized as preventive responses. These responses are somehow strategies which help building the coping capabilities of the social communities. The residents of certain surveyed localities, being aware of the grim infrastructural and water system related problems in their immediate neighbourhood, took precautions by elevating the entrance of their houses to prevent waste water overflows and floods that enter their households. They covered open drains with stone slabs and got the windows and doors netted in order to safeguard against mosquito problems, etc. They try to adopt preventive behaviour like restricting their water use so as to generate less wastewater, purifying water before consumption atleast for the children, etc. Apart from these structural and behavioural precautions, communities also start social networking in an organised manner in order to learn from each other's experience and share knowledge about measures and strategies to be adopted. Preventive responses are somehow strategies which help building the coping capabilities of the social communities.

8.3.2 Adaptive Responses

These responses are actions and strategies which are launched after the event has occurred. The social community and the environment must adjust to these changes and get gradually adapted to the new system/situation. This is of a long-term basis, e.g. the continuation of living in unhygienic surroundings without feeling bothered is also seen as a 'situational adaptation'. Adaptation was about facing the fact that infrastructural inadequacy was inevitable at the given socio-political situation; it involved acceptance of the condition and making changes accordingly to strike a harmony.

It was repeatedly noticed in the field that communities which frequently faced waste water and sanitation problems in their household had somehow adapted to this prevailing situation and were not much bothered or at least they denied to be grossly affected by the uncertainty and irregularity of its maintenance. They were no longer bothered to see or get exposed to puddles of waste water and daylong lying garbage and muck. They seemed to have mentally accepted the prevailing pathetic sanitation condition of their neighbourhood and remained satisfied as long as they could maintain their household premises clean.

Adaptive responses also include activities which would strengthen people's capabilities to endure future shocks of presumably similar nature e.g. installation of sewer pipes of larger diameter, having alternative arrangements during the peak season of wastewater disposal problems (monsoon months) etc. Furthermore, adoption of good hygiene behaviours in daily lifestyle in order to minimize the effect of wastewater exposure can be seen as a good example of non-structural response on the part of social groups.

8.3.3 Coping Responses

These responses refer to the process of managing crisis circumstances, seeking to minimise, reduce or tolerate stress and expending efforts to live with the problems. They may include short-term and temporary actions too which are needed to manage the hazardous event or stresses. Coping responses get operationalise particularly after the event strikes and may need short- as well as long-term measures to reduce its impact immediately as well as for future occurrences, e.g. flooding due to sewer blockage needed the sewer to be cleaned either by sewer staff of city municipality or by private cleaners immediately. It moreover, called for desiltation of the drains and proper maintenance of the sewer lines regularly.

These responses involve taking actions aimed at reducing the extent of resultant implications. They usually include immediate strategies which are put into actions during the time of crisis. It was widely reported during the field survey that households adopted locally learnt domestic measures to cope with the problems of wastewater nuisance e.g. as the sewage water was getting leaked into the water supply pipe lines, residents usually let water run for sometimes before collecting them for consumption. They usually spread oil on the stagnant wastewater to avoid the breeding of mosquitoes or even temporarily diverted the generated wastewater to a tank or ditch which could be emptied later.

Coping responses also include activities undertaken by organised social groups like the Resident's Welfare Associations (RWAs) of the colony for restoring normalcy as well as reducing implications. Apart from other activities, such actions may comprise of measures for developing economic and social safety networks and providing a forum for communication; they facilitate learning from each other's experiences.

Apart from preventive, adaptive and coping responses which were more directly aiming at the maintenance of normal conditions, reduction of event impact or prevention of the event itself, social communities also responded indirectly towards anticipated risks and stresses e.g. reusing wastewater for purposes like sweeping the floor or flushing the toilet. These are also indirect responses to reduce water demand and simultaneously minimize the wastewater generation to avoid water-logging due to improper disposal. Furthermore, government and non-government organizations, health workers and community educators creating awareness among the social groups on the health hazards, sensitizing them to maintain cleanliness in and around the houses and not letting water stagnate, etc. are all examples of indirect responses to prevent potential hazards related to domestic wastewater mismanagement.

Responses to an event or outbreak may be coordinated, as through the policies of governments or through welfare associations aimed at eliciting the same action from many actors, or uncoordinated, as with independent actions of individuals, households or small communities. Both types of response can be either anticipatory or based on past experience (Stern, Young and Druckman, 1992). Response falls simultaneously into more than one category type as they are not mutually exclusive. Moreover, coordinated actions by governments, institutions and other cooperative associations can create new options for uncoordinated actors, prohibit or promote certain community actions as well as raise or lower the effectiveness of community responses e.g. existing RWA in the colonies active could prove to be very effective in solving the wastewater and sanitation problem in co-operation with the concerned water work department in the area.

8.4 Household and Community Measures for Managing Wastewater Problems in the Surveyed Areas

In the surveyed areas it appeared that the households took to various local strategies for managing the wastewater and defending themselves against the negative implications of wastewater and sanitation infrastructural stress depending upon their perception, capabilities and awareness of available options. Responses to water system management were better organized for planned colonies but unorganized and discrete; on the individual household basis, particularly in informal settlements. Kind of social responses and some commonly practiced measures at household levels for managing wastewater related problems in different residential colonies surveyed are listed in table 8.1.

Table 8.1: Household Measures Adopted for Managing Water and Wastewater Problems in the Surveyed Colonies

Type of colony	Kind of response	Measures adopted for wastewater management
JJ cluster	1. Unorganised responses. 2. Cope with the problem daily. 3. Find other alternatives. 4. Try to reduce vector abundance.	▪ Illegally connect to the sewer network. ▪ Get water from distant sources or from other colonies having piped water supply. ▪ Cover the open drains by stone slabs. ▪ Channel the household wastewater to the ditch and manually empty it into the nearby drain. ▪ Spread oil on stagnant water to avoid the breeding of mosquito.
Resettlement	1. Remain prepared to face water stress. 2. Adopt temporary preventive measures. 3. Depend upon government support for solution.	▪ Spray oil or disinfectants on stagnant water. ▪ Clean the drains individually. ▪ Reported to local political leader who would approach the Municipal Corporation office and get the work done.
Authorized	1. Advance protection. 2. Treatment of water. 3. Organised response through social networks.	▪ Resident Welfare Association usually looks after the maintenance of sewer system and cleaned regularly. ▪ In case of main sewer problem (e.g blockage) complain to the Municipal Corporation office or employ private cleaner for minor repairs etc.
Unauthorized	1. Adaptive measures. 2. Used local management strategies. 3. Avoidance of exposure to raw sewage. 4. Indirect response by minimizing wastewater generation.	▪ Disposal into on-site septic tanks. ▪ Channel the household wastewater to the open drains. ▪ Raised entrance to the house. ▪ Reuse the water to minimize the disposal and reduce water demand. ▪ Clean the drains individually.
Urban Village	1. Take to temporary coping measures. 2. Maintain cleanliness. 3. Avoid contacting wastewater.	▪ Use boring pumps to withdraw fresh groundwater. ▪ Clean individually or hire private cleaners. ▪ Mostly try to take precautions while going out of the house.

Source: Own draft based on household survey, 2005-2006 (N=696)

In the absence of sewer facilities in informal settlements, people usually took to on-site disposal mechanisms in the form of septic tanks. The responding households in unauthorised and JJ colonies located in the East discharged their wastewater from the household to a covered or uncovered ditch. This wastewater accumulated there to the full capacity of the ditch, which would later be manually emptied into the main drain in the vicinity or into the river Yamuna, depending upon the distance. Some of the households living along the bank of the river took to open defecation into the river itself, as this was the most convenient option available. Others usually had a septic tank which was cleared once in 3-5 years depending upon its capacity. Similar situations prevailed in urban villages in the southern location.

In situations where the sewer network was present, but due to illegal or informal status of the colony it was deprived of a connection, households privately connected to the main sewer (illegally). It was fairly convenient for the households which had the locational advantage of being very close to the manhole where the sewer opening could easily connect or had an open drain passing nearby. Such type of arrangement was more commonly seen in the JJ clusters and unauthorised colonies of the central location where the informal quarters almost merged with the authorised colonies.

Apart from adopting restrictive habit to use less water, minimization of wastewater generation was also commonly practiced in the form of 'wastewater reuse'. Water after washing of clothes was reportedly used for sweeping the floor or flushing the toilet. At localities where the availability of fresh water was scarce reusing of water was done to reduce the demand and at the same time minimize the wastewater generation as its instant disposal was also a problem.

It clearly appeared from the field experiences that residents of the authorized colonies are better socially networked and also organized in form of Resident Welfare Associations, with an elected president, vice president and a group of members. These associations considered themselves responsible for the general betterment of the colony. They looked after the security and hygiene needs of the colony, problems and maintenance of the basic services within the colony, etc. They were also better informed about the functioning of

Delhi Jal Board and the concerned officers therefore; any problem with such basic civic services was soon solved.

Thereby, colonies which had some form of resident's groups to bring the individual households together for a joint action mostly took to group responses which was somehow organised though not perfectly. It was noted that many respondents in informal settlements were too pessimistic about the improvement of the existing condition. They usually answered that the informal status of the colony did not bring them under the responsibility of the government and therefore they did not know who was responsible for the basic services and cleanliness of the area and whom they should approach for their prevailing sewer and sanitation problems.

It is the locally posted officials of DJB who looked into the daily matters concerning water and sewerage in their respective areas. The sweepers and sewer workers (*safai karmacharis*) were hired by DJB to clean the *nalas*, collect the garbage and remove blockages and attend to the complaints of the residents. During the time of urgency residents also approached these sweepers personally and hired them to do the cleaning at an additional charge. It was widely reported by the residents of almost all the surveyed residential areas that they had to hire these sweepers privately to get the *nalas* and drains in their immediate neighbourhood cleaned. This was an additional cost on the household expenditure which the family had to bear on a bimonthly or weekly basis.

In cases when the cost was not affordable by the households or group of households living in the same lane, they had to do the cleaning themselves. Usually, the area around the house was somehow cleaned by them but it was not possible for the household member to clean up the entire area or lane, which usually left the neighbours unsatisfied or with a feeling that the muck and garbage has been deposited in front of the neighbour's house in the process of cleaning their own. It was usually a source of conflict usually among the women in the neighbourhood houses.

The following quotation made from one of the female respondent's interview very clearly brings out the dissatisfaction which she has to bear everyday:

> *"I usually wait till my neighbour had done the cleaning so that I do not have to again remove the garbage. It is convenient for me to clean later as my house is at the end of the lane and usually all the garbage and mucks in the nala flushed from other houses gets deposited in front of mine. Everyday there is a fight (conflict) in our lane because of water or cleaning of nala. The safai karmacharis are not regular and even if they come they do not clean properly, we have to do it ourselves"* (Open part of the household questionnaire).

Additionally, there were also private sewer cleaners who worked as per the demand and requirement. These private sewer cleaners were expensive, costing about 700-1000 INR to clean the home sewer and remove mucks. In case a private sewer cleaner is involved it is the household who bears the cost of cleaning. People of a common colony also took to this option for collectively pooling in money and getting the sewer cleaned in their lane under the initiative taken up by any active individual of the locality. These were some of the unorganized or self-help option which the resident could use during the hours of need. These types of private sewer cleaners were frequently found operating in unauthorised colonies and in urban villages where the official sewer services were not provided by the city's civic body.

People possessing economic freedom to take care of sewer malady were in a better position to help themselves whereas marginalized population of the informal residential quarters seemed to be depending completely upon the mercy of the local leaders, since the local leaders of the area, usually known as the p*radhan,* in the informal quarters were more approachable and were in a better position to communicate with the higher authorities about the need of the colony. Therefore, the residents usually took their grievances to the *pradhan*.

There commonly existed biasness in dealing with the complaints lodged with the concerned department depending upon the social status of the person approaching. This was well known by the residents and became evident from one of the responses during field interview:

> *"The entire area is not good, the sewer gets blocked during monsoon and the lanes get flooded, so it needs to be cleaned and constructed properly. Sewers and nalas need to be cleaned regularly. The safai karmacharis come only when complained and that too only when the local leaders or any influential person complains"* (Open part of the household questionnaire).

This was one of the reasons why the local residents were hesitant to approach the department itself as there always remained a fear of 'not being heard'. It cannot be denied that some extent of negligence and reluctance does remain on the part of government departments to properly look into these everyday local problems which are largely avoidable. Public grievances still remained that the civic agency responsible for the maintenance of the existing infrastructure is grossly inadequate. Discussions with the community's representatives when viewed in conjunction with the numerous comments added to the survey forms; it becomes more evident that a significant portion of the residents feel the government is not taking proper steps to solve the problem of sewer provision and hygiene maintenance in their area.

Dependence upon the government was very pronounced. Residents always looked upon the government for any concrete action without taking or being unable to take strong initiative themselves. They think it is completely government's responsibility to look after the basic services. Even in the informal quarters where nobody pays anything for water and sewerage services residents expect the government to care. They usually express their grudge by saying that 'needs of the poor are not looked after by the government'. With this mental construct, residents of JJ clusters expect to be relocated or provided with a better settlement facility; resettlement and unauthorised colonies expect better provision and maintenance of the basic services in their neighbourhood.

But, the residents themselves usually lacked responsible behaviour when it came to care about 'public property' such as the community drains and manholes which were dumped with solid garbage even after prohibition to do so. It was frequently noticed that although the drains in the households were cleaned individually, there was a general apathy towards the common drains immediately outside the houses and in the neighbourhood.

Therefore, efforts made for household's cleanliness did not really save them from harmful exposures as the condition of their immediate neighbourhood was still pathetic.

Community participation sounds good for finding a common solution for local actors. But the very root of community participation depends on several factors including the level of education, income, awareness and the severity of problems faced in the area and the willingness of community members to cooperate, trust, devote time for the common cause and to make things work. One of the respondents of unauthorised colony in East Delhi when elaborating upon the practicality and resident's interest in community participation there clearly remarked that:

> *"The residents here are from different caste and communal background so there is no unity and most of people living here are tenants, they are private workers and so they have no time and no interest for any community work"* (Open part of the household questionnaire).

Due to numerous obstacles for the residents, particularly the ones inhabiting informal settlement and their gross incapability to solve or alleviate problems pertaining to infrastructural gaps and improper management, the wastewater disposal, irregular maintenance, inadequate sanitation and other allied problems discussed earlier remained an issue to be looked into seriously by the city government. More so, when the majority of the residents are neither in capacity and nor in power to response adequately to these infrastructural provision and maintenance crisis in the growing megacity.

8.5 Institutional Response: Adopted Strategies and its Effectiveness

Providing all citizens in the NCT equal access to an adequate and satisfactory level of basic water and sanitation infrastructure would require a sound financial base and commitment for greatly improved efficiency in operation and maintenance of the existing sewer and water system, systematic expansion of the sewer network to all the un-served urban areas, good coordination and planned development, exploration of options to reduce wastewater generation as well as reusing the domestic wastewater for non-portable purposes.

Institutional responses are primarily geared by policy implementations. In the case of Delhi too, elaborate plans and policies exists to take care of the city needs. After elaborate study of the existing condition of environmental services objectives which were outlined in the Delhi Urban Environment and Infrastructure Improvement Project DUEIIP[26] (Delhi 21) for achieving the goal of "appropriate sanitation and drainage for all" were outlined as follows:

- Providing systematic repair and maintenance of the sewer and drainage networks.
- Investment in better solid waste management.
- Expanding the existing wastewater collection to serve all areas.
- Upgrading and constructing sewage treatment plants.
- Providing local wastewater treatment where primary sewers are not available.
- Providing appropriate sanitation where sewerage is not practical.
- Urban planning to provide public spaces for peak flood water retention.
- On-channel storage on main drains to attenuate flood flows.

Additionally, there are schemes to augment existing drain capacity, cover the *nalas* and open drains and ensure proper maintenance. To achieve these objectives future policies intended to be implemented are establishment of independent regulator to ensure targeted service delivery, a rise in sewerage tariff (with subsidies for the poor) to cover the sewage collection, treatment and operations and make the management financially self-sufficient, further ensure properties are connected to sewerage network and promote environmental health awareness and good hygiene practices, especially among the urban poor.

Historically, wastewater systems were provided to reduce the level of waterborne diseases such as cholera and typhoid. However, more recently, the service level to be

[26] "The Government of NCT of Delhi and Ministry of Environment, Government of India, sponsored this study with Japanese funding through the World Bank with a view to examine the existing situation and formulate policies, action plans for leading Delhi from its present situation to a more environmental friendly and better governed city in the next 20 years. The Team of Consultants consisted of specialists in various fields placed together by GHK International, UK and Operation Research Group, India. A series of consultations took place before the document was finalized. Followed with all necessary zeal and interest the series of strategic actions suggested are expected to lead Delhi to a well managed, clean and dynamic city serving its citizens, the nation and the world" DUEIIP, 2001: preface page.

achieved by the wastewater system is being driven more by environmental issues. This is especially true in case of Delhi where recent works have been constructed to comply with the Honorable Supreme Court Orders. The focus of works now is to minimize the impact of wastewater effluents on the water quality of the river Yamuna (Delhi Jal Board, 2004b). In this respect, on the macro level, the main goal and response of the state has been in direction of pollution abatement of the Yamuna via improvement in wastewater collection, treatment and disposal system.

Under the direction of honourable Supreme Court, Delhi has enormously for restoring the quality of river Yamuna through YAP (Yamuna Action Plan) and other river cleaning activities and actions. YAP-II is in the second phase now (2004-2008). Under this plan augmentation of sewage treatment capacity, laying of new sewer lines and rehabilitating the existing one was undertaken. The plan further aimed at providing low cost toilets and connecting the waste of slums and unauthorised settlements to the treatment plants. It can be estimated that since the mid-1990s Delhi government has invested about 2.02 billions to 2.70 billions USD on building sewage and wastewater treatment facilities and by the end of YAP-II it would have invested approximately 3.15 billions to 4.23 billions USD just to clean up 22 km segment of the river traversing the city (CSE, 2005). But with little success as the quality of the river continues to deteriorate.

Further, there was zone-wise plan of action; each of the eight zones of Delhi is directly under zonal engineers who are responsible for provision and maintenance water and sewer in their respective zonal area. Further at locality level are the junior engineers who are based in different local offices of DJB. The everyday problems related to water and sewers are looked into by the junior engineers. These problems constitute minor repair works and maintenance; further actions on the infrastructural improvement and change are under the control of higher DJB officials.

The interview with one of the junior engineers from Central Public Work Department (CPWD) in one of the surveyed area gives first-hand information on the kind of actions and responses to the reported complaints, which usually are executed by them.

> *"The major work of junior engineer is daily routine maintenance repair minor electricity and water leakage and sewer problems. These small works are looked after internally by our own workers. If it is something major then the consultants are brought in. Sewer is connected to the main trunk sewer and it is under DJB control. It is only the internal problems of the colony which is looked after by CPWD. The proposal for change and repair of sewer lines is under consideration"* (Quoted from the discussion with interviewee No. 11 listed in Appendix II).

It is the junior engineers who are easily approachable by the residents for their problems and are considered to be the responsible authority, but in reality although there remains enough complain and need for major change and maintenance but until the official order is provided by the Delhi Jal Board, it remains difficult for the junior engineer to respond or take any further action. This kind of power control and execution is surely hindering timely provision of urgently needed responses at local levels.

Irrespective of promising policy measures and plans undertaken for appropriate sewerage and sanitation for all citizens', large extent of areas still remains unsewered and the river quality continues to degrade. Understanding why wastewater and sanitation problem still exist, although governmental institutions and individual communities are constantly working towards alleviation of this long-standing problem, requires various strategies adopted by the institutions as well as those taken by individual community till now to be reviewed for their effectiveness in result and identifying reasons for their failure. This would further facilitate identification of response gaps and help find means to fix them.

The plans for sewerage provision in reality have shown limited results. There were also actions taken in the direction of improving sewerage and sanitation but without success; treatment plants capacity were augmented, pumping stations built and sewer lines laid but they were not connected to households; large extents of sewer lines at various surveyed sites of east and south Delhi, particularly at Mehrauli area were still awaiting to be made functional. Numerous treatment plants already built are working below capacity and untapped sewage continues to flow down to the river. A large proportion of illegal population has not been sufficiently cared for by the city government as there still remains no policy to provide them with sewerage. Only a small percentage of the regularised unauthorised colonies have been provided with sewer connection, the quality of which remains highly substandard and the maintenance is completely neglected.

Since the areas where sewage is generated remains inadequately linked to pumping stations and the treatment plants carry on underutilisation of its installed capacity, this only re-attests major planning gaps, lack of foresight and vision. The sewerage treatment plant locations are inappropriate and not thoughtfully planned. They were randomly strewed (on the basis of land availability) and not built with pollution management perspective. The situation is further worsened when the treated effluent is discharged into the drains which are already receiving raw sewerage from unconnected areas downstream and by the time it joins the river treated effluent gets polluted again and thereby all the treatment effort is actually wasted.

At the regional level, the staff working for sewer department is not skilfully trained to perform efficiently. The local *safai karmacharis* or sweepers learn the skill of sewer and drain cleaning, day to day maintenance, removing mucks and desilting over time by practice. Moreover, these are the underpaid labour class and there is no further incentive for them to work efficiently. It was also reported by the residents of various colonies that the *safai karmacharis* or sweepers remain absent for days and are reluctant in performing their duties regularly. Therefore, even with a good number of local staff engaged for cleaning and maintenance work, lanes in majority of the colonies remain unclean with heaps of waste and mucks lying rotten for days, emitting fowl odour and breeding disease vectors before they are finally removed.

Conclusively, the civic body in-charge of these basic utilities are heavily pressurised by rapidly increasing demand on one hand and highly scarce public funds on the other. Additionally, existence of multiple structural and organisational hindrances and undue political interference hinder effective responses. Moreover, inaccurate estimations, planning flaws, various bureaucratic issues and lack of surveillance have resulted in ineffective and excessively wasteful interventions.

8.6 Existing Gaps and Deficiencies for Effective Responses

Urban system resilience is greatly enhanced by efficient institutional structure, beneficial relationship between municipal and national government (Solway, 1994 c.f. Pelling, 2003: 81) and involvement of all stake-holders. Weak institutional organization coupled with poor urban governance have led to numerous obstacles which have directly hindered efficient management and adequate infrastructural access on one hand and indirectly threatened human health and environmental security on the other. Under such circumstances, at city level, some social community even if they have potentials to help themselves find it increasingly difficult to deal with the problem of securing a safe livelihood as they are faced with numerous economic, political and legal hindrances acting as limiting factors towards their developmental attempts. The manifold managerial, governance shortcomings and resource constraints hindering effective responses and effort to provide adequate water and sewerage disposal facility for all can be summarized at the institutional and community level.

8.6.1 Institutional Shortcoming

The worsening problem of wastewater management and inadequate sanitation attests that current governmental actions have been highly inadequate in alleviating them. Years of planning and infrastructural upgradation too have failed to achieve declared goals and the developmental results have not benefited all social communities equally. In addition, multiple structural institutional set up, scarce funding, undue political interference and other organizational obstacles have hindered achievement of targeted results. Various shortcomings at the institutional level are described below:

8.6.1.1 Multiple Authorities in-Charge

In the national capital territory of Delhi, water supply and wastewater service go together and is a public responsibility. There are several authorities engaged in the development and maintenance of water supply and sewerage in the city, namely, DDA (Delhi Development Authority), DJB (Delhi Jal Board), MCD (Municipal Corporation of Delhi), DCB (Delhi Cantonment Board), and NDMC (New Delhi Municipal

Corporation).Conflicting priorities of different authorities and lack of a common action plan affects delivering of services for the city in general.

Additionally, the administrative zones, water supply zones and sewerage zones do not match which again leads to planning and organizational problems. With numerous agencies in charge and overlapping responsibilities make it difficult for the common people to approach the right department in case of need indicating lack of good information policy. Therefore, a coordinating body between these agencies, common zonal consensus and action plan is essential for efficient functioning of this service system and making basic services equally accessible by all.

8.6.1.2 Fragmented Responsibility

Division of responsibility between various agencies in-charge is an important issue according to the study. In many cases it also gets problematic for the commoners to complain about certain persistent problems in their locality, e.g. sewerage is under DJB but the maintenance of the major canals and its surrounding area falls under the responsibility of flood and irrigation department. Therefore, the surrounding areas of the canal could not be cleaned up by the local sweepers and breeding of mosquitoes along the side of the canal could not be checked as its maintenance (weeding and clearing grasses) was not under the DJB responsibilities, for which the flood and irrigation department needed to be approached separately.

Any matter to be resolved or decision to be taken need to be pass through different levels of official procedures which were usually complicated, lengthy and time consuming. Clearance of a single order needs to go through numerous tables ‘officially’ before it is implemented. Delays are also common even for rectification of the smallest problem. Such delays and pessimistic experiences in getting the work done by official authorities usually act as major hindrances in retaining the trust of common people.

8.6.1.3 Lack of Accountability

There is lack of transparency about the responsibilities of the different agencies in-charge for water and sanitation in the city. Since the individual agency’s task and responsibility remains unclear, there exists lack of accountability too. Prevalence of widespread corruption among the officials and reluctance in action is widely reported by the general public. There needs to be a regulation in operational mechanism of the water and sanitation sector. Responsibilities of the involved agencies and department need to be made explicitly clear even to the general public through good information techniques.

Moreover, the performances and targets achieved must be under strict surveillance. Above all proper steps should be taken to make action and responses time-bound. There are no doubts about the plans and intentions of the civic agencies to be working for general good but the targets laid down must be achieved within a stipulated time period. Regular reporting and evaluation of performance of various sectors of the water, wastewater and sanitation concerned civic bodies would help in efficient functioning and management.

8.6.1.4 Weak Financial Base

The financial base for wastewater and sanitation service sector is fundamentally important. Public sector provides these services at a highly subsidized rate. The cost recovery mechanism for infrastructural provision and maintenance is very limited for the city government. Since the available finances are limited they need to be managed efficiently by the water and sanitation managers. But, in the absence of common plan of action, regulation and co-ordination need based targets are not achieved.

Over the years continuous investment has been directed in the Yamuna Action Plan with the aim of cleaning the river but with no success. Decentralization in service provision, involvement of private agencies for selective maintenance, good quality service provision and effective cost recovery plans may prove helpful improving the financial base. Willingness of the household to pay for the sanitation and wastewater services can also increase if the quality of service provision is good and people’s trust is restored.

8.6.1.5 Unstable Managerial Position and Political Influences

Instability in the higher managerial position in Delhi Jal Board and other concerned authorities of the water and wastewater sector is yet another issue. Priorities for one official may not be same for the other holding the same position for making decision. Matters remain pending and take more than expected time if frequent change in managerial position takes place. Such issues do not have considerable impact on day to day management but they certainly affect the progress and decision making on macro level of management.

Undue political involvement and domination influences the decision makers of service sectors too. Political arrangement limits the operational independence of the managers to a great extent. Although being on the agenda list of all the politicians over the year, water and sewerage conditions of the residential colonies in Delhi have not improved. Promises of equal access to safe drinking water and provision of sanitation to households has remained crucial to attract the vote bank of massive underprivileged population. But the wastewater and sanitation situation has not perceivably improved also due to lack of continued political commitments.

It is necessary to keep the service sector free of political manipulations, which can be achieved more importantly by making the sector financially self-sufficient and transparent. Managers of the basic infrastructures and services need to remain autonomous to have independence in taking decision, which should go in the direction of prioritizing fulfillment of people's need and work towards sustainable performance. Better stability in the managerial position and time-bound task fulfillment might be helpful for the officials to provide better services and management without undue delays.

Apart from these factors, other hindrances that constrain efficient institutional performance are inadequately and poorly trained staff, frequent changes in the policies and programme and low level of work efficiency. These are further exacerbated by mushrooming of new residential areas and constant increase of population with lower capabilities, jointly increasing the demand which cannot be sufficiently met within the existing resources resulting in gross management and planning failure.

8.6.2 Constraints at Community/Household Level

Social community and individual households find it increasingly difficult to deal with the prevailing situation of stress. Several local household measures, like covering up the adjoining open drain, collecting wastewater in ditches and tanks and hiring private sewer cleaners, were helpful for dealing with the problem shortly. But they were ad-hoc provisions, highly unsustainable and ineffective in the long run. Some social communities of informal settlement quarters, who were possessing economic capability to help themselves (by privately applying for water and sewer connection or construction of drainage channels and sewer tanks) were faced with various institutional and legal constraints. Hindrances at the community and household levels are discussed in detail below.

8.6.2.1 'Illegal' Status of the Colony

Under the present policy, no sewerage is provided in unauthorised colonies. In the last years of planned development a good number of unauthorised/regularized colonies have been connected to sewer (GNCTD, 2002-03). But the quality of services provided was surely below standard and grossly inadequate.

The illegal status of the residential areas keeps them out of civic service provision. It further prohibits them from taking to other options to help themselves. Procedures involved in getting a legal water supply or even getting a sewer connection at areas where such possibilities technically exist requires submission of various documents before the authority pertaining to the proof of residency, which in many cases are complicated for people to obtain. In such matters they prefer to find the easy way out by illegally connecting to the nearby pipeline. Complicated official procedures and legal constraints also prevented residents from efficiently taking to self-help.

Additionally, inequitable distribution of water, sanitation and other services depending upon the social status of the neighbourhood deprive people of their basic rights and increases resentment amongst the deprived social groups. The actions and responses of the residents within their limited resources remain inadequate and inefficient.

The president of a Resident Welfare Association's (RWA) from one of the surveyed unauthorised colonies reveals various kinds of hindrances towards improvement of unauthorised colonies, which are not yet regularised and are unable to get any financial aids from the city government.

> *"Regularization of all unauthorized colonies can improve all Delhi because more than 70% of inhabitants of Delhi live in this kind of colonies. We do not get or take any benefit of the government programs because most programs which are given by govt. to RWA require at least 250 households. But this colony only has 195 households so we do not qualify for such benefits"* (Quoted from the discussion with interviewee No. 6 in Appendix II).

8.6.2.2 Financial Incapability

Institutions in developing countries dealing with water and sanitation issues have rarely been designed to cater for large numbers of poor people. At the level of operations, public utilities are often constrained by bureaucratic requirements (IHE, 2003)[27]. Given the complexities of sewerage inadequacies, social groups have to depend upon their own limited resources, which remain grossly ineffective in dealing with problems related to basic services of wastewater and sanitation. Coping capabilities and efficiency of response towards wastewater infrastructural stress to a great extent depend upon the financial competence of social groups.

It has been clearly observed that the households belonging to comparatively higher economic strata, although residing in an informal setting, could effectively respond towards the inadequate infrastructural provisions by privately availing of on-site sanitation (septic tanks). Further, they could construct underground tanks to collect the domestic wastewater which could be emptied or cleared later. They also got connection to the nearby drains. The on-site sewers were also adequately maintained by availing

[27] Issues concerning institutional options in wastewater and sanitation in developing countries: Synthesis report for the Institutional and Management Options Working Group Water Supply and Sanitation Collaborative Council, Prepared by IHE, the UNESCO Institute of Water Education, Version 23/5/2003 (MPVD).

private sewer services whereas their counterparts with lower income could barely meet their household needs and for them investment into sewer and sanitation was out of their financial capability.

8.6.2.3 Prevailing Local Politics

Residents in most cases approached the MLA (member of legislative assembly) of their locality for the water, wastewater and sanitation related problems in their colonies as they were considered to be more influential in getting the work done. It was largely reported during the field study that areas under command of influential local leaders, particularly of the ruling party were more privileged in getting additional tankers of water and getting sewer-related problems fixed.

In a few cases the residents were very much satisfied with the performance of the elected leaders and were willing to re-elect them as they proved to be of help in looking after their day to day basic needs. This made it clear that the social groups were aware of undue political influences on the management of the basic services.

Interestingly, even the lane in which the president of RWA or some colony local leader resided were fortunate in getting favours in the form of timely responses by *safai karmacharis* (MCD sweepers); the wastes and mucks were removed and the *nalas* (drains) were regularly cleaned. Such extraneous influences were the reason for unequal treatment and inequitable provision of services to social groups.

8.6.2.4 Lack of Information

Residents were not fully aware of the right place/person to approach during emergency related to sewer and sanitation. Multiple agencies in charge of the services also created shifting of responsibility. A good proportion of households (35%) said that they did not know whom or where to approach for their wastewater and sanitation problems.

Usually the nearest MCD or DJB office was informed but in most cases, residents just depended upon the local leader or the RWA as they could get the problem fixed soon. Moreover, residents, particularly of the resettlement and unauthorised/regularised colonies, reported that the department and the local officers were reluctant in responding to their day to day problem; only when the drains overflowed or flooding got serious that the problem could attract attention.

Delhi Jal Board has established an Emergency Grievance Response System where water and sewer related grievances can be reported; even online complaints can be registered on the official website of DJB, but none of the households surveyed were aware of this facility. This was due to lack of information dissemination by the local officers concerning upcoming facilities as well as ignorance and limited internet access and use for these purposes.

Therefore, awareness building and information propagation about upcoming services and options provided by the civic bodies would be useful in responding to the prevailing sewer and sanitation problems more adequately and effectively.

8.6.2.5 Hindrances to Effective Social Networking

Social networking and community participation proves to be helpful to mitigate local problems. In Delhi, the Resident's Welfare Association (RWA) is one such kind of cooperation between the residents of a community which usually looks after the day to day management of basic provisions, organizes community activities and helps in better communication, understanding and solution of local problems. It provides an open forum for discussion and communication with the higher officials when need arises. In other cases, residents of a common locality can participate in socializing and work towards the general development. These groups also have an elected president who works with a group of other elected members and looks after the functioning and management of basic utilities in the locality. All RWAs need to be registered in order to benefit from the government programme.

Working of RWA of authorised colonies particularly the ones inhabited by comparatively higher income groups (e.g., co-operative housing in East Delhi), was more fruitful and efficient than compared to their counterparts in the disadvantaged neighbourhood with comparatively underprivileged population in the informal colonies.

Many of the lower income informal localities had some sort of people's group existing but were not functioning due to lack of funds and devoted participants. Moreover, these groups were not registered with the MCD; therefore, they were not able to benefit from government programmes and financial support. Poor people found it difficult to devote time for association work, which affected its proper functioning and task fulfilling. Additionally, lack of mutual cooperation, trust and common consensus among the members also hinder efficient functioning of social groups and reduced chances of community participation for local level solution to ongoing sewer and sanitation problems.

The following narration by one of the resident representative brings us very close to the point that lack of mutual cooperation among the members of residents group and involvement of local politics reflects negatively on the groups trust, performances and results in response biasness.

> *"About 60% of people here are more vulnerable because of lack of infrastructure (especially waste water disposal). They are not poor in general but not connected to the sewer network. As high as 90% of people in this unauthorised colony depend on RWA for their problem but the problems are not looked into efficiently or properly by higher officials; for example; if the tube well is not working, then they complain to the DJB officer and it is repaired; so people have some kind of trust in RWA, but in the last two years due to internal problems within RWA (the group is getting politicised and some members are getting politically influenced) party people are favouring their own party (BJP and Congress party). If people support the ruling or dominant party they get some favours from the community leader or MLA and even from higher officials as their problems are looked into very fast. If not, then matters remain pending for a long time before any action is taken. There is too much of politics now"* (Quoted from the discussion with interviewee No. 5 in Appendix II).

8.7 Concluding Remarks

Effective response has always proved to reduce risk and decrease the need for serious action. Since we can considerably eliminate and avoid the wastewater related hazard, timely needed responses to the risk can therefore prevent potential outbreaks and environmental- and health-related emergencies in future. Moreover, it can also be helpful in reducing the household financial burden by directly saving time spent on wastewater- and sanitation-related hassles for useful economic activities and also through reduced expenditure on water-related illness by improved sanitation and hygiene conditions.

It is clear from the above discussion that institutions in fast growing urban areas water, wastewater and sanitation issues are increasingly getting complex. Various institutional legal and social constraints have hindered effective responses towards management of problems related to sewerage and sanitation services for a large number of poor people. Effective actions to reduce wastewater-related risk by efficient response needs to be taken at the national, regional, community as well as household level, and further linked to each other. All the actions need to be within a time-bound framework. There are multiple factors in play which need to be taken into consideration during the planning for urban settings. This implies to look for integrated solutions at an affordable price.

Despite governmental responses with new plans and policies, the water system infrastructure has remained highly inadequate. The government of a megacity, like in Delhi, must plan and design the provision of basic service to cater adequately to the huge ‘illegal’ population of informal quarters as well. Future efforts and policies must aim at overcoming these obstacles and expanding private sector participation (PSP) to increase efficiency through incentive and performance management as well as improved public information systems and transparency of these operations.

Presently, private sector involvement is only limited to construction and technical operation. Thus, extending private sector involvement to include maintenance of the discrete distribution and collection network can improve the quality of services. Moreover, encouragement of private sector financing and higher cost recovery would provide a stronger financial base and free the scarce public funds for other important investments in social development.

Households on the basis of their perception and capabilities act to reduce the implications of wastewater nuisance by taking up precautionary actions where possible and endure the unavoidable circumstances when the household measures fails. Local measures are capable of providing preventions for a short time but the long-term structural solution of the problems is beyond household capabilities, which urgently require need-based effective response from the civic agencies to be executed with proper coordination at the community, zone/region and state level.

People’s involvement at all levels – from planning to implementation – can be helpful in building trust and making the provision and maintenance of water- and sanitation-related basic services ‘everyone’s business’. Though actions at household and community level are important and highly required but unless the root causes of infrastructural inadequacies and hindrances to effective response are removed, the currently unplanned actions would continue to be superficial and all planned interventions and agendas would finally prove to be extensively wasteful experimented endeavours.

Chapter 9

Conclusions and Recommendations: Key Steps for Future Actions

9.1 Introduction

The previous chapters have proven that megacities are not only threatened by consequences of sudden external shocks and hazardous events but they are also prone to slow risk events as well as a potpourri of social segregation, disparities, conflicts, inadequacies and stresses which generate harmful social, economic and environmental consequences. Social groups inhabiting these centres are frequently subjected to risk, social vulnerability and health insecurity due to lack of environmental services, denial of basic rights, and inadequate infrastructural access like water supply, wastewater disposal and sanitation. In this context, the present case study of Delhi explains various aspects of wastewater-related risks that urban citizens are living with and the level of social vulnerability they are subjected to in connection with waste water.

This chapter concludes the present research and makes some broad recommendations on the basis of its findings. Since each individual chapter had its own concluding remarks earlier, it seems appropriate to synthesise them in this chapter and draw important findings which need to be highlighted. Herewith, the chapter answers the research questions and outlines major findings. It further discusses probable solutions for more improving wastewater management and finally points out the scope and limitations of the study.

9.2 Answers to the Research Questions

1. Where mainly is wastewater generated and what is the status of its management?

The wastewater generated from the surveyed areas was largely domestic in nature. It comprises water generated from household activities such as washing, cleaning, bathing and toilet water comprising of sewage with faecal matter. The wastewater is laden with soap, detergents and allied chemicals, organic detriments, etc. as they are produced by the households in the day to day activities. Included are also waste waters generated by activities like home-based beauty parlours and small-scale household industries like book binding, printing, handicrafts, sewing and embroideries, etc., carried out in some of the surveyed areas which were primarily ‘residential’ colonies. These activities add to the generation of extra wastewater. Moreover, non-segregation of toilet water from other domestic wastewater loaded the sewage with high level of faecal coliform bacteria which the sewerage treatment plants are not equipped to decimate.

Wastewater generation is increasing steadily but its management in the study area is highly precarious. Large extent of residential area (approximately 35%) is still unsewered and unconnected to the sewerage treatment plant. Field observation and survey results re-emphasise the lapse in wastewater infrastructure in the study area which are highlighted in the following:

- Authorised colonies which secured piped water supply at household as well as from multiple other available sources consequently generated more wastewater due to their increased usage habit.
- Although water supply is provided for unauthorised and illegal colonies, too, via tanker supply or community water points, no provision of secured wastewater disposal is made.
- Sewer coverage is better at central location than compared to east and south location survey sites. About 95% of the households in surveyed colonies of Central Delhi were having access to sewer facility as compared to only 55% at East Delhi and a little more than 40% in South Delhi.
- About one-third of the surveyed population had no access to any wastewater disposal infrastructure which forced them to either restrict their water use so as to generate less wastewater and/to take other alternative disposal practices of compromised hygiene.

2. What are the risks of wastewater mismanagement in the study areas?

Insufficient and unreliable water supply, inadequate sewer coverage, improper management of wastewater and frequent malfunction of the existing wastewater and sewer system are some of the major issues that disrupts the daily life activities of the residents leading to various kinds of water system related risks to humans and environment. Water-borne, water-related and water-washed diseases have become common illnesses widely reported in the city all year round. They can be attributed to consumption of contaminated water, open defecation and garbage disposal and exposures to all-time wastewater stagnation in puddles and open drains which also serve as breeding grounds for disease-carrying vectors.

Wastewater mismanagement poses:

- Environmental risks in terms of water pollution by harmful contaminants present in sewage, emission of fowl odour and degradation of environmental aesthetics.
- Health risks of contacting water-borne, water-related and water-washed diseases due to consumption of contaminated water.
- Economic risks of incurring expenditures on treatment of diseases which could be largely avoidable. Additional expenditures on managing the wastewater privately.

3. How are people exposed to wastewater and what are the causes for their defencelessness?

The locus of exposure to various wastewater related harmful perturbations in case of Delhi is embedded in the location, status of the residential quarter, general demographic characteristics, social profile and level of access to the wastewater and sanitation infrastructure by the households. Human exposure to wastewater occurred either through direct contact with raw sewage or by consumption of sewage contaminated water.

Providing quantitatively and qualitatively adequate as well as easily accessible basic services is one of the major responsibilities of good urban governance. But in Delhi the prevailing wastewater and sanitation conditions are indicative of severe water system infrastructural stress, incapability and gross neglect of the municipal authorities in providing and maintaining required sanitation services of acceptable standard to the citizens. The condition also reflects to some degree people's ignorance and apathy towards wastewater problems which also contributes enormously to their exposures to various wastewater hazard risks.

Various causes pertaining to planning failure, insufficient financing, legal and political hindrances as well as socio-cultural and behavioural drawbacks which are responsible for the existence of wastewater hazards and increasing social defencelessness against it, operates at national, neighbourhood and household levels and is summarised in Table 9.1.

Table 9.1: Causes of Defencelessness against Wastewater Hazards

	City Level	**Neighbourhood Level**	**Household Level**
Physical/Planning	1) Hyper-urbanisation. 2) Increasing informality. 3) Planning failure and infrastructural inadequacy.	1) Violation of planning norms. 2) Inadequate sewer network. 3) Old and silted drainage system. 4) Existence of poorly maintained open drains.	1) Locational marginalization. 2) Lack of access to sewerage. 3) Unhygienic onsite disposal.
Environmental	1) Wastewater management crisis. 2) Water pollution. 3) Monsoon flooding.	1) Unhygienic surrounding. All time flooded narrow lanes. 2) Fowl odour and aesthetic degradation. 3) Mosquitoes and rodent infestation.	1) Contaminated water supply. 2) Wastewater flooding at households.
Socio-cultural	1) Fragmented and unclear institutional responsibilities. 2) Complicated bureaucracy.	1) Conflicts and lack of co-operation. 2) Lack of effective social networking and community participation	1) Pressure of other household problems. 2) Lack of awareness and information.
Economic	1) Unreviewed investment. 2) Unequal sectoral allocation of funds.	1) Lack of funds for social groups like Resident Welfare Association. 2) Skewed allocation of financial resources towards advantaged neighbourhood.	1) Increased household expenditure. 2) Financial crisis.
Behavioural	1) Institutional corruption. 2) Fragmented responsibility in administration	1) Reluctant attitude of the community members.	1) Open washing, open defecation and physical contact with raw sewage. 2) Compromised hygiene behaviour.
Legal	1) Constrained legal procedures.	1) Informal status of the colony.	1) Unclear ownership rights.
Political	1) Weak governance. 2) Lack of coordinating bodies	1) Dominance and biasness towards members of favoured political groups.	1) Selective favours from local leaders/*Pradhans*

Source: Own draft

4. What are the household and institutional responses and how effective are they?

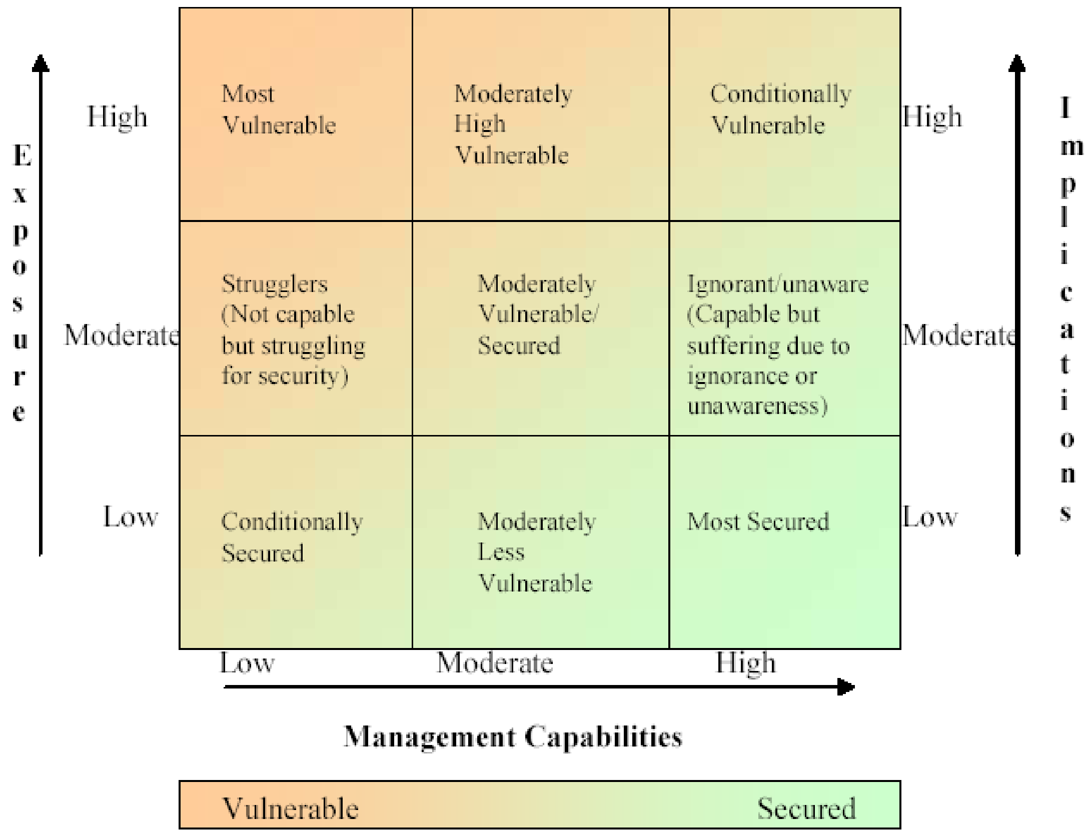
Households on the basis of their perception and management capabilities respond to reduce the implications of wastewater hazard by coping, adjusting and adapting to it. They take up precautionary actions like elevating the entrance of the houses to prevent wastewater from entering the households, netting the windows against mosquitoes, etc. where possible and endure the unavoidable circumstances when the household measures fails. Households individually and in co-operation with each other adopted organised as well as unorganised local measures such as getting the sewers cleaned either individually or by hiring private cleaners, etc. to deal with wastewater problems, but they were usually on short-term basis as the main sewers remained silted and the seasonal flooding could not be avoided. When the root of the problem is more complicated pertaining to planning and other structural defects solutions get beyond the scope of household level management.

Proper management of wastewater goes right in the direction of controlling water pollution, improving health and maintaining environmental aesthetic. As it is one of the major responsibilities of the city government, it undertakes to do this by establishing an appropriate set of organisations like Delhi Jal Board, Irrigation and Flood Control Department, Conservancy and Sanitary Engineering under Municipal Corporation of Delhi, Delhi Pollution Control Committee, etc. working towards its provision, maintenance and sustainable management. Plans and policies are worked out to extend the sewer coverage, improve wastewater collection and augment the sewerage treatment plant capacity. In Delhi although most of the endeavour towards wastewater management has been undertaken with the vision of improving the water quality in river Yamuna, the achievement is still below satisfactory as the quality of water in the river continues to deteriorate, large extent of residential areas are still not sewered and the maintenance of the existing ones are poor.

5. Which individual/households/social groups are more vulnerable and why?

Social vulnerability in this case is identified in terms of exposure to wastewater, management capacity and extent of harmful implications. This perspective brings forth that the most vulnerable individuals/households/social groups are those who are at most exposure to wastewater hazards, have the weakest management capabilities and consequently suffer maximum harmful implications. Individuals/households/social groups could be most secured or most vulnerable or anywhere between these two extremes. They could either be conditionally secured or conditionally vulnerable, not capable but struggling for security or capable but still suffering due to ignorance or unawareness about available coping options (Fig. 9.1).

Fig. 9.1: Varying Degree of Social Vulnerability



Source: Own draft

Since the chosen unit in the present case is 'household' analysis of the vulnerability component namely wastewater exposure, management capacity and the suffering from implications in terms of reported illnesses, are done at household level, which found them to be differentially vulnerable or secured depending upon their level of susceptibility, endurance and coping with the harmful implications of wastewater hazards. Only 39 (5.6%) of the surveyed households were most secured whereas 294 households (42%) were moderately vulnerable and 70 households (10%) were most vulnerable to the wastewater hazards (Table. 9.2).

Table 9.2: Distribution of Surveyed Households on the basis of Varying Degree of Social Vulnerability

Health Implication (No. of Households)	Management Capacity	Degree of social Vulnerability	Number of Households
< 2 cases of reported illnesses in the household Low (217)	High	Most secured	39
	Moderate	Moderate low vulnerable	90
	Low	Conditionally secured	88
2-3 cases of reported illnesses in the household Moderate (346)	High	Ignorant/unaware	44
	Moderate	Moderate vulnerable/secured	151
	Low	Strugglers	151
> 3 cases of reported illnesses in the household High (133)	High	Conditionally vulnerable	10
	Moderate	Moderately high vulnerable	53
	Low	Most vulnerable	70

Source: Own household survey 2005-2006, N= (696)

Households with high exposure as well as high suffering from implications but possessing low management capabilities are the **most vulnerable**. This may be owing to a combination of circumstances like unprotected locational setting, illegal residential status with precarious provision of wastewater disposal infrastructures and safe drinking water supply along with poor socio-economic conditions and lack of effective social networking. On the contrary, **most secured** households primarily with formal residential status and legal provision of water system, were less frequently/rarely facing wastewater related problems and consequently were least exposed and least sufferers of wastewater hazard implications. These households possessed high management capabilities and diversified options to choose in order to deal with wastewater problems.

Moderately vulnerable/secured households were at medium exposure and had similar level of management capabilities. They could either take up precautionary actions or manage to escape the exposure with their given level of capabilities and thereby be **moderately less** vulnerable or when the level of exposure increased due to the failure of adopted measures at their given level of moderate management capabilities their vulnerability increased to **moderately high** level. Households with low level of capabilities but still not severely impacted due to their constant effort are classed as **strugglers** i.e. not capable but still struggling for security whereas households who were completely capable of coping and management but still suffered were either **ignorant or unaware** about the management options available. Therefore, they were consistently impacted by the harmful implication although they were socio-economically and politically able to combat it.

Households which possessed low management capabilities but luckily were least exposed as well as had lower level of implications are **conditionally secured** as their security is not backed by a strong level of capabilities in terms of education, economic stability or social and political networking. On the other hand households with high exposure level, which had a high level of capabilities, were willing and able to help themselves but were somehow prevented from doing so due to social, institutional and political hindrances. Therefore, they continued to suffer high level of implications; such households are termed as **conditionally vulnerable**.

Even within the households certain social groups like women, children, elderly and handicapped were at greater vulnerability due to higher level of their exposure probability pertaining to their activities and comparatively lower capabilities to prevent and cope with the ill hazards of wastewater. It is rather difficult to specifically demarcate the location of each category of these households in Delhi as different category types co-exist within very close quarters.

6. What are the possible solutions for prevailing wastewater problems?

It is important to point that the actions and interventions are needed at every stage to combat the progression of social vulnerability emanating due to lack of appropriate public services like provision of safe water, wastewater disposal, sanitation, etc. Till date primarily structural solutions have been sorted for them, which have shown only limited results in alleviating the wastewater problems. It is, therefore, important to highlight the need for non-structural solutions as well. A balanced combination of structural (extension of sewer lines, building of sewage collection system and enhancing the treatment capacity etc.) as well as non-structural solutions (educating social groups, awareness building, capacity enhancement etc.) is necessary for dealing with the prevailing wastewater problems.

Time-bound actions to reduce wastewater related risk by efficient response need to be taken at the national, regional, community as well as household level, and further linked to each other. All the actions need to be explicitly defined within a time-bound framework. It is absolutely necessary to get the available strategies into place and dig deeper into the possible actions involving scientific research, findings implementations as well as community sensitisation which can be undertaken to prevent hazardous outbreaks where possible, cope and mitigate the occurred ones and atleast be prepared to face the surprise events which are beyond ones present knowledge and anticipation. Availability and easy access to diversified options for prevention, coping and adaptation to the existing problem could reduce the extent of implications.

In order to address the issue of inadequate infrastructure and management particularly water and wastewater sector in urban areas it is necessary to take into consideration the different socio-economic strata of the society itself, particularly the types of housing areas. High income urban communities, for instance, are generally willing to pay for sewerage services and higher water supply tariffs for good standard services. It is therefore important to segregate the tariff framework for the people on the basis of colony types and the standard of provided services.

Some possible solutions can come by adoption of the following recommendations:

- Sensitising the social group (awareness and education)
- Diversifying the options for prevention, coping and adjustment
- Extending the scope for public-private partnership
- Removal of constraints to self-help
- Area specific planning keeping also the need of huge in-migrant (illegal) population in mind
- Wastewater recycling and reuse

It is imperative to educate particularly the female members about the potential impacts of wastewater exposure and encouraging them to participate in a cooperative manner towards its mitigation as far as possible and beyond that taking the issue to the civic body directly. This hinted at provision of more accessibility to the available community sanitation options for women and simultaneously education and awareness about the resultant impacts to womenfolk.

9.3 Wastewater Reuse: An Integrated Remedial Measure

It is clear from the above discussion that institutions in fast growing urban areas water, wastewater and sanitation issues are increasingly getting complex. Various institutional and social hindrances have prohibited adequate access of basic water and sanitation services by a large number of poor people. There are multiple factors in play which need to be taken into consideration during planning for urban settings. This implies to look for integrated solutions at an affordable price.

Reusing wastewater within the city is an interesting alternative to deal with the problem of water shortage and increased wastewater generation. Delhi generates an immense volume of wastewater, all of which goes down the drain polluting the river. If this effluent is taken back into the water system it can ease the pressure on the existing freshwater resource of the city to a great extent and save the river from degradation. Since the traditional means of water supply augmentation, wastewater management and pollution abatement is inadequate; recycling of effluents seems to be an important step in controlling pollution and preserving healthy environment.

Reuse of wastewater can be laid as an option to partially supplement the present water supply, enhance wastewater management and reduce environmental pollution. Reclaimed wastewater can be reused for various non-potable purposes at household as well as city level like flushing of toilets at households, for road flushing and as water for mixing concrete, brick making and other construction purposes, use in industries as cooling water, booster feed water and other industrial process water, for fire fighting, in horticulture and urban agriculture both in the city and periurban area. Although the initial cost in terms of effort and investment seems to be high but if put together all the factors including the environmental and health costs that the public is paying at the current situation, wastewater reuse seems well justified from the socio-economic point of view. With proper planning and organisation reclamation and reuse can prove to be a sustained wastewater management technique in urban settings.

This might involve introducing the dual-pipe system which would provide high standard safe drinking water whereas the second supply can cater to non-potable uses which does not require very high quality control. In Delhi, where illegal connections are frequent and many customers have no idea of the quality and resultant health risks, where household installations are on the whole unreliable and of substandard construction, it is highly inadvisable to implement dual-pipe supply systems to reduce the health risks by supplying high quality water for drinking (demand for which would be much less in quantity) and the high demand of water to be used for non-potable uses can be met with water of medium quality.

Thus, wastewater reuse can be seriously be included in water and sanitation planning as an integrated measure to augment water supply and control wastewater hazards. Further options for wastewater reuse can be explored and major water users can be approached to ascertain their interest in using treated wastewater.

9.4 Major Findings

The findings of the present study, which are based on empirical field work, support the theoretical concept that social vulnerability is the defencelessness of certain individual/households/social groups against stresses which impact them through harmful implications of multiple types. The degree of social vulnerability is determined by the outcome of struggle between their exposure to wastewater problems, related stresses and their coping capabilities. In this respect some of the major findings about wastewater related social vulnerability in Delhi are listed below under the following heads:

Exposure side:

- The rate of urbanisation in Delhi is faster than the capacity of local government to adequately manage it. This is reflected in almost all the sectors like housing, water supply, sanitation, wastewater disposal and health care where plans have failed to achieve their goals.
- Planning for only structural solutions to the problems has shown limited results. Extension of physical infrastructure without its proper maintenance and direction to the public for its correct usage was largely a wasteful endeavour with only limited solution to the problem.
- Inhabitants of megacity Delhi are exposed to multiple threats to their basic rights, health security and overall well being, which cannot be granted by only considering physical exposures to hazards, infrastructural stresses and other harmful environmental perturbations or solely by strengthening their economic capabilities.
- Unsafe conditions as reflected in specific situations of various types of colonies in formal and informal settings and marginalization of social groups to the disadvantaged locations partly determined the cause of their vulnerability in the city's urban setting.

Coping and Management side:

- Adaptation of preventive and coping strategies depended upon the diversity and accessibility of the available options, economic affordability of the households and level of social networking at the local level. In this respect, the poor have access to fewer options to deal with risks.
- Although the socio-economic attributes of households remain a supportive factor, households lacking knowledge and awareness about the available options for

preventing, coping and adapting remained socially vulnerable to the prevailing stress.

- People's perception plays a very important role in determining the overall vulnerability of social groups. It influences the level of risk awareness among individuals and social groups. The manner in which an individual or social group perceives existing problems affects the extent of their exposure and simultaneously moulds their response towards it.
- Wastewater disposal related problems were not perceived as an important hygiene related issue among the residents of Delhi. It emerged that although the respondents were aware about the wastewater hazards most of them were not considering any serious preventive measures due to unawareness about the available options or their inability to access them.
- The prevailing institutional and political environment of the area, level of co-operation among the residents and effectiveness of community participation are important in influencing the overall resource capabilities and resilience of the community.

Organised and good quality public services can help build people's trust in the management and also increase people's willingness to pay for the services. Apart from directly alleviating environmental and public health risks better water, sanitation and wastewater disposal facilities would also help in reducing the economic risk by allowing the residents to cut down avoidable household expenditure on health and waste management.

It is necessary to respond effectively towards alleviating the wastewater disposal related problems aiming at the mitigation as well as removal of its root causes. This draws emphasize on various types of long-term and short-term action plans involving structural and non structural measures to improve the wastewater ands sanitation situation in the city. In this respect appropriate institutional as well as individual actions are needed at various stages in the process of interaction between human and environmental systems to protect against threats to social community and environment itself.

9.5 Scope and Limitations of the Study

The present study takes a step forward in the analysis of vulnerability by also looking into the environmental-health implications. It identifies points where effective action and intervention is needed in order to alleviate vulnerability of the social groups. The study also provides insights into the scope of community participation and reiterates the importance of co-operation and social networking in building up the community's resilience towards hazards.

This study highlights the loopholes in the present community as well as institutional responses towards wastewater management in the city. Therefore, the recommendation of the study to adopt a balanced mix of structural and non structural solutions can serve as a basis for effective action planning and related policy implementation at the institutional level which can be helpful in dealing with urban wastewater management problems.

The present research is a part of the project which aims at integrating social analysis and remote sensing approaches. In order to integrate the results derived from social analysis with that of image processing, all the surveyed households will in the final step of the project be georeferenced on the image, and the result about household exposure, management capabilities and implications as extracted from the processing of household questionnaire would be further linked to them for better analysis and understanding of the ground situation, thereby supplementing the visual details as perceived and interpreted from the remote sensing data. It is expected that this integrated modelling of remote sensing and social science research approaches would be able to provide quick insight into the dynamics of fast changing megacities, and transferability of the developed methodology to areas of similar setting would help in understanding situations of larger areas with greater precision in shorter time.

In the present case, vulnerability analysis is done on household level selecting indicators which reflected the core determinants of exposures, management capability, and implications. The indicators display in a direct manner the social vulnerability of the households across colony types. They however, do not show the dependence and variations according to the magnitude of the problem faced by the different households.

The study is primarily based on extensive household surveys where the primary data collected is limited to representative colonies purposively selected from various locations. Thus, throughout, it should be kept in mind that the data obtained are answers to pre-formulated questions. This not only places constraints on what can realistically be expected of a household survey, but affects how the results can and cannot be interpreted. Since the analyses are done on area- and colony-specific basis, the results can only be applied to other areas of similar settings with careful alterations.

The existing documentation of colony types outline their characteristics in terms of provision of basic services, land use, legal status of the land on which they are built, etc. It is, however, worth mentioning that there is no official definition for these settlement types and there also exists discrepancies regarding universal acceptance and usage of terminologies too (Batra, 2005). During the course of fieldwork, it was frequently noticed that there was no clearly perceivable demarcation between certain colony types (e.g., between unauthorised and resettlement), i.e., existence of colony of different legal status but similar physical structure within very close quarters sometimes even merging with one another, thereby making the differentiation between different colonies difficult.

Moreover, it needs to be highlighted that in this study different colony types are taken to be the broad frame for categorisation, and it reflects the level of wastewater exposure in a direct manner but they cannot be interpreted directly for overall social vulnerability of its residents because the informal status, precarious wastewater disposal infrastructure or unhygienic surroundings, which enhance exposure to wastewater, could get negated by the management capabilities of the social groups in terms of their effective response and option to adopt preventive and coping measures against wastewater hazards.

Further research is needed to find out alternate wastewater management solutions for fast growing cities, which include identification of even the subtle root causes for the same, policy reviews, explicitly defining the actions/interventions and probing further into the prospect of integrated remedial measures, e.g. wastewater reuse, decentralised wastewater management at the community level, etc. Simultaneously, further research is also needed for recommending suitable strategies for sensitising the vulnerable groups, making them aware about the available options, building their capacity to access them in a diversified manner and enhancing the resilience of social communities in urban areas.

However, the present case study has been able to highlight the criticality to focus on urban risks and social vulnerability due to perpetual exposure to harmful or unfavourable perturbations of varying nature pertaining to physical, environmental, institutional and economic stresses. These may not necessarily be extreme events but still pose increased threats to environmental and human securities and show implications on more long-term basis. It further calls for making urban system more shock-absorbent, keeping it prepared to handle the known stresses and also to face the unknown ones.

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Appendix

Appendix I

UNIVERSITY OF COLOGNE

UNIVERSITY OF MUNICH

DEPARTMENT OF GEOGRAPHY

HOUSEHOLD QUESTIONNAIRE

No.________________

Interviewer:___________________ Date:___________________ Time:___________

Address of the House:____

GPS reading:____

Introduction: This is a survey done for a Ph.D research by the Universities of Cologne and Munich, Germany. The purpose of this is to find out your personal perception and views regarding the issues of water and wastewater in Delhi. The information so collected would be ONLY used for academic purpose and only anonymously .

OBSERVATION:

1. Type of house ____________ Garden _______________

2. Name of the colony and Type_____________________________

3. Housing material_________________

4. Roof material __________________ flat or sloping______________

5. Amenities In the house:
   T.V________________________
   Fridge______________________
   Vehicle (specify)_____________
   Washing machine_____________
   Telephone___________________
   Air conditioner________________

Air Cooler____________________

6. Is there a overhead water tank (how many and volume) ___________________________

7. Is there a private hand pump (Y/N) If Yes, then its distance from the house______________________.

8. Is the house connected to a sewer system___________________

9. Is there an open drain or canal draining wastewater (Y/N) If Yes, then its distance from the house______________________

10. Does the wastewater drains to a local ditch / open_______________

11. Is the wastewater generated, directed to the kitchen garden_________________

PERSONAL INFORMATION:

1. Name
2. Age
3. Sex
4. Education
   i. No school qualification
   ii. Primary school until_________________
   iii. Secondary school until___________________
   iv. Graduation__________
   v. Post Graduation___________
   vi. Technical education__________
   vii. Others_______________
5. Caste:_________________________________
6. No. of Family members______________ (Age-Sex Structure)

7. Occupation of the head of the household: ___________________

8. How many earning member are there in the family___________________

9. How much is your monthly household income? Write the figure if given.

   i. Less than 2000/-

   ii. 2000/- to 5000/-

   iii. 5000/- to 10000/-

   iv. More than 10000/-

10. Do you have a ration card or get any benefit from the government?

11. Have you added some extension to the earlier construction here ?

    Yes / No What and why?

12. How did you get to k now about this place?

14. When did the respondent has moved here? And reason for moving to this place?

    i. Nearness to family and relative
    ii. Nearness to place of work
    iii. In search of employment
    iv. Cheaper rent
    v. Others

15. From where have you moved to this place? (mention the place)

    i. Within NCT of Delhi
    ii. Some other place outside NCT
    iii. From the village within NCR
    iv. Neighboring states Like UP, Rajasthan, Bihar etc..
    v. Others

<u>WATER AVAILABILITY AND CONSUMPTION</u>

1. What is the source of water at your residence? (Multiple answer to be recorded)

   i. Municipal tap in house
   ii. Municipal tap in the community

iii. Hand pump to extract the groundwater.
iii. Well
iv. Pond
v. Water vendors
vi. Tankers by DJB
vii. Others

2. How much are you charged for the following and do you think it is appropriate?

i. Meter bills
ii. Tankers
iii. Bottled water
iv. Others
v. Total

3. How long is the pipe (DJB) water supply available in a day?

Once / Twice / Thrice / Others__________________(note the timing)

i. Less than 4 hours.
ii. 4 to 8 hours
iii. 8 to 12 hours
iv. 12 to 24 hours
v. Others

4. Do you think water supply is sufficient with respect to the quantity, pressure, flow?

Yes / No, Why?

5. Have you taken any measures in your household or in your neighbourhood to overcome these problems? If Yes, what?

If No, then do you intend to take some measures in future? What have been the obstacles until now?

6. If there is a water crisis, then is it……

i. Hamper economic activities (How).
ii. Hamper household activities (How).

iii. Force you to reschedule your activities in order to be available during the Municipal supply of water.

7. Do you need to fetch water from outside your house, Y/N, (If Yes, then what is…..)

i. Distance of the water point_________________
ii. Time spent to fetch water_____________________
iii. Associated cost incurred __________________________
iv. Number of family members engaged to get water________
v. How often_____________________________

8. How much water on an average is used for? (No. of buckets)

Summer Winter Monsoon

i. Bathing
ii. Washing
iii. Toilet flushing
iv. Cleaning
v. Car washing
vi. Watering lawns and gardens
vii. Others

9. If there is insufficient water supply, does it cause conflict?

i. Within household
ii. In the locality household
iii. Public water point

10. Has the quantity/quality of water required at by your household has changed over last 5 year?

i. Increased	i. Improved
ii. Decreased	ii. Deteriorated
iii. Remained constant	iii. No change

Reasons:

WASTEWATER / SEWERAGE WATER

1. Where does the household wastewater drain?

2. Do you face household wastewater disposal problem in your present situation?

3. Where does the toilet water drain?

4. Do you face sewerage disposal problem?

Yes / No (what kind)

5. Is wastewater disposal a problem in your own house or in the immediate neighbourhood or both

If Yes, What kind?

6. Are the drains in your locality well maintained and who maintains it?

Yes / No

7. How frequently are the drains/nalas in your area cleaned?

i. Monthly
ii. Half Yearly
iii. Yearly
iv. Do not know

8. How frequently does the drain/nalas in the locality get overflowed?

i. Seasonally, monsoon seasons mainly
ii. Most of the time
iii. Rarely

9. Should community be held responsible for dealing with wastewater generated?

Yes / No

<u>WATER / WASTEWATER RELATED ENVIRONMENTAL AND HEALTH RISKS</u>

1. Has there ever been any kind of water quality problem in water supply?

   Yes / No

   If Yes, the nature of problem

2. Does the water that is used have some fowl odour / colour?

   Yes / No

   If yes then why do you think it is so?

3. Do you always boil the water before consumption? If Yes then for how long?

   Yes / No

4. Is there some official recommendation from the water authority to boil drinking water?

5. Is there some restriction of using hand pump water for consumption in this area? Why do you think it is so?

6. How strongly do you feel affected by the following problem in your area?

   a) The wastewater disposal

      i. Strongly affected
      ii. Moderately affected
      iii. Little affected
      iv. No effect

   b) Foul odour

      i. Strongly affected
      ii. Moderately affected
      iii. Little affected
      iv. No effect

   c) Others, namely: Mosquitoes, flies, rats, cockroaches and why?

	Mosquitoes	Flies	Rats	Cockroaches	others
Strongly affected					
Moderately affected					
Little affected					
No effect					

Reason:

7. Whom do you hold responsible for the cleanliness of the area?

8. Have you heard about such incident of sewage water leaking into drinking water in your household or your immediate neighbourhood?

   Yes/No

   If yes then relate when and how did it happened?

9. Have you noticed any positive or negative effects of the infrastructure development, like waste water disposal or sewerage system in the area?

   i. Positive changes (what kind)____
   ii. Negative changes (what kind)_______________________________________
   iii. No comments____

10. What kind of problem does the present wastewater disposal system pose?

    i. Foul odour
    ii. Dirty water logging
    iii. Mosquitoes and other insects breeding
    iv. Eyesore
    v. Chocked and overflowing drains
    vi. Others
    vii. No problem

11. Do you or any other member of your family (particularly children) sometime get in physical contact with the wastewater in the open drain, canal or ditches? Yes or No

    If Yes then how?

12. Do children also defecate in the wastewater channels in front of the house? if Yes, Why?

13. Have you or a family member had any health problem during the past 12 months?

Problem	Age	Sex	How long?	Cost (Rs)
Flu like symptoms: 1. Fatigue 2. Fever 3. Shivering (not due to low temperature) 4. Perspiration (not due to physical activity) 5. Joint and muscle aches 6. Trembling limbs				
Respiratory symptoms: 1. Cough 2. Shortness of breath				
Irritation symptoms: 1. Nose irritation 2. Throat irritation 3. Eye irritation 4. Skin irritation 5. Skin rash 6. Other skin problem				
Neurological symptoms: 1. Headache 2. Forgetfulness 3. Dizziness				
Gastrointestinal symptoms: 1. Lack of appetite 2. Vomiting 3. Diarrhoea				
Diseases: (has any of these been diagnosed by a doctor) 1. Cholera 2. Dysentery 3. Malaria 4. Dengue 5. Jaundice/hepatitis 6. Typhoid 7. Hookworm 8. Filariasis				
Others:				

14. Has there been any death in the family in last 1 year_______________Age_________Sex_______

Reason for death____________________

PERCEPTION REGARDING WATER / WASTEWATER

1. Do you know of recent activities from NGOs, RWAs, CBOs, DJB and others to improve water supply in your neighbourhood? Give examples. Do you benefit from them? (Y/N) Why?

2. How would you rate the present wastewater disposal system in your area?
   i. Very Good
   ii. Good
   iii. Poor
   iv. Non existent
   v. Cannot say

3. Where do you think the wastewater/sewer finally drains to?

4. Does it receive some kind of treatment?

5. Do you think the present way of wastewater disposal in your community is safe or it has some adverse effect on the environment? How?

6. Why do you think wastewater/sewer disposal is at all a problem in your area?

7. Were you aware of such sanitation problem before settling in this area?
   Yes/No

8. Are you aware that the sewage water is also reused?

9. Is wastewater being reused for agricultural purpose in your area?

10. What are the probable wastewater reuse options in your view?
    i. Washing vehicles

ii. Watering plants
iii. Flushing toilets
iv. Agricultural purposes
v. Others

11. Do you also adapt to some of these alternatives? Specify which one?

12. If the government announces some plan for reusing reclaimed wastewater what would be your reaction?

13. Do you think the concept of community participation is practical in your area for encouraging community based wastewater management techniques?
    Yes / No (Why)

14. Who do you think should take the initiatives of managing the wastewater in your area?
    i. Individuals at household levels
    ii. Local committees
    iii. Government

RESPONSES

1. Are you satisfied with the water supply situation?
   Y/N
   If not, why and whom do you think is responsible?

2. Do you think wastewater and sewerage is managed properly in your area?
   Yes/No, If No, why?

3. Whom do you approach if you face some problem with drainage?

4. Are you aware of health risks from wastewater lying in the open? What do you do regarding it?

5. Do you think reuse of reclaimed wastewater can be a means to cope with wastewater disposal problems?

6. What are your suggestions to cope with…………
   i. Water shortage problems?

   ii. Waste water / sewerage problems?

<u>घरेलू प्रश्नसूची</u>

क्र. संख्या:____________

उत्तरदाता का नाम:________________________ तिथि:_____________
समय:______________

घर का पता:
____

Gps
Reading:____
___

भूमिका: यह एक सर्वे है जो कि पीएचडी शोध के लिए. म्यूनिख यूनिर्वसिटी, जर्मनी द्वारा करवाया जा रहा है. इसके ज़रिए हम नीचे दिए गये मुददों के संदर्भ में आपकी व्यक्तिगत राय व दृष्टिकोण को जानना चाहते है। जो भी जानकारी मिलेगी उसे महज़ अकादमिक अध्ययन के लिए ही इस्तेमाल किया जाएगा।

<u>अवलोकन</u>

1. घर की ढांचगत स्थित___________________________बगीचा (गार्डन)
____
2. कॉलोनी का नाम और
टाईप____
3. मक़ान में लगी
सामग्री____
4. छत पर लगी
सामग्री____
5. घर में इनमें से क्या-क्या मौजूद है:
   टीवी____________________
   फ्रिज़____________________________
   वाहन (कौन सा)_____________________
   कपड़े धोने की मशीन________________
   टेलिफोन___________________________
   एयर-कन्डीशनर______________________
   कूलर______________________________
6. क्या आपके यहां पानी का टैंक है___________________________________

7. क्या यहां निजी हेन्डपम्प है (हां/ना). यदि हां, तो घर से इसकी दूरी कितनी है____

8. क्या घर, सीवर व्यवस्था से जुड़ा हुआ है_______________________________

9. क्या इस्तेमाल किया हुआ गंदा पानी यहां खुले में बहता, है या नाली के ज़रिए बहता है (हां/नहीं) यदि हां तो घर से इसकी दूरी क्या है__________________________________

10. क्या इस्तेमाल किया हुआ गंदा पानी बहकर किसी स्थानीय नाली या गढढे में जाता है____

11. क्या इस्तेमाल किया हुआ पानी सीधे बगीचे में जाता है____________________

<u>व्यक्तिगत जानकारीयां:</u>

1. नाम -
2. उम्र -
3. लिंग -
4. शिक्षा -
   - i स्कूली शिक्षा नहीं_________________
   - ii. प्राथमिक स्कूली शिक्षा _______________तक
   - iii. माध्यमिक स्कूली शिक्षा ______________तक
   - iv. स्नातक ___________________________
   - v. स्नातकोत्तर_________________________
   - vi . तकनीकि शिक्षा _____________________
   - vii. अन्य _____________________________

5. जाति______________
6. परिवार के सदस्यों की संख्या _______________
7. घर के प्रमुख का रोज़गार _________
8 घर में कमाने वाले कितने सदस्य हैं __________
9. आप के घर की मासिक आमदनी कितनी है? बताने पर संख्या लिखें।
   - i. 2000 से कम

ii. 2000 से 5000

iii. 5000 से 10000

iv. 10000 से अधिक

10. क्या आपके पास राशन कार्ड है या आपको सरकार से कुछ अन्य सुविधाएं मिलती हैं

11. आप यहां कितने सालों से रह रहें हैं?

i. एक साल से कम

ii. एक से तीन साल

iii. तीन से पांच साल

iv. पांच साल से अधिक

12. क्या आपने पुराने निर्माण में कुछ बढ़ोत्तरी की है?

हां/ना क्यों?

13. आपको इस जगह के बारे में जानकारी कैसे मिली?

घरेलू सर्वे - स्वास्थ /प्रयावरण स्कूली शिक्षा

1.) क्या घर में स्कूल जाने वाले बच्चे हैं? (हां/ना)

अ- यदि हां, तो कितने/ उम्र क्या है/ कौंन सी कक्षा में?

ब- जिस स्कूल में जाते हैं उसका क्या नाम है?

बच्चे	***उम्र***	कक्षा	स्कूल
1			
2			
3			
4			
5			

2.) क्या आपका बच्चा/ बच्चे आपको बताते हैं कि उन्होंने स्कूल में स्वास्थ के मुददे पर कुछ सीखा है? (हां/ना)

अ. वह ठीक-ठीक आपको क्या बताते है

3.) क्या आपका बच्चा/ बच्चे आपको बताते हैं कि उन्होंने स्कूल में प्रर्यावरण के विषय में कुछ सीखा है

अ. वह ठीक-ठीक आपको क्या बताते है

4.) क्या आपका बच्चा/ बच्चे के व्यवहार में स्कूल में पढ़ाये गए प्रर्यावरण वह स्वास्थ संबंधी विषय के चलते कोई बदलाव आता है

अ. उनमें किस तरह का बदलाव आता है

5.) आपका बच्चा/बच्चे को स्कूल में पढ़ाई गई पर्यावरण व स्वास्थ संबधी शिक्षा के चलते क्या आपने अपने व्यवहार में कोई बदलाव किया है?

अ. आपने मुख्य रूप से क्या बदलाव किया

14. यदि आपका उत्तर दाता पिछले पांच साल के अंदर वर्तमान जगह पर आया है, तो उस का कारण क्या है?

i. परिवार और रिश्तेदारी से नज़दीकी
ii. काम की जगह से नजदीकी
iii. रोज़गार की तलाश में
iv. सस्ता किराया
v. अन्य

15. आप इस जगह पर कहां से आएं हैं ? (जगह का नाम लिखे)

i - राष्ट्रीय राजधानी क्षेत्र दिल्ली से
ii- राष्ट्रीय राजधानी क्षेत्र दिल्ली से बाहर किसी अन्य जगह से
iii- राष्ट्रीय राजधानी क्षेत्र दिल्ली के किसी गांव से
iv- पड़ोसी राज्यों जैसे उत्तरप्रदेश, राजस्थान, बिहार, इत्यादि से
v अन्य किसी जगह से

<u>पानी की मौजूदगी और उपभोग</u>

1. आपके घर में पानी का स्रोत क्या है? (कई तरह के जवाब दर्ज किये जाएं)

i. घर में निगम के नल से
ii. मौहल्ले में निगम के नल से
iii. हेंडपम्प से
iv. कुआँ
v . तालाब से
vi. पानी बेचने वालों से
vii. दिल्ली जल बोर्ड के टैन्कर से
vii. अन्य किसी स्रोत से

2. आप निम्नलिखित के लिए कितना भुगतान करते हैं और क्या आप सोचते हैं कि यह जायज़ है?
i. मीटर बिल
ii. टैन्कर
iii. बोतल बंद पानी
iv. अन्य
v. कुल

3. एक दिन में पाइप से पानी की पूर्ति कितनी बार होती है
एक बार/दो बार/तीन बार/अन्य____________(समय को नोट किजिए)
i. चार घंटे से कम
ii. चार से आठ घटे
iii. आठ से बारह घंटे
iv. बारह से चौबिस घंटे
v. अन्य

4. जिस दवाब, मात्रा और बहाव से पानी की पूर्ति होती है क्या आप उससे संतुष्ट हैं?
हां/नहीं, क्यों?

5. क्या आपने इन समस्याओं को कम करने के लिए कोई क़दम उठाया है?
यदि हां, क्या?

यदि नहीं, तो क्या आप भविष्य में इस तरह का कोई क़दम उठाने के बारे में सोंचते हैं?

6. क्या आपको किसी बाहरी स्रोत से पानी लाना पड़ता है, तब ______
i. पानी के स्रोत की दूरी _______________________
ii. पानी लाने में कितना समय लगता है_________________

iii. अन्य खर्च जोड़कर _____________

iv. पानी लाने में परिवार के कितने सदस्य लगे हैं_____________

v. ऐसा कितनी बार होता है_____________

7. यदि पानी का संकट है तो क्या इससे..........

i. आर्थिक गतिविधियों में परेशानियाँ आती है

ii. घरेलू गतिविधियों में परेशानियाँ आती है

iii. आपको दवाब में अपनी गतिविधियों को पानी की उपलब्धता के अनुसार तब्दील करना पड़ता है

8. औसतन पानी की कितनी खपत होती है? (बाल्टियों की संख्या लिखें)

	<u>गर्मियों में</u>	<u>सर्दियों में</u>	<u>मानसून में</u>
i. नहाने में			
ii. धुलाई में			
iii. टोयलेट में			
iv. सफ़ाई में			
v. कार की धुलाई में			
vi. बग़ीचे और आंगन में			
vii. अन्य			

9. पानी का संकट होने पर क्या इसे लेकर झगड़ा होता है? क्यों?

i. घर के अंदर

ii. मोहल्ले के घरों में

iii. सार्वजनिक पानी के स्थलों पर

10. क्या आप को लगता है कि पिछले पांच सालों में आपके घर में ज़रूरी पानी की मात्रा में बदलाव आया है?

i. ज़रूरत बढ़ी है

ii. ज़रूरत कम हुई है

iii. पहले जैसी ही है

कारण:

<u>इस्तेमाल पानी/पानी की निकासी</u>

1. घर का इस्तेमाल किया गया पानी कहां जाता है?

2. वर्तमान स्थिति में क्या आपको घर में इस्तेमाल किए गये पानी की निकासी को लेकर समस्या का समना करना पड़ता है?

3. टोयलेट के पानी की निकासी कहां होती है?

4. क्या आपको सिवरेज़ डिसपोजल की समस्या का सामना करना पड़ता है?
हां/नहीं

5. खुद अपने घर में या अपने पड़ोसी के यहां या दोनों जगह
यदि हां, किस प्रकार की?

6. क्या आप के मौहल्ले में नालियों की देखरेख बेहतर तरीके से होती है और उनकी देखरेख कौन करता है?
हां/नहीं

7. आप के इलाके में नालों कि सफ़ाई कितने समय में होती है
   i. महिने में
   ii. छः महिने में
   iii. एक साल में
   iv. नहीं जानते

8. आम तौर पर आपके मौहल्ले में नालों से पानी बहार कब निकलता है?
   i. मुख्यत: बरसात के दौरान
   ii. अक्सर
   iii. कभी-कभार

9. क्या अपने बेकार किए पानी को बहाने से पहले उसका शोधन करने की जिम्मेदारी समुदायों को दी जाने चाहिए?
हां/नहीं

<u>पानी/गन्दे पानी संबंधित पर्यावरण और स्वास्थ के खतरे</u>

1. क्या आप ऐसा सोचते हैं कि आपके पानी की पूर्ति के स्रोत गंदे पानी के कारण प्रदूषित हो रहे हैं? हां/नहीं

2. क्या कभी आपको मिलने वाले पानी की गुणवत्ता को लेकर गंभीर समस्या पेश आयी है?
हां/नहीं
यदि हां, तो समस्या की प्रकृति

3. जो पानी आप इस्तेमाल करते हैं उसमें गंदगी या रंग में फर्क आता है?
हां/नहीं
यदि हां तब आपको ऐसा क्यों लगता है कि वह ऐसा है?

4. क्या आप पानी का इस्तेमाल करने से पहले हमेशा उसे उबालते हैं?

यदि हां तो कितनी देर तक?

हां/नहीं

5. क्या पीने के पानी को लेकर जल विभाग द्वारा कोई आधिकारी सलाह दी गयी?

6. क्या हेंडपम्प द्वारा पानी के इस्तेमाल को लेकर किसी तरह की मनाई इस इलाके में है? आपके अनुसार ऐसा क्यों है?

7. अपने इलाके में निम्नलिखित समस्याओं से आप कितने गहरे तक प्रभावित हैं?

अ.) गंदे पानी का निपटान

i. बुरी तरह प्रभावित

ii. कुछ हद तक प्रभावित

iii. बहुत कम प्रभावित

iv. बिल्कुल प्रभावित नहीं

ब.) बदबूदार महक

i. बुरी तरह प्रभावित

ii. कुछ हद तक प्रभावित

iii. बहुत कम प्रभावित

iv. बिल्कुल प्रभावित नहीं

स.) अन्य, जैसे, कीड़े-मकोड़े, मक्खियां, चूहे, कॉकरोच?

	कीड़े	मक्खियां	चूहे	कॉकरोच	अन्य
बुरी तरह प्रभावित					
कुछ हद तक प्रभावित					
बहुत कम प्रभावित					
बिल्कुल प्रभावित नहीं					

कारण:

8. इलाके की सफाई के लिए आप किस को जिम्मेदार मानते हैं?

9. आपने किसी ऐसी घटना के बारे में सुना है जिसमें मल-जल/ गंदा पानी रिस कर आपके घर या पड़ोस में पीने के पानी में मिल रहा हो?

हां/ना

यदि हां, तो बताएं कि ये कब और कैसे हुआ था?

10. क्या आपने अपने इलाके में आधारभूत सेवाओं के विकास, जैसे इस्तेमाल हो चुके पानी के निपटान] या सीवर व्यवस्था में किसी सकारात्मक या नकारात्मक फ़र्क पर गौंर किया है

i. सकारात्मक फ़र्क____

ii. नकारात्मक फ़र्क____

iii. नहीं कह सकते ____

11. आप या आपके परिवार में से कोई सदस्य पिछले बारह महिनों में स्वास्थ संबंधी समस्या से ग्रस्त हुआ है?

समस्या	***उम्र***	***लिंग***	***कितने समय से***	***डाक्टर से परामर्श/दवाइयाँ(खर्च)***
<u>**फ्लू जैसे रोग लक्षण**</u> 1. फेटीग्यू 2.फीवर/बुख़ार 3 कँमकँपी /ठिठुरना (कम तापमान की वज़ह से नहीं) 4. पसीना (शारीरीक गतिविधि की वज़ह से नहीं) 5.जोड़ों और मसल में दरद 6.होठों का थरराना/काँपना				

समस्या	उम्र	लिंग	कितने समय से	डाक्टर से परामर्श/दवाइ याँ(खर्च)
<u>श्वास/सांस संबंधी रोग लक्षण है</u> 1 कफ 2.कफ के साथ बलगम 3.धीमी गति से सांस				
<u>चिड़चिड़ापन/उत्तेजना के रोग लक्षण</u> 1.बंद/बहती नाक 2.नाक में उत्तेजना 3.गले में ख़राश/उत्तेजना 4. आँख में उत्तेजना 5. त्वचा उत्तेजना 6.त्वचा में रैश (शरीर पर चिकत्ता पड़ना) 7. त्वचा संबंधी अन्य परेशानी				
<u>तंत्रिका संबधी रोग लक्षण</u> 1. सर में दर्द 2. मष्तिक में दवाब महसूस करना 3. एकाग्र करने में मुश्किल 4. याददाश्त कमजोर होना 5. चक्कर आना				

समस्या	*उम्र*	*लिंग*	*कितने समय से*	*डाक्टर से परामर्श/दवाइ याँ(खर्च)*
<u>गैस संबंधी रोग लक्षण</u> 1. भूख कम लगना 2. उल्टी आना 3. दस्त			**<u>घरेलू प्रश्नसूची</u>** क्र. संख्या:_____________ उत्तरदाता का नाम:_________________________ तिथि:_____________ समय:______________ घर का पता: ____ Gps Reading:____ **भूमिका: यह एक सर्वे है जो कि पीएचडी शोध के लिए. म्यूनिख यूनिर्वसिटी, जर्मनी द्वारा**	

समस्या	*उम्र*	*लिंग*	*कितने समय से*	*डाक्टर से परामर्श/दवाइयाँ(खर्च)*
<u>रोग/**बिमारियां: (**क्या इनमें से किसी भी रोग का डाक्टर द्वारा इलाज़ किया गया है**)**</u> 1. हैज़ा 2.पेचीश 3.मलेरियां 4.डेंगू 5.पीलिया/यकृत-शोथ (हेपेटाइटिस) 6.टायफाइड 7.हुकवार्म 8.फ़ाइलेरिया				
अन्य				

13.वर्तमान में इस्तेमाल पानी की निपटान व्यवस्था किस तरह की समस्याएं पेश करती हैं?

- i बदबूदार पानी
- ii गंदे पानी का इकट्ठा होना
- iii मच्छर और अन्य कीड़ों का पैदा होना
- iv आँखों में चुबना
- v नालों का बहना
- vi अन्य
- vii कोई समस्या नहीं

<u>पानी संबंधित ज्ञानबोध/इस्तेमाल पानी</u>

1. क्या हाल के दिनों में गैंर सरकारी संगठनों,आवासिय समितियों, सीबीओ, दिल्ली जल बोर्ड या किसी अन्य द्वारा आपके इलाके व आस-पास में पानी की पूर्ति को लेकर किसी गतिवधियों के बारे में आप जानते हैं?

उदारहाण दीजिए। आपको उनसे लाभ हुआ?(हां/ना) कैसे?

3. अपने इलाके में इस्तेमाल हो चुके गंदे पानी के निपटान व्यवस्था के बारे में आपकी क्या राय है? i i

क- बहुत बेहतर

ख- बेहतर

ग- म़ौजूद नहीं

घ- नहीं कह सकते

8. आपकी राय में इस्तेमाल हुआ पानी अंत में कहां जाता है?

9. क्या यह शोधन प्रक्रिया से गुज़रता है?

10. क्या आप सोचते है कि आपके समुदाय में फिलहाल इस्तेमाल हो चुके गंदे पानी की निपटान व्यवस्था सुरक्षित है या इसका पर्यावरण पर गंभीर असर पड़ रहा है? कैसे ?

11. क्या आपको लगता है कि गंदे पानी की निपटान व्यवस्था आपके इलाके में है? क्यों ?

12. इस इलाके में आने से पहले क्या आप सफ़ाई की समस्या से अवगत थे? हां/नहीं

8. क्या आप जानते हैं गंदे पानी को फिर से इस्तेमाल किया जा सकता है?

9. क्या आपके इलाके में गंदे पानी को खेती के लिए दोबारा इस्तेमाल किया जा रहा है?

10. आपकी नज़र में संभवत: किन विकल्पों के लिए गंदे पानी को फिर से इस्तेमाल किया जा सकता है?

i. कार की धुलाई

ii. पोधौ को पानी देना

iii. मलमूत्र की सफाई के लिए

iv. खेती के लिए

v. अन्य

11. क्या आप भी इनमें से किसी विकल्प को चुनतें हैं? मुख्यत: किसे?

12. यदि सरकार ऐसे पानी को दोबारा इस्तेमाल करने के लिए किसी योज़ना की घोषणा करती है तो उस पर आपकी क्या प्रतिक्रिया होगी?

13. क्या आप सोचते हैं कि सामूदायिक भागीदारी की अवधारणा आपके इलाके में इस रूप में व्यवाहरिक होगी की वह समूदाय आधारित गंदे पानी की तकनीकि देख-रेख को बढ़ावा दें?

हां/नहीं

14. आपकी नज़र में इस्तेमाल पानी की देख-रेख की पहल आपके इलाके में किसे लेनी चाहिए?

i. घर के स्तर पर व्यक्ति

ii. स्थानीय कमेंटियां

iii. सरकार

<u>शहरीकृत गांव या खेती युक्त ज़मीन पर घरेलू मालिकाना:</u>

1. क्या आपके पास खेती के लिए ज़मीन है? कितनी?

हां/नहीं

2. आप कौन-सी फसल उगाते हैं? क्यो?

3. सिंचाई की क्या व्यवस्था है?

4. क्या सिंचाई के लिए प्रर्याप्त पानी उपलब्ध है?

5. आप कौन-सी खाद इस्तेमाल करते हैं? कितनी?

6. यदि सिंचाई के लिए शोधन हुए गंदे पानी का इस्तेमाल किया जाता है तब क्या आपको स्वास्थ संबंधी किसी समस्या का सामना करना पड़ता है? (यदि सिंचाई के पानी का स्रोत वेस्ट-वॉटर नहीं है तो सवाल न. 8 और 10 को छोड़ दें) .

10. क्या आप ऐसे पानी का फसलों की सिंचाई के लिए इस्तेमाल होने से स्वास्थ संबंधित समस्या से अवगत हैं?

11. क्या सिंचाई के लिए ऐसे पानी के समपर्क में आने पर आपको कुछ स्वास्थ संबंधी या त्वचा संबंधी समस्या का सामना करना पड़ता है?

हां/नहीं, यदि हां, तो क्या?

12. आपके अनुसार सिंचाई के लिए ऐसे पानी का इस्तेमाल क्यों किया जा रहा है?

i. क्योंकि सिंचाई के लिए पानी की कमी है।

ii. क्योंकि उसमें पोषक तत्व होते हैं।

iii. क्योंकि यह आसानी से उपलब्ध है।

iv. क्योंकि यह सरकार द्वारा सिंचाई के लिए उपलब्ध कराया जाता है।
v. अन्य

<u>प्रतिक्रियाएं</u>

7. क्या आप पानी के वित्तरण की व्यवस्था से संतुष्ट है?
   हां/ना
   यदि नहीं, तो क्यों, आप की समझ से इसकी ज़िम्मेदारी किसकी है?
8. क्या आप मानते है कि आपके इलाके में बरबाद हो रहे पानी और सीवर व्यवस्था को ठीक से संभाला जा रहा है?
   हां/ना, यदि नहीं, क्यों?
9. पानी के निकासी की समस्या पेश आने पर आप किसके पास जा रहे हैं?
10. क्या खुले में पड़े इस्तेमाल पानी से होनी वाले स्वास्थ संबंधित खतरों के बारे में आप जानते हैं? इस संबध में आप क्या करते हैं.
11. क्या आप ऐसा सोंचते हैं कि इस्तेमाल किए गए गंदे पानी को फिर से इस्तेमाल करने लायक बना कर गंदे पानी के निपटान संबंधी समस्या से सामना करने का तरीका हो सकता है?
12. आपके सुझाव क्या हैं।सामना करने / निपटने के लिए ....

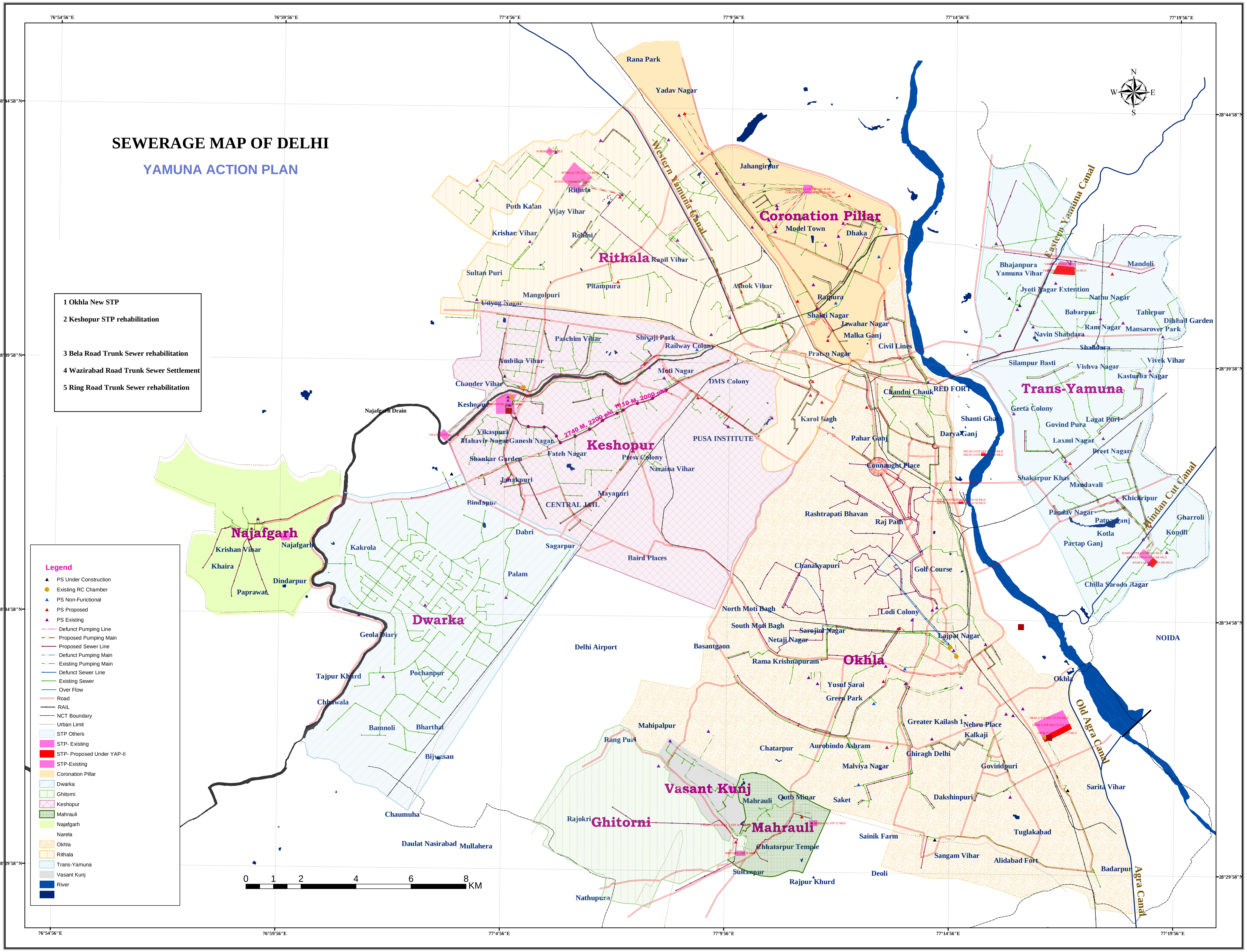
    i. पानी की कमी की समस्या से

    ii. इस्तेमाल किए जा चुके पानी/गंदा पानी/सीवरेज़ की समस्या से

Appendix II

List of Guided Interviewees/Discussants

1. Mr. N.R. Babu, Senior Environmental Specialist
2. Mr. M. Bhatnagar, Indian National Trust for Art and Cultural Heritage, INTACH
3. Mr. A.K. Jain, Town Planner, Delhi Development Authority
4. Mr. A. Kundra, Additional Chief Executive Officer, Delhi Jal Board
5. President of the Resident Welfare Association of C-Block, New Ashok Nagar
6. President of the Resident Welfare Association of D-Block, New Ashok Nagar
7. President of the Housing Committee of Delux, Vasundhara and Govind Apartments (Vasundhara Enclave)
8. Vice-President of the Resident Welfare Association of Greater Kailash II
9. President of the Resident Welfare Association of Bhomiheen camp
10. President of the Resident Welfare Association of Dujana House
11. Junior Engineer of Aram Bagh
12. Vice-President of the Resident Welfare Association of Chudiwalan
13. President of the Resident Welfare Association of Haveli Azam Khan
14. Secretary of the Resident Welfare Association of Sector III, Gole Market



Source: Delhi Jal Board, 2008

Exposure Index of the Surveyed Households **Appendix IV**

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
C2_5	3	3	4	1	5	5	5	5	5	1	1	3	5	5	51	3.6426
C2_6	5	5	4	1	5	5	5	5	1	1	1	5	5	5	53	3.7851
C2_7	4	1	4	1	5	5	5	5	5	1	1	3	5	5	50	3.5713
C2_8	5	1	4	1	5	5	5	5	1	1	1	3	5	5	47	3.3574
C2_9	5	3	4	1	5	5	5	5	5	1	1	3	5	5	53	3.7851
C2_10	1	1	4	1	5	5	5	4	1	1	1	5	5	5	44	3.1426
C2_11	5	3	4	1	5	5	5	5	1	1	1	3	5	5	49	3.5
C2_12	5	5	4	1	5	5	5	5	5	1	1	3	5	5	55	3.9287
C2_13	5	3	5	1	5	5	5	5	5	1	1	3	5	5	54	3.8574
C2_14	5	3	5	1	5	5	5	5	1	1	1	5	5	5	52	3.7149
C2_15	5	1	4	1	5	5	5	5	5	1	1	3	5	5	51	3.6426
C2_16	5	3	4	1	5	5	5	5	5	1	1	3	5	5	53	3.7851
C2_17	5	5	3	2.5	5	5	5	5	5	1	1	3	5	5	55.5	3.9649
C2_18	3	5	4	2.5	5	5	5	5	5	1	1	3	5	5	54.5	3.8926
C2_19	5	5	3	1	5	5	5	5	1	1	1	3	5	5	50	3.5713
C2_20	5	3	3	1	5	5	5	5	1	1	1	3	5	5	48	3.4287
C2_21	1	1	4	1	5	5	5	5	1	1	1	3	5	5	43	3.0713
C2_22	1	5	4	1	5	5	5	5	1	1	1	3	5	5	47	3.3574
C2_23	5	5	4	1	5	5	5	5	5	1	1	5	5	5	57	4.0713
C2_24	5	1	5	1	5	5	5	5	1	1	1	5	5	5	50	3.5713
C2_25	1	3	4	1	5	5	5	5	5	1	1	3	5	5	49	3.5
C2_26	5	5	5	1	5	5	5	5	1	3	1	5	5	1	52	3.7149
C2_27	5	1	4	1	5	5	5	5	5	1	1	3	5	5	51	3.6426
C2_28	1	5	4	1	5	5	5	5	5	5	1	3	5	5	55	3.9287
C2_29	1	1	4	1	5	5	5	5	1	5	1	3	5	5	47	3.3574
C2_30	1	1	4	1	5	5	5	5	5	5	1	5	5	5	53	3.7851
C2_34	1	5	4	2.5	5	5	5	5	5	5	1	3	5	5	56.5	4.0351

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
C2_35	5	1	4	2.5	5	5	5	5	5	5	1	3	5	5	56.5	4.0351
C2_36	5	5	4	2.5	5	5	5	2	5	5	1	3	5	5	57.5	4.1074
C2_37	5	3	4	2.5	5	5	5	2	5	5	1	5	5	5	57.5	4.1074
C2_38	5	5	4	2.5	5	5	5	2	5	5	1	3	5	5	57.5	4.1074
C2_39	5	5	4	2.5	5	5	5	5	1	5	1	3	5	5	56.5	4.0351
C2_40	5	5	1	2.5	5	5	5	5	1	5	1	3	5	5	53.5	3.8213
C2_41	5	1	4	3.5	5	5	5	2	5	1	1	5	5	5	52.5	3.75
C2_56	5	1	4	2.5	5	5	5	5	1	1	1	5	5	5	50.5	3.6074
C2_66	1	1	4	3	5	5	5	5	1	5	1	5	5	5	51	3.6426
C2_67	5	5	4	1	5	5	5	3	1	5	1	3	5	5	53	3.7851
C2_68	3	3	5	3.5	5	5	5	3	1	5	1	5	5	5	54.5	3.8926
C2_69	5	3	5	3.5	5	5	5	5	5	5	1	3	5	5	60.5	4.3213
C2_70	5	5	4	3.5	5	5	5	5	1	5	1	3	5	5	57.5	4.1074
C2_71	5	5	5	3.5	5	5	5	5	5	5	1	5	5	5	64.5	4.6074
C2_72	5	5	4	5	5	5	5	5	1	5	1	3	5	5	59	4.2149
C2_73	5	1	5	5	5	5	5	5	1	5	1	5	5	5	58	4.1426
C2_74	3	5	5	1	5	5	5	5	5	5	1	5	5	5	60	4.2851
C2_75	1	1	4	1	5	5	5	5	1	5	1	5	5	5	49	3.5
C2_76	3	3	5	1	5	5	5	5	5	5	1	3	5	5	56	4
C2_77	1	5	4	1	5	5	5	3	5	5	1	5	5	5	55	3.9287
C2_78	1	5	4	2.5	5	5	5	5	5	5	1	5	5	5	58.5	4.1787
C2_79	5	5	4	5	5	5	5	5	5	5	1	5	5	5	65	4.6426
C2_80	5	1	4	1	5	5	5	5	1	5	1	5	5	5	53	3.7851
C2_81	5	3	5	3.5	5	5	5	3	1	5	1	3	5	5	54.5	3.8926
C2_82	3	3	5	3.5	5	5	5	3	5	5	1	3	5	5	56.5	4.0351
C2_83	5	5	4	3.5	5	5	5	5	5	5	1	5	5	5	63.5	4.5351
C2_84	5	1	5	3.5	5	5	5	5	5	5	1	5	5	5	60.5	4.3213
C2_85	3	1	5	5	5	5	5	5	5	5	1	5	5	5	60	4.2851
C2_86	1	5	4	3.5	5	5	5	5	1	5	1	5	5	5	55.5	3.9649

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
C2_87	3	3	4	2.5	5	5	5	5	5	5	1	5	5	5	58.5	4.1787
C2_88	5	5	4	2.5	5	5	5	5	5	5	1	5	5	5	62.5	4.4649
C2_89	1	1	4	2.5	5	5	5	5	5	5	1	5	5	5	54.5	3.8926
C2_90	3	3	5	2.5	5	5	5	5	5	5	1	5	5	5	59.5	4.25
C2_91	3	1	4	2.5	5	5	5	5	1	5	1	5	5	5	52.5	3.75
C2_92	3	3	5	2.5	5	5	5	5	5	5	1	5	5	5	59.5	4.25
C2_93	5	1	4	2.5	5	5	5	5	5	5	1	5	5	5	58.5	4.1787
C2_94	5	1	5	2.5	5	5	5	5	1	5	1	3	5	5	53.5	3.8213
C2_95	1	5	4	1	5	5	5	5	1	1	1	3	5	5	47	3.3574
C2_96	5	5	4	3.5	5	5	5	5	1	5	1	5	5	5	59.5	4.25
C2_97	5	5	3	3.5	5	5	5	5	1	1	1	5	5	5	54.5	3.8926
C2_98	5	1	5	5	5	5	5	5	1	5	1	5	5	5	58	4.1426
C2_99	5	1	5	1	5	5	5	3	1	5	3	3	5	5	52	3.7149
C2_100	3	3	5	3.5	5	5	5	3	1	5	3	3	5	5	54.5	3.8926
C2_101	3	3	5	2.5	5	5	5	3	1	5	3	3	5	5	53.5	3.8213
C2_102	5	1	5	2.5	5	5	5	3	1	5	1	3	5	5	51.5	3.6787
C2_103	3	3	5	2.5	5	5	5	3	1	5	3	3	5	5	53.5	3.8213
C2_104	3	3	5	3.5	5	5	5	3	5	5	1	3	5	5	56.5	4.0351
C2_105	3	3	4	3.5	5	5	5	5	5	5	1	3	5	5	57.5	4.1074
C2_106	5	5	5	2.5	5	5	5	5	5	5	1	5	5	5	63.5	4.5351
C2_107	3	3	4	2.5	5	5	5	5	5	5	1	5	5	5	58.5	4.1787
C2_108	5	3	4	3.5	5	5	5	5	5	5	1	5	5	5	61.5	4.3926
C2_109	5	5	5	2.5	5	5	5	5	5	5	1	5	5	5	63.5	4.5351
C2_110	1	1	4	3.5	5	5	5	5	5	5	1	5	5	5	55.5	3.9649
C2_111	3	5	5	2.5	5	5	5	5	1	5	1	5	5	5	57.5	4.1074
C2_112	3	3	5	2.5	5	5	5	5	5	3	5	3	5	1	55.5	3.9649
C2_113	3	3	5	2.5	5	5	5	5	5	3	3	3	5	5	57.5	4.1074
C1_1	5	1	4	1	5	5	5	2	1	1	1	3	5	5	44	3.1486
C1_2	3	3	3	1	5	5	5	2	1	5	1	1	5	5	45	3.2149

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
C1_22	1	1	4	1	5	5	5	3	1	1	1	5	5	5	43	3.0713
C1_23	1	1	3	3.5	5	5	5	3	1	1	1	3	5	5	42.5	3.0351
C1_24	5	5	4	3.5	5	5	5	5	1	1	1	3	5	5	53.5	3.8213
C1_25	5	5	4	1	5	5	5	5	1	1	1	3	5	5	51	3.6426
C1_26	5	1	5	3	5	5	5	5	1	1	1	3	5	5	50	3.5713
C1_27	3	5	5	1	5	5	5	2	1	3	3	5	5	5	53	3.7851
C1_28	5	1	4	1	5	5	5	2	1	3	1	5	5	5	48	3.4287
C1_29	5	3	4	1	5	5	5	2	1	1	1	5	5	5	48	3.4287
C1_30	5	5	3	1	5	5	5	2	5	1	1	5	5	5	53	3.7851
C1_31	5	5	3	1	5	5	5	4	1	1	1	5	5	5	51	3.6426
C1_32	5	5	4	1	5	5	5	4	1	1	1	5	5	5	52	3.7149
C1_33	1	5	4	1	5	5	5	5	1	1	1	5	5	5	49	3.5
C1_34	1	1	3	1	5	5	5	5	5	1	1	3	5	5	46	3.2851
C1_35	1	5	3	1	5	5	5	2	5	1	1	5	5	5	49	3.5
C1_36	5	5	4	2.5	5	5	5	2	1	1	1	3	5	5	49.5	3.5351
C1_37	5	3	4	1	5	5	5	2	1	1	1	5	5	5	48	3.4287
C1_38	5	3	4	1	5	5	5	2	1	3	1	5	5	5	50	3.5713
C1_39	5	1	2	1	5	5	5	2	5	5	1	5	5	5	52	3.7149
C1_40	5	1	3	1	5	5	5	2	5	1		3	5	1	42	3
C1_41	1	3	2	1	5	5	5	2	1	1	1	3	5	5	40	2.8574
C1_42	1	1	4	1	5	5	5	2	1	5	1	3	5	5	44	3.1426
C1_43	3	5	4	1	5	5	5	5	5	1	1	3	5	1	49	3.5
C1_44	5	5	4	1	5	5	5	2	1	1	1	3	5	5	48	3.4287
C1_45	5	1	4	1	5	5	5	1	5	5	1	5	5	5	53	3.7851
C1_46	5	1	5	1	5	5	5	1	5	1	1	5	5	5	50	3.5713
C1_47	3	1	4	1	5	5	5	1	5	1	1	5	5	5	47	3.3574
C1_48	3	1	4	1	5	5	5	1	5	5	1	5	5	5	51	3.6426
C1_49	3	3	3	1	5	5	5	5	5	1	1	5	5	5	52	3.7149
C1_50	5	1	5	1	5	5	5	5	5	1	3	5	5	5	56	4

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
C1_51	5	5	3	1	5	5	5	2	5	1	1	5	5	5	53	3.7851
C1_52	1	5	3	1	5	5	5	2	1	5	1	5	5	5	49	3.5
C1_53	1	1	3	2.5	5	5	5	2	1	1	1	5	5	5	42.5	3.0351
C1_54	5	5	4	1	5	5	5	5	1	5	1	5	5	5	57	4.0713
C1_55	5	5	4	1	5	5	5	5	1	5	1	3	5	5	55	3.9287
C1_56	3	1	3	1	5	5	5	2	1	1	1	3	5	5	41	2.9287
C1_57	3	3	5	1	5	5	5	2	5	1	1	5	5	5	51	3.6426
C1_58	1	3	3	1	5	5	5	5	5	3	1	3	5	5	50	3.5713
C1_59	1	5	3	1	5	5	5	5	5	1	1	5	5	5	52	3.7149
C1_60	5	1	4	1	5	5	5	5	5	1	1	5	5	5	53	3.7851
C1_61	1	1	3	1	5	5	5	2	1	1	1	5	5	5	41	2.9287
C1_65	3	1	3	1	5	5	5	5	1	5	1	5	5	1	46	3.2851
C1_66	5	1	4	1	5	5	5	5	1	5	1	3	5	5	51	3.6426
C1_67	3	3	4	1	5	5	5	5	1	3	1	5	5	5	51	3.6426
C1_68	3	3	4	1	5	5	5	4	1	3	1	1	5	5	46	3.2851
C1_69	3	3	3	1	5	5	5	5	1	3	1	5	5	5	50	3.5713
C1_70	5	1	3	1	5	5	5	5	5	3	1	5	5	5	54	3.8574
C1_71	5	5	3	1	5	5	5	5	1	3	1	3	5	5	52	3.7149
C1_72	3	3	5	1	5	5	5	5	5	1	1	5	5	5	54	3.8574
C1_73	5	3	5	1	5	5	5	4	1	5	3	3	5	5	55	3.9287
C1_74	5	3	4	1	5	5	5	4	1	5	1	3	5	5	52	3.7149
C1_75	3	5	4	1	5	5	5	4	1	5	1	3	5	5	52	3.7149
C1_76	5	5	4	2.5	5	5	5	4	1	5	3	3	5	5	57.5	4.1074
C1_77	5	1	4	2.5	5	5	5	4	1	5	3	3	5	5	53.5	3.8213
C1_78	5	1	4	2.5	5	5	5	5	1	1	1	3	5	5	48.5	3.4649
C1_79	3	5	3	1	5	5	5	5	1	1	1	3	5	5	48	3.4287
C1_80	1	5	5	2.5	5	5	5	5	1	1	1	3	5	5	49.5	3.5351
C1_81	1	1	3	2.5	5	5	5	5	1	3	1	3	5	5	45.5	3.25
C1_82	5	5	4	2.5	5	5	5	5	1	3	1	3	5	5	54.5	3.8926

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
C1_83	3	5	5	1	5	5	5	1	5	1	1	5	5	5	52	3.7149
C1_84	3	5	4	2.5	5	5	5	5	1	5	1	5	5	5	56.5	4.0351
C1_85	5	3	4	1	5	5	5	5	1	1	1	5	5	5	51	3.6426
C1_86	1	1	3	1	5	5	5	5	1	1	1	5	5	5	44	3.1426
C1_87	5	1	2	2.5	5	5	5	5	1	1	1	5	5	1	44.5	3.1787
C1_88	1	5	4	1	5	5	5	5	5	1	1	5	5	5	53	3.7851
C1_89	5	1	4	1	5	5	5	5	5	5	1	3	5	5	55	3.9287
C1_90	1	1	4	5	5	5	5	4	5	5	1	3	5	5	54	3.8574
C1_91	5	5	4	1	5	5	5	5	5	5	1	5	5	5	61	4.3574
C1_92	3	3	3	2.5	5	5	5	5	5	1	1	5	5	5	53.5	3.8213
C2_1	5	5	4	1	1	4	2.5	5	5	3	1	3	5	5	49.5	3.5351
C2_2	5	1	4	3.5	1	1	1	4	1	5	1	3	1	1	32.5	2.3213
C2_3	1	1	4	3.5	1	1	1	4	1	5	1	3	5	5	36.5	2.6074
C2_4	3	1	4	3.5	1	1	1	4	1	5	1	3	5	5	38.5	2.75
C2_31	5	5	3	2.5	1	4	2.5	4	1	3	1	1	5	1	39	2.7851
C2_32	1	1	4	2.5	1	1	1	3	1	5	1	5	5	1	32.5	2.3213
C2_33	1	1	4	2.5	1	1	1	3	1	5	1	5	5	1	32.5	2.3213
C2_42	1	5	4	1	1	1	2.5	4	1	1	1	1	5	1	29.5	2.1074
C2_43	1	5	4	1	1	4	2.5	5	1	5	1	5	5	5	45.5	3.25
C2_44	1	5	4	1	1	2	2.5	5	1	5	1	5	5	5	43.5	3.1074
C2_45	1	5	4	1	1	2	2.5	4	1	5	1	5	5	5	42.5	3.0351
C2_46	5	3	5	1	1	4	2.5	5	5	1	1	1	5	5	44.5	3.1787
C2_47	5	3	4	1	1	4	2.5	5	5	1	1	1	5	1	39.5	2.8213
C2_48	3	3	5	5	1	4	2.5	4	1	5	1	1	5	5	45.5	3.25
C2_49	5	5	1	3	1	4	2.5	5	5	1	1	3	5	5	46.5	3.3213
C2_50	1	5	4	1	1	2	2.5	4	5	1	1	1	5	5	38.5	2.75
C2_51	3	5	4	3.5	1	1	1	4	1	5	1	3	5	5	42.5	3.0351
C2_52	1	5	4	3.5	1	1	1	4	1	5	1	3	5	5	40.5	2.8926
C2_53	3	5	5	3.5	1	4	2.5	5	1	5	1	3	5	5	49	3.5

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
C2_54	1	3	5	3.5	1	4	2.5	5	5	3	1	3	5	5	47	3.3574
C2_55	5	5	4	3.5	1	4	2.5	5	5	1	1	3	5	5	50	3.5713
C2_57	5	5	5	3.5	1	1	1	1	1	5	1	3	1	1	34.5	2.4649
C2_58	1	5	4	2.5	1	1	1	4	1	5	1	1	1	1	29.5	2.1074
C2_59	5	5	4	2.5	1	1	2.5	4	1	1	1	3	5	5	41	2.9287
C2_60	1	5	4	2.5	1	1	2.5	4	1	5	1	5	5	5	43	3.0713
C2_61	1	1	4	2.5	1	2	2.5	4	1	5	1	5	5	5	40	2.8574
C2_62	5	5	5	2.5	1	4	2.5	5	1	5	1	3	5	5	50	3.5713
C2_63	3	3	4	2.5	1	4	2.5	5	1	5	1	3	5	5	45	3.2149
C2_64	1	5	4	2.5	1	4	2.5	5	1	5	1	3	5	5	45	3.2149
C2_65	1	1	4	2.5	1	1	1	5	1	5	1	1	5	1	30.5	2.1787
C1_3	5	5	5	1	4	5	5	5	1	3	1	3	5	5	53	3.7851
C1_4	1	1	4	1	4	5	1	5	1	5	1	3	5	5	42	3
C1_5	3	3	5	1	4	5	5	5	1	3	1	5	5	5	51	3.6426
C1_6	1	5	4	1	4	5	5	5	1	3	1	5	5	5	50	3.5713
C1_7	3	3	5	1	4	5	5	5	5	5	1	5	5	5	57	4.0713
C1_8	1	5	4	1	4	5	5	5	5	3	3	1	5	1	48	3.4287
C1_9	5	5	3	1	4	5	5	5	1	3	3	3	5	1	49	3.5
C1_10	5	5	3	1	4	5	5	5	1	3	1	1	5	1	45	3.2129
C1_11	1	1	3	1	4	5	1	5	1	1	1	3	5	1	33	2.3571
C1_12	1	1	1	1	4	5	5	5	5	3	1	5	5	5	47	3.3571
C1_13	3	3	4	1	4	5	5	5	5	3	1	3	5	1	48	3.4285
C1_14	3	5	5	1	4	5	5	5	5	5	1	3	5	5	57	4.0714
C1_15	5	5	4	1	4	5	5	5	5	1	1	5	5	5	56	4
C1_16	5	1	3	1	4	5	5	5	5	1	1	3	5	5	49	3.5
C1_17	3	1	5	1	4	5	5	5	1	3	1	1	5	1	41	2.9287
C1_18	1	5	4	1	4	5	5	5	5	3	1	3	5	1	48	3.4287
C1_19	5	5	4	1	4	5	5	5		5	1	3	5	1	49	3.5
C1_20	3	3	4	1	4	5	5	5	5	5	1	3	5	1	50	3.5743

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C1_21	1	5	4	1	4	5	5	5	5	1	1	5	5	5	52	3.7142
C1_62	1	5	2	1	4	5	5	5	1	1	1	3	5	5	44	3.1428
C1_63	1	1	4	1	4	5	5	5	1	1	1	3	5	1	38	2.7142
C1_64	5	5	5	1	4	5	5	5	1	5	1	3	5	5	55	3.9285
C1_93	1	1	4	1	4	5	5	5	5	1	1	3	5	5	46	3.2857
C1_94	5	3	5	1	4	5	5	5	5	1	1	3	5	5	53	3.7857
E2_1	3	3	5	1	4	5	5	4	1	1	3	1	5	5	46	3.2857
E2_2	5	3	4	1	4	5	1	2	1	1	3	3	5	5	43	3.0714
E2_3	3	3	5	1	4	5	5	2	1	1	3	3	5	5	46	3.2857
E2_4	5	5	4	1	4	5	5	2	5	1	3	1	1	1	43	3.0714
E2_5	5	5	5	1	4	1	1	4	1	1	1	1	1	1	32	2.2857
E2_6	3	1	4	1	4	5	5	2	1	1	1	5	1	1	35	2.5
E2_7	3	3	5	1	4	5	1	2	1	1	1	5	1	1	34	2.4285
E2_8	3	3	4	1	4	5	5	2	1	1	1	5	5	5	45	3.2142
E2_9	1	1	3	1	4	5	1	1	5	1	1	1	1	1	27	1.9285
E2_10	1	3	4	1	4	5	1	2	5	1	1	5	1	1	35	2.5
E2_11	1	3	3	1	4	5	5	1	1	1	1	5	5	1	37	2.6428
E2_12	1	5	4	1	4	5	5	2	1	1	1	5	5	5	45	3.2142
E2_13	1	1	4	1	4	5	5	2	1	1	1	5	5	5	41	2.9285
E2_14	1	1	3	1	4	1	5	4	5	1	1	1	5	1	34	2.4285
E2_15	1	3	4	1	4	3	1	4	1	1	1	1	1	1	27	1.9285
E2_16	5	5	4	1	4	5	5	4	1	3	1	1	1	1	41	2.9285
E2_17	1	3	2	1	4	5	5	1	1	5	1	1	1	5	36	2.5714
E2_18	1	5	4	1	4	3	1	4	1	3	1	1	1	5	35	2.5
E2_19	1	1	5	1	4	5	5	1	1	1	3	3	1	1	33	2.3574
E2_20	5	1	4	1	4	5	5	2	5	1	3	3	1	1	41	2.9285
E2_21	5	5	4	1	4	5	5	2	5	5	3	1	1	5	51	3.6428
E2_22	3	3	4	1	4	5	5	2	5	1	3	1	1	1	39	2.7857
E2_23	1	5	4	2.5	4	5	5	2	1	1	3	1	1	5	40.5	2.8928

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E2_24	1	1	1	1	4	5	5	2	5	1	3	5	1	1	36	2.5714
E2_25	5	3	4	1	4	5	5	2	1	5	3	3	5	1	47	3.3571
E2_26	1	1	4	1	4	5	5	2	5	3	3	3	5	1	43	3.0714
E2_27	1	3	4	2.5	4	5	5	2	1	3	3	1	5	5	44.5	3.1785
E2_28	3	5	4	2.5	4	5	1	3	5	3	3	1	1	1	41.5	2.9642
E2_29	5	3	5	1	4	5	5	2	5	1	1	5	5	1	48	3.4285
E2_30	5	5	4	1	4	5	5	2	5	1	3	3	5	5	53	3.7857
E2_31	1	3	4	1	4	5	1	2	1	3	1	5	5	1	37	2.6428
E2_32	5	5	4	2.5	4	5	5	2	5	1	1	1	5	1	46.5	3.3214
E2_33	5	5	5	2.5	4	5	5	2	5	1	1	1	5	5	51.5	3.6785
E2_34	5	5	5	1	4	5	5	2	1	1	1	1	5	5	46	3.2857
E2_35	3	3	5	1	4	5	1	2	1	5	1	5	1	1	38	2.7142
E2_36	1	5	4	1	4	5	5	2	1	5	1	3	1	1	39	2.7857
E2_37	1	5	4	1	4	5	5	2	1	1	1	3	5	5	43	3.0714
E2_38	1	1	4	1	4	5	1	2	1	5	1	5	5	5	41	2.9285
E2_39	3	1	5	3.5	4	5	5	2	5	5	1	5	5	5	54.5	3.8928
E2_40	5	5	5	1	4	5	5	3	1	5	1	1	5	5	51	3.6428
E2_41	3	3	5	2.5	4	5	5	3	1	5	3	1	5	5	50.5	3.6071
E2_42	1	1	3	1	4	5	5	3	1	5	1	1	1	1	33	2.3571
E2_43	1	5	4	1	4	5	5	3	1	1	1	1	1	5	38	2.7142
E2_44	5	1	4	1	4	5	5	2	1	1	1	3	5	5	43	3.0714
E2_45	5	5	5	1	4	5	5	2	5	1	1	1	1	5	46	3.2857
E2_46	5	5	5	1	4	5	5	2	1	5	1	5	5	5	54	3.8571
E2_47	1	5	3	1	4	5	5	2	1	5	1	5	5	5	48	3.4285
E2_48	5	1	4	1	4	5	5	2	1	5	1	1	5	5	45	3.2142
E2_49	1	5	4	1	4	5	5	2	1	5	1	3	5	1	43	3.0714
E2_50	3	1	4	1	4	5	5	2	1	3	1	1	5	1	37	2.6428
E1_11	1	1	3	2.5	1	1	1	1	1	5	1	1	1	1	21.5	1.5357
E1_12	1	1	4	2.5	1	1	1	5	1	5	1	1	1	1	26.5	1.8928

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E1_13	3	5	3	2.5	1	1	1	5	1	5	1	1	1	1	31.5	2.25
E1_18	1	1	4	2.5	1	2	1	5	1	5	1	1	1	1	27.5	1.9642
E1_42	3	3	5	5	1	2	1	4	5	5	3	1	1	1	40	2.8571
E1_43	5	1	3	3.5	1	2	2.5	4	1	5	5	5	1	1	40	2.8571
E1_47	3	3	4	1	1	1	2.5	4	1	3	3	3	1	1	31.5	2.25
E1_48	3	3	4	1	1	2	1	2	5	5	3	3	1	1	35	2.5
E2_51	3	5	3	2.5	2	5	1	3	1	5	1	5	1	5	42.5	3.0357
E2_52	3	5	3	2.5	2	5	1	3	5	3	1	1	5	1	40.5	2.8928
E2_53	3	5	4	2.5	2	5	1	3	5	5	1	1	5	1	43.5	3.1071
E2_54	1	1	4	5	2	5	1	3	1	5	1	1	5	1	36	2.5714
E2_55	5	1	5	5	2	5	1	3	1	5	1	1	5	5	45	3.2142
E2_56	5	5	5	5	2	5	1	3	1	5	1	1	5	5	49	3.5
E2_57	5	3	5	3.5	2	5	1	3	1	5	1	1	5	5	45.5	3.25
E2_58	1	1	4	3.5	2	5	1	3	1	5	1	3	5	5	40.5	2.8928
E2_59	1	3	4	2.5	2	5	1	3	1	5	1	1	5	5	39.5	2.8214
E2_60	1	5	4	2.5	2	5	1	3	1	3	1	5	5	5	43.5	3.1071
E2_61	3	5	4	2.5	2	5	3.5	3	1	5	1	1	1	1	38	2.7142
E2_62	5	1	5	2.5	2	5	1	3	1	1	1	1	1	1	30.5	2.1785
E2_63	3	3	5	2.5	2	5	1	3	1	5	1	1	1	1	34.5	2.4642
E2_64	3	3	5	2.5	2	5	1	3	1	5	1	5	1	1	38.5	2.75
E2_65	1	1	4	3.5	2	5	1	3	1	5	1	1	1	1	30.5	2.1785
E2_66	5	3	2	3.5	2	5	1	3	1	5	1	3	5	5	44.5	3.1785
E2_67	3	3	5	3.5	2	5	1	3	5	1	1	3	1	1	37.5	2.6785
E2_68	3	5	5	3.5	2	5	1	3	5	3	1	3	5	1	45.5	3.25
E2_69	5	5	5	3.5	2	5	1	3	1	3	1	3	5	5	47.5	3.3928
E2_70	1	1	4	3.5	2	5	1	3	5	5	1	1	5	1	38.5	2.75
E2_71	3	1	4	2.5	2	5	1	4	1	3	1	1	1	1	30.5	2.1785
E2_72	3	1	5	2.5	2	5	1	3	5	3	1	1	1	1	34.5	2.4642
E2_73	5	5	5	2.5	2	5	1	3	1	5	1	3	5	5	48.5	3.4642

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E2_74	1	5	4	3.5	2	5	1	3	1	5	1	3	5	1	40.5	2.8928
E2_75	3	5	5	2.5	2	5	1	3	1	3	1	3	1	5	40.5	2.8928
E2_76	5	3	5	2.5	2	5	1	3	1	5	1	3	5	5	46.5	3.3214
E2_77	3	3	5	3.5	2	5	1	4	5	5	1	3	5	5	50.5	3.6071
E2_78	3	5	4	3.5	2	5	1	4	1	3	1	1	5	1	39.5	2.8214
E2_79	1	3	4	3.5	2	5	1	4	1	5	1	1	5	1	37.5	2.6785
E2_80	5	5	5	3.5	2	5	1	4	5	3	1	1	5	1	46.5	3.3214
E2_81	1	5	5	3.5	2	5	1	4	1	5	1	1	1	1	36.5	2.6071
E2_82	1	1	4	2.5	2	5	1	4	1	5	1	1	1	1	30.5	2.1787
E2_83	5	5	5	2.5	2	5	1	1	1	5	3	1	1	1	38.5	2.75
E2_84	1	3	4	2.5	2	5	1	2	5	1	1	3	5	1	36.5	2.6071
E2_85	5	1	3	2.5	2	5	1	2	1	1	1	1	1	1	27.5	1.9642
E2_86	5	5	5	2.5	2	5	1	3	5	1	3	1	1	1	40.5	2.8928
E2_87	3	3	5	2.5	2	5	1	3	5	5	3	3	5	1	46.5	3.3214
E2_88	1	5	4	2.5	2	5	1	3	1	3	3	3	5	1	39.5	2.8214
E2_89	1	5	4	1	2	5	1	3	1	3	3	3	5	1	38	2.7142
E2_90	1	5	4	2.5	2	5	1	3	1	3	1	5	1	1	35.5	2.5357
E2_91	1	5	4	2.5	2	5	1	3	5	3	3	3	5	1	43.5	3.1071
E2_92	3	3	5	2.5	2	5	1	1	5	5	3	3	5	5	48.5	3.4642
E2_93	1	5	4	5	2	5	1	1	1	5	1	1	1	1	34	2.4285
E2_94	1	5	4	2.5	2	5	1	1	1	5	3	5	5	5	45.5	3.25
E2_95	1	5	4	2.5	2	5	1	1	1	3	3	5	1	1	35.5	2.5357
E2_96	5	5	5	2.5	2	5	1	3	1	5	1	1	1	1	38.5	2.75
E2_97	1	5	4	2.5	2	5	1	1	1	1	1	3	5	1	33.5	2.3928
E2_98	1	5	5	2.5	2	5	1	3	1	5	1	3	5	5	44.5	3.1785
E1_1	1	3	4	2.5	2	5	1	5	5	5	3	1	5	1	43.5	3.1071
E1_2	1	5	4	2.5	2	5	5	3	1	5	1	1	5	1	41.5	2.9642
E1_3	1	1	4	2.5	2	5	5	5	5	5	3	1	5	5	49.5	3.5357
E1_4	1	1	5	5	2	5	5	5	5	5	3	1	5	5	53	3.7857

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
E1_5	3	1	4	3.5	2	5	5	5	5	5	3	1	5	5	52.5	3.75
E1_6	1	5	4	3.5	2	5	5	5	5	3	3	1	5	5	52.5	3.75
E1_7	5	5	5	3.5	2	5	2.5	4	1	3	3	3	5	5	52	3.7142
E1_8	5	5	4	1	2	5	1	5	1	5	3	3	5	5	50	3.5714
E1_9	1	3	5	5	2	5	1	1	1	5	3	5	5	5	47	3.3571
E1_10	1	5	4	3.5	2	5	2.5	1	5	5	3	3	5	5	50	3.5714
E1_15	1	1	4	2.5	2	5	1	1	1	5	3	5	5	5	41.5	2.9642
E1_16	1	3	4	2.5	2	5	1	1	5	5	3	5	5	1	43.5	3.1071
E1_17	3	1	4	2.5	2	3	1	1	1	5	3	5	5	1	37.5	2.6785
E1_19	1	5	3	1	2	5	1	5	5	5	3	3	1	1	41	2.9285
E1_20	3	3	4	2.5	2	5	1	5	5	5	3	1	1	1	41.5	2.9642
E1_21	3	1	3	2.5	2	5	1	5	5	5	3	3	5	5	48.5	3.4649
E1_22	1	5	3	2.5	2	5	1	5	5	5	3	1	5	5	48.5	3.4642
E1_23	1	5	3	2.5	2	5	3.5	5	1	5	1	1	5	5	45	3.2142
E1_24	5	5	5	5	2	5	5	5	1	5	1	3	5	5	57	4.0714
E1_25	1	1	4	2.5	2	5	3.5	5	1	5	1	1	5	1	38	2.7142
E1_26	3	3	4	1	2	5	1	5	1	3	3	1	5	1	38	2.7142
E1_27	3	3	5	3.5	2	5	1	5	1	5	3	3	5	5	49.5	3.5357
E1_28	3	3	4	5	2	5	2.5	5	1	5	3	3	1	5	47.5	3.3928
E1_29	3	3	5	1	2	5	5	5	1	5	1	3	5	5	49	3.5
E1_30	3	3	4	1	2	5	2.5	5	1	5	3	1	5	1	41.5	2.9642
E1_31	3	3	3	1	2	5	2.5	5	1	5	3	3	5	5	46.5	3.3214
E1_32	3	3	5	5	2	5	1	5	1	5	3	1	5	1	45	3.2142
E1_33	3	1	4	3.5	2	5	2.5	2	1	5	1	1	5	1	37	2.6428
E1_34	1	3	4	2.5	2	5	1	4	1	3	1	1	5	1	34.5	2.4642
E1_35	3	3	4	2.5	2	5	2.5	4	1	5	3	1	5	1	42	3
E1_36	5	5	3	2.5	2	5	2.5	5	1	5	3	1	5	1	46	3.2857
E1_37	1	1	3	3.5	2	5	1	5	1	5	1	3	5	1	37.5	2.6785
E1_38	1	5	3	3.5	2	5	1	2	5	5	1	1	5	5	44.5	3.1785

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E1_39	1	5	3	3.5	2	5	5	5	5	5	3	5	5	5	57.5	4.1071
E1_40	1	3	4	3.5	2	5	2.5	2	5	5	3	3	5	5	49	3.5
E1_41	1	5	4	3.5	2	5	2.5	2	5	5	3	5	5	5	53	3.7851
E2_99	5	3	5	3.5	5	5	5	5	5	5	3	5	5	5	64.5	4.6071
E2_100	5	3	5	3.5	5	5	5	5	5	5	3	5	5	5	64.5	4.6071
E2_101	5	3	5	3.5	5	5	5	5	5	5	3	5	5	5	64.5	4.6071
E2_102	5	3	5	3.5	5	5	5	5	5	5	3	5	5	5	64.5	4.6071
E2_103	5	3	5	5	5	5	5	5	5	5	3	5	5	5	66	4.7142
E2_104	5	5	4	5	5	5	5	5	5	5	3	5	5	5	67	4.7857
E2_105	5	5	5	3.5	5	5	5	5	5	5	3	5	5	5	66.5	4.75
E2_106	5	5	5	3.5	5	5	5	5	5	5	3	5	5	5	66.5	4.75
E1_14	3	1	5	3.5	5	5	1	5	1	5	3	5	5	5	52.5	3.75
E1_44	5	1	3	3.5	3	5	5	5	1	1	3	3	5	5	48.5	3.4642
E1_45	5	1	4	3.5	3	5	5	2	1	5	3	1	5	5	48.5	3.4642
E1_46	1	1	4	3.5	3	5	5	2	1	1	3	3	5	1	38.5	2.75
E1_50	1	5	2	1	3	5	5	1	1	5	3	1	5	1	39	2.7857
E1_51	3	5	5	3.5	3	5	5	5	1	3	3	5	5	5	56.5	4.0357
E1_52	1	1	4	1	3	5	5	5	1	3	3	5	5	5	47	3.3571
E1_53	3	3	5	2.5	3	5	5	2	1	1	3	1	5	5	44.5	3.1785
E1_54	5	5	4	1	3	5	5	5	1	11	3	5	5	5	63	4.5
E1_55	1	5	2	1	3	5	5	1	1	5	3	1	5	1	39	2.7857
E1_56	3	3	1	1	3	5	5	1	5	3	3	1	5	1	40	2.8571
E1_57	1	5	4	1	3	5	5	1	5	3	3	1	5	5	47	3.3571
E1_58	5	5	3	1	3	5	5	1	5	5	3	1	5	5	52	3.7142
E1_59	1	3	4	3.5	3	5	5	1	5	5	3	1	5	5	49.5	3.5357
E1_60	3	3	4	3.5	3	5	5	1	5	5	3	1	5	5	51.5	3.6785
E1_61	1	5	5	2.5	3	5	1	1	1	5	3	5	5	5	47.5	3.3928
E1_62	1	5	3	1	3	5	1	5	1	5	3	3	5	5	46	3.2857
E1_63	1	5	4	1	3	5	5	5	1	5	1	3	5	5	49	3.5

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E1_64	1	5	4	1	3	5	5	5	1	5	1	3	5	5	49	3.5
E1_65	1	1	4	1	3	5	5	5	1	5	1	5	5	5	47	3.3571
E1_66	1	1	4	1	3	5	5	5	1	5	1	3	5	5	45	3.2142
E1_67	1	5	4	1	3	5	5	5	5	5	1	3	5	5	53	3.7857
E1_68	3	3	5	1	3	5	5	5	1	5	1	3	5	5	50	3.5714
E1_69	3	3	4	2.5	3	5	5	5	5	5	1	3	5	5	54.5	3.8928
E1_70	3	3	4	1	3	5	5	5	1	5	1	3	5	5	49	3.5
E1_71	3	3	3	1	3	5	5	5	5	5	1	3	5	5	52	3.7142
E1_72	3	3	4	1	3	5	5	5	1	5	1	3	5	5	49	3.5
E1_73	3	3	4	1	3	5	5	5	1	3	1	3	5	5	47	3.3571
S2_76	3	3	4	1	2	5	1	2	1	5	1	3	5	5	41	2.9285
S2_77	5	3	4	1	2	5	1	2	1	5	1	3	5	5	43	3.0714
S2_72	3	5	5	1	2	5	1	2	5	5	1	1	5	5	46	3.2857
S2_73	3	5	3	1	2	5	1	2	1	5	1	1	5	5	40	2.8574
S2_74	3	5	3	1	2	5	2.5	2	1	5	1	3	5	5	43.5	3.1071
S2_75	3	1	4	1	2	5	1	2	1	5	1	3	5	5	39	2.7857
S2_126	1	1	4	1	2	5	2.5	2	5	3	1	1	5	1	34.5	2.4642
S2_127	1	5	4	2.5	2	5	2.5	2	5	5	3	1	1	1	40	2.8571
S2_128	1	5	4	1	2	5	2.5	2	5	3	3	1	5	1	40.5	2.8928
S2_129	1	5	2	2.5	2	5	2.5	2	5	3	3	1	5	1	40	2.8571
S2_130	1	5	4	2.5	2	5	1	2	1	5	3	3	1	1	36.5	2.6071
S2_131	3	5	4	1	2	5	1	2	1	5	3	1	5	5	43	3.0714
S2_132	3	1	3	1	2	5	1	2	1	5	3	1	5	5	38	2.7142
S2_133	1	5	4	1	2	5	1	2	1	5	3	1	5	5	41	2.9285
S2_134	1	5	4	1	2	5	1	2	1	3	1	1	5	1	33	2.3571
S2_135	1	5	4	2.5	2	5	1	2	1	5	3	1	5	1	38.5	2.75
S2_136	3	5	4	2.5	2	5	1	2	5	3	1	1	5	1	40.5	2.8926
S2_137	3	5	5	2.5	2	5	1	2	5	3	1	3	5	5	47.5	3.3928
S2_138	5	5	4	1	2	5	1	2	5	5	1	3	5	1	45	3.2142

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S3_53	1	1	4	2.5	2	5	1	2	1	5	1	1	5	1	32.5	2.3214
S3_55	1	3	4	2.5	2	5	2.5	5	1	5	1	3	5	5	45	3.2142
S3_86	5	5	5	2.5	2	5	2.5	5	1	3	1	1	5	5	48	3.4285
S3_87	5	5	5	2.5	2	5	2.5	5	1	5	1	5	1	5	50	3.5714
S1_84	5	5	5	1	2	5	1	5	5	3	1	5	1	5	49	3.5
S1_85	3	3	4	1	2	5	1	2	1	3	1	3	5	5	39	2.7857
S1_86	1	5	3	2.5	2	5	1	2	1	5	1	3	5	1	37.5	2.6785
S1_87	3	5	4	1	2	5	1	2	1	5	1	1	5	1	37	2.6428
S1_88	5	5	4	2.5	2	5	1	5	1	3	1	3	5	5	47.5	3.3928
S1_89	1	5	4	2.5	2	5	1	2	1	5	1	1	1	1	32.5	2.3214
S1_90	1	3	4	2.5	2	5	1	2	1	5	1	1	1	1	30.5	2.1785
S1_91	1	1	3	2.5	2	5	1	2	1	5	1	1	1	1	27.5	1.9642
S1_92	1	5	3	2.5	2	5	1	2	1	5	1	1	5	1	35.5	2.5357
S1_78	3	3	4	2.5	2	5	1	2	1	3	1	1	1	1	30.5	2.1785
S1_79	5	3	4	2.5	2	5	1	2	5	3	1	1	5	5	44.5	3.1785
S1_80	5	5	5	2.5	2	5	1	2	1	3	1	1	1	1	35.5	2.5357
S1_67	3	3	3	1	2	5	1	2	1	3	1	1	5	5	36	2.5714
S1_68	3	5	4	2.5	2	5	1	2	1	3	1	1	5	5	40.5	2.8928
S1_69	5	1	4	1	2	5	1	2	5	3	1	1	5	1	37	2.6428
S1_70	5	5	5	2.5	2	5	1	5	1	2	1	3	1	1	39.5	2.8214
S1_62	3	1	4	2.5	2	3	1	2	5	5	1	1	5	5	40.5	2.8928
S2_1	3	1	3	1	1	4	1	3	1	1	1	1	1	5	27	1.9285
S2_2	1	5	3	1	1	4	1	1	1	1	1	1	1	5	27	1.9285
S2_3	1	1	4	1	1	4	1	3	1	1	1	1	1	1	22	1.5714
S2_4	3	3	5	2.5	1	4	1	3	1	5	1	1	1	5	36.5	2.6071
S2_5	1	3	3	1	1	4	1	3	1	1	1	1	1	5	27	1.9285
S2_6	1	1	1	2.5	1	4	1	5	1	5	1	5	1	1	30.5	2.1785
S2_7	3	1	4	2.5	1	4	1	5	1	5	1	3	1	1	33.5	2.3928
S2_8	1	1	4	2.5	1	4	1	5	1	5	1	3	1	5	35.5	2.5357

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S2_9	1	1	4	2.5	1	4	1	5	1	5	1	3	1	1	31.5	2.25
S2_10	1	1	4	1	1	4	1	5	1	5	1	3	1	1	30	2.1428
S2_11	3	3	4	1	1	4	1	1	1	5	1	1	1	1	28	2
S2_12	5	3	4	1	1	4	1	1	1	5	1	1	1	1	30	2.1428
S2_13	1	1	4	1	1	4	1	5	1	5	1	1	1	1	28	2
S2_14	3	1	5	1	1	4	1	3	1	5	1	1	1	1	29	2.0714
S2_15	1	5	4	1	1	2	1	5	1	1	1	3	1	5	32	2.2857
S2_16	3	3	5	1	1	2	1	3	1	5	1	3	1	5	35	2.5
S2_17	3	3	5	1	1	2	1	1	1	5	1	1	1	1	27	1.9285
S2_18	1	5	4	1	1	4	1	3	1	1	1	3	1	1	28	2
S2_19	1	5	4	1	1	4	1	3	1	1	1	3	1	1	28	2
S2_20	1	1	3	2.5	1	2	1	3	1	5	1	1	1	1	24.5	1.75
S2_21	3	5	3	1	1	4	1	2	1	5	1	3	1	5	36	2.5714
S2_22	1	1	4	1	1	2	1	3	1	5	1	3	1	1	26	1.8571
S2_23	1	1	4	1	1	2	1	3	1	1	1	3	1	5	26	1.8571
S2_24	1	1	5	1	1	2	1	3	1	1	1	1	1	1	21	1.5
S2_81	1	3	4	1	1	4	2.5	2	1	5	3	3	5	5	40.5	2.8928
S2_82	3	3	4	1	1	4	2.5	2	1	5	3	3	5	5	42.5	3.0357
S2_83	1	5	4	1	1	4	2.5	2	1	5	3	3	5	5	42.5	3.0357
S2_84	1	5	4	1	1	2	1	2	1	1	3	1	5	5	33	2.3571
S2_85	3	3	4	1	1	4	1	2	1	1	3	1	5	1	31	2.2142
S2_86	1	5	5	1	1	4	2.5	2	1	1	3	1	5	1	33.5	2.3928
S2_87	1	1	4	1	1	4	1	2	1	1	3	1	1	1	23	1.6428
S2_88	3	1	4	1	1	4	2.5	2	1	1	3	1	1	1	26.5	1.8928
S2_89	1	3	4	1	1	4	2.5	2	1	1	3	1	1	5	30.5	2.1785
S2_90	1	5	4	1	1	4	2.5	2	1	1	3	1	1	1	28.5	2.0357
S2_91	1	5	5	1	1	4	2.5	2	5	1	1	1	1	1	31.5	2.25
S2_92	1	5	4	1	1	4	2.5	2	1	5	3	1	1	5	36.5	2.6071
S2_93	3	3	3	1	1	4	2.5	2	1	5	1	5	1	5	37.5	2.6785

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S2_94	1	3	4	1	1	4	1	1	5	1	1	1	1	1	26	1.8571
S2_95	1	3	4	1	1	4	1	1	5	1	1	3	1	1	28	2
S2_96	1	3	5	1	1	4	1	1	5	5	3	3	1	1	35	2.5
S2_97	1	3	4	1	1	4	2.5	1	5	5	3	1	1	1	33.5	2.3928
S2_98	3	3	4	1	1	4	2.5	1	5	1	3	5	5	5	43.5	3.1071
S2_99	3	3	4	1	1	4	2.5	1	5	1	1	5	5	5	41.5	2.9642
S2_121	1	3	5	1	1	4	2.5	1	1	1	3	3	5	5	36.5	2.6071
S2_122	3	3	4	2.5	1	4	2.5	5	1	5	3	3	5	5	47	3.3571
S2_123	3	3	1	2.5	1	4	2.5	2	1	3	1	3	5	1	33	2.3571
S2_124	1	1	4	1	1	4	2.5	2	1	3	1	3	5	5	34.5	2.4642
S2_125	3	3	2	1	1	4	2.5	2	1	1	1	3	5	1	30.5	2.1785
S3_1	3	3	5	3.5	1	4	1	3	1	1	1	1	1	1	29.5	2.1071
S3_2	3	1	4	3.5	1	4	2.5	3	1	1	1	1	1	1	28	2
S3_3	1	5	4	2.5	1	2	1	3	1	3	1	1	1	1	27.5	1.9642
S3_4	1	5	5	2.5	1	4	1	4	1	3	1	3	1	1	33.5	2.3928
S3_5	1	5	4	2.5	1	1	1	4	1	3	3	3	1	1	31.5	2.25
S3_6	3	5	5	2.5	1	1	2.5	4	1	3	1	1	1	1	32	2.2857
S3_7	3	3	5	2.5	1	2	1	4	1	3	1	1	1	1	29.5	2.1071
S3_8	1	1	4	1	1	2	1	4	1	1	1	1	1	1	21	1.5
S3_9	1	3	4	2.5	1	4	1	4	1	3	1	3	1	1	30.5	2.1785
S3_10	3	5	4	2.5	1	4	1	4	1	3	1	1	1	1	32.5	2.3214
S3_11	3	3	4	1	1	4	1	4	1	5	1	1	1	1	31	2.2142
S3_12	1	1	4	1	1	4	1	4	1	3	1	3	1	1	27	1.9285
S3_13	1	3	5	1	1	4	1	4	1	3	1	3	1	1	30	2.1428
S3_14	3	1	5	1	1	4	1	4	1	3	1	3	1	1	30	2.1428
S3_15	1	5	4	1	1	2	1	4	1	3	1	3	1	1	29	2.0714
S3_16	3	3	5	1	1	4	1	3	1	5	1	5	1	5	39	2.7857
S3_17	1	1	4	1	1	4	1	3	1	3	1	3	1	1	26	1.8571
S3_18	1	3	4	1	1	4	1	3	1	5	1	1	1	1	28	2

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
S3_19	1	3	4	2.5	1	1	1	3	1	5	1	1	5	1	30.5	2.1785
S3_20	1	3	4	1	1	1	1	3	5	3	1	1	5	1	31	2.2142
S3_21	3	5	4	1	1	2	1	3	1	3	1	5	5	1	36	2.5714
S3_22	1	1	4	2.5	1	4	1	3	1	5	1	3	5	1	33.5	2.3928
S3_23	5	3	5	2.5	1	4	1	3	1	5	1	1	1	1	34.5	2.4642
S3_24	5	3	4	1	1	2	1	3	1	3	1	5	1	1	32	2.2857
S3_25	3	1	5	2.5	1	4	1	3	5	3	1	1	1	5	36.5	2.6071
S3_26	5	5	5	2.5	1	4	1	3	1	3	1	3	1	5	40.5	2.8928
S3_27	1	1	4	1	1	4	1	3	1	3	1	5	1	1	28	2
S3_28	3	5	4	1	1	4	1	3	1	5	1	1	1	1	32	2.2857
S3_29	3	1	5	1	1	4	1	3	1	5	1	1	1	1	29	2.0714
S3_30	1	5	4	1	1	4	1	3	1	3	1	3	1	1	30	2.1428
S3_31	3	5	4	1	1	2	1	3	1	3	1	3	1	5	34	2.4285
S3_32	1	3	5	2.5	1	2	2.5	5	5	3	1	1	1	1	34	2.4285
S3_33	1	3	4	1	1	2	1	5	1	5	1	1	1	1	28	2
S3_34	1	1	4	1	1	4	1	3	1	3	1	3	1	1	26	1.8571
S3_35	3	5	5	2.5	1	4	1	3	1	5	1	3	1	5	40.5	2.8928
S3_36	3	3	5	1	1	2	1	3	1	3	1	5	1	5	35	2.5
S3_37	1	1	4	1	1	4	1	3	1	3	1	1	1	1	24	1.7142
S3_38	1	1	4	2.5	1	4	1	3	1	5	1	5	1	1	31.5	2.25
S3_83	1	3	4	2.5	1	4	1	3	1	3	1	1	1	1	27.5	1.9642
S3_84	3	1	4	2.5	1	4	1	3	1	3	1	1	1	1	27.5	1.9642
S3_85	1	5	4	2.5	1	4	1	5	1	3	1	1	1	1	31.5	2.25
S2_25	3	3	4	1	4	5	5	5	5	3	1	5	5	5	54	3.8571
S2_26	5	3	4	1	4	5	5	5	1	3	1	5	5	5	52	3.7142
S2_27	1	5	4	1	4	5	5	5	1	3	1	1	5	5	46	3.2857
S2_28	1	5	4	1	4	5	5	5	1	3	1	1	5	5	46	3.2857
S2_29	1	5	4	1	4	5	5	5	5	3	1	1	5	1	46	3.2857
S2_30	5	1	4	1	4	5	5	5	5	3	3	5	5	5	56	4

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
S2_31	1	3	4	1	4	5	5	5	1	3	3	1	5	1	42	3
S2_32	1	1	4	1	4	5	5	5	1	3	3	3	5	1	42	3
S2_33	1	1	4	1	4	5	5	5	1	3	3	1	1	1	36	2.5714
S2_34	1	1	4	2.5	4	5	5	5	1	3	3	1	1	1	37.5	2.6785
S2_35	1	3	4	1	4	5	5	5	1	5	3	3	5	1	46	3.2857
S2_36	3	5	4	1	4	5	5	5	5	3	3	5	1	1	50	3.5714
S2_37	3	5	5	1	4	5	5	5	1	3	3	5	5	1	51	3.6428
S2_38	1	5	4	1	4	5	5	5	5	3	3	3	1	1	46	3.2857
S2_39	1	5	2	1	4	5	5	5	5	3	3	5	1	1	46	3.2857
S2_40	1	5	3	1	4	5	5	5	1	3	3	5	5	5	51	3.6428
S2_41	3	1	4	1	4	5	5	5	1	3	3	1	5	5	46	3.2857
S2_42	3	3	4	1	4	5	5	2	1	3	3	1	5	5	45	3.2142
S2_43	5	1	4	1	4	5	5	5	1	3	3	1	5	5	48	3.4285
S2_44	3	3	4	1	4	5	5	2	1	3	3	1	5	5	45	3.2142
S2_45	5	5	4	1	4	5	5	2	1	3	1	1	5	5	47	3.3571
S2_46	3	3	2	1	4	5	5	2	5	3	1	3	1	1	39	2.7857
S2_47	3	3	3	1	4	5	5	5	1	3	1	3	1	1	39	2.7857
S2_48	3	3	3	1	4	5	5	5	1	3	1	3	1	1	39	2.7857
S2_49	1	5	3	1	4	5	5	5	1	3	1	3	1	1	39	2.7857
S2_50	3	5	3	1	4	5	5	5	5	5	1	1	5	5	53	3.7857
S2_51	3	3	3	1	4	5	5	3	5	3	1	1	5	5	47	3.3571
S2_52	1	1	2	1	4	5	5	5	1	3	1	1	1	1	32	2.2857
S2_53	1	3	3	1	4	5	5	5	1	3	1	1	5	5	43	3.0714
S2_54	1	3	4	1	4	5	5	5	1	3	1	1	5	5	44	3.1428
S2_55	1	5	4	1	4	5	5	5	1	3	1	1	5	5	46	3.2857
S2_56	1	1	4	1	4	5	5	5	1	3	1	1	5	1	38	2.7142
S2_57	1	5	4	1	4	5	5	5	5	3	1	1	5	1	46	3.2857
S2_58	5	5	4	1	4	5	5	3	5	5	1	1	5	5	54	3.8571
S2_59	1	1	3	1	4	5	5	3	1	3	1	1	5	5	39	2.7857

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
S2_60	3	3	4	1	4	5	5	3	1	3	1	1	5	5	44	3.1428
S2_61	3	3	4	2.5	4	5	5	5	1	3	1	1	5	5	47.5	3.3928
S2_62	1	1	4	1	4	5	5	5	5	3	1	3	5	1	44	3.1428
S2_63	1	3	3	1	4	5	5	5	5	3	3	3	5	5	51	3.6428
S2_64	3	3	4	1	4	5	5	5	1	3	3	1	5	5	48	3.4285
S2_65	1	3	4	2.5	4	5	5	3	1	5	3	3	5	1	45.5	3.25
S2_66	1	5	4	2.5	4	5	5	3	1	1	3	1	1	1	37.5	2.6785
S2_67	3	3	5	2.5	4	5	5	4	1	3	3	1	5	1	45.5	3.25
S2_68	3	1	3	2.5	4	5	2.5	5	1	3	3	1	5	1	40	2.8571
S2_69	5	1	5	2.5	4	5	5	5	1	5	1	1	5	1	46.5	3.3214
S2_70	3	3	4	2.5	4	5	5	5	1	5	1	3	5	5	51.5	3.6785
S2_71	3	3	4	2.5	4	5	5	5	1	5	1	3	5	5	51.5	3.6785
S2_100	1	5	4	2.5	4	5	5	5	5	3	1	3	5	1	49.5	3.5357
S2_101	5	3	4	1	4	5	5	5	5	3	1	1	1	1	44	3.1428
S2_102	1	5	4	1	4	5	5	5	1	3	1	1	1	1	38	2.7142
S2_103	1	1	4	2.5	4	5	5	5	5	3	1	1	5	5	47.5	3.3928
S2_104	1	3	4	2.5	4	5	5	5	1	3	1	1	5	1	41.5	2.9642
S2_105	3	3	5	1	4	5	5	5	1	5	3	1	5	5	51	3.6428
S2_106	5	5	5	2.5	4	5	5	5	1	5	3	1	5	5	56.5	4.0357
S2_107	1	3	3	1	4	5	5	5	5	3	3	1	5	5	49	3.5
S2_108	1	5	4	2.5	4	5	2.5	5	1	5	3	1	5	1	45	3.2142
S2_109	3	3	3	1	4	5	5	5	1	5	3	3	5	5	51	3.6428
S2_110	3	1	4	2.5	4	5	5	5	1	3	3	3	5	5	49.5	3.5357
S2_111	5	3	3	2.5	4	5	5	5	5	3	3	3	5	5	56.5	4.0357
S2_112	1	5	4	2.5	4	5	5	5	1	3	3	3	5	5	51.5	3.6785
S2_113	3	1	4	1	4	5	5	2	5	3	5	3	5	5	51	3.6428
S2_114	5	1	4	2.5	4	5	5	2	5	3	5	3	5	5	54.5	3.8928
S2_115	3	5	4	2.5	4	5	5	2	5	3	5	3	5	5	56.5	4.0357
S2_116	3	5	4	2.5	4	5	5	2	5	3	5	3	5	5	56.5	4.0357

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
S2_117	1	3	4	1	4	5	5	2	5	3	5	1	5	5	49	3.5
S2_118	3	5	4	1	4	5	5	2	5	5	5	1	5	5	55	3.9285
S2_119	3	3	4	1	4	5	5	5	5	5	5	1	5	5	56	4
S2_120	1	5	2	1	4	5	5	5	1	5	5	1	5	5	50	3.5714
S3_58	5	1	4	1	4	5	5	3	1	3	5	5	5	5	52	3.7142
S3_59	3	3	5	1	4	5	5	5	5	3	5	5	5	5	59	4.2142
S3_60	5	5	5	2.5	4	5	5	5	5	3	5	5	5	5	64.5	4.6071
S3_61	3	5	5	3.5	4	5	5	5	1	5	5	3	5	5	59.5	4.25
S3_62	5	3	5	2.5	4	5	5	5	5	3	5	5	5	5	62.5	4.4642
S3_63	3	3	5	1	4	5	5	5	5	3	5	5	5	5	59	4.2142
S3_64	5	3	5	1	4	5	5	5	1	3	5	5	5	5	57	4.0714
S3_65	1	5	4	1	4	5	5	5	5	3	5	5	5	5	58	4.1428
S3_66	5	5	4	1	4	5	5	5	1	5	5	5	5	5	60	4.2857
S3_67	5	1	4	1	4	5	5	5	5	3	5	3	5	5	56	4
S3_68	3	5	5	2.5	4	5	5	5	5	1	5	3	5	5	58.5	4.1785
S3_69	5	3	5	2.5	4	5	5	5	5	3	5	3	5	5	60.5	4.3214
S3_70	3	3	5	2.5	4	5	5	5	5	3	5	5	5	5	60.5	4.3214
S3_71	1	5	4	2.5	4	5	5	5	5	5	5	5	5	5	61.5	4.3928
S3_72	5	5	4	2.5	4	5	5	5	5	3	5	5	5	5	63.5	4.5357
S3_73	5	1	5	2.5	4	5	5	5	1	3	5	5	5	5	56.5	4.0357
S3_74	5	3	5	2.5	4	5	5	5	1	5	5	3	5	5	58.5	4.1785
S3_75	5	1	4	1	4	5	5	5	1	5	5	3	5	5	54	3.8571
S2_78	3	3	5	1	3	5	5	2	5	3	3	3	5	5	51	3.6428
S2_79	3	3	5	1	3	5	5	2	5	5	3	3	5	5	53	3.7857
S2_80	3	1	4	1	3	5	5	2	1	5	3	5	5	5	48	3.4285
S2_139	1	5	4	1	3	5	1	5	1	5	1	3	5	1	41	2.9285
S2_140	5	5	4	1	3	5	1	5	1	5	1	3	5	5	49	3.5
S2_141	5	5	4	1	3	5	1	5	1	5	1	3	5	5	49	3.5
S2_142	3	3	4	1	3	5	2.5	5	1	3	3	5	5	5	48.5	3.4642

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S2_143	3	3	4	1	3	5	5	2	1	3	3	3	5	1	42	3
S2_144	3	3	4	1	3	5	1	5	1	3	3	3	5	1	41	2.9285
S2_145	5	5	4	1	3	5	2.5	5	1	3	3	1	5	5	48.5	3.4642
S2_146	5	5	5	1	3	5	2.5	5	1	5	3	1	5	1	47.5	3.3928
S2_147	1	1	4	1	3	5	2.5	5	1	3	3	1	5	1	36.5	2.6071
S2_148	5	5	5	1	3	5	2.5	5	1	5	3	1	5	5	51.5	3.6785
S1_1	5	5	5	1	3	5	5	5	5	3	3	3	5	5	58	4.1428
S1_2	5	5	4	1	3	5	1	5	1	3	1	1	5	1	41	2.9285
S1_3	3	3	5	1	3	5	5	5	5	5	1	3	5	5	54	3.8571
S1_4	3	5	5	1	3	5	5	5	5	1	1	3	5	5	52	3.7142
S1_5	5	3	3	1	3	5	2.5	5	1	1	3	3	5	5	45.5	3.25
S1_6	5	5	5	1	3	5	5	5	1	1	3	5	5	5	54	3.8571
S1_7	1	1	4	1	3	5	3.5	5	1	5	3	5	5	5	47.5	3.3928
S1_8	5	5	5	1	3	5	3.5	5	1	5	1	5	5	5	54.5	3.8928
S1_9	1	5	4	1	3	5	1	5	1	5	1	5	5	5	47	3.3571
S1_10	1	5	3	1	3	5	5	5	1	3	1	1	5	5	44	3.1428
S1_11	1	1	4	1	3	5	1	5	1	3	1	3	5	5	39	2.7857
S1_12	5	1	4	1	3	5	1	5	1	3	1	3	5	5	43	3.0714
S1_13	5	5	5	1	3	5	5	5	1	3	1	1	5	5	50	3.5714
S1_14	5	1	5	1	3	5	3.5	5	1	3	1	1	5	5	44.5	3.1785
S1_15	3	3	5	1	3	5	1	5	5	3	1	1	5	5	46	3.2857
S1_16	5	1	5	1	3	5	3.5	5	1	3	1	1	5	5	44.5	3.1785
S1_17	3	3	5	1	3	5	1	5	1	5	1	5	5	1	44	3.1428
S1_18	3	5	5	1	3	5	1	5	5	5	1	3	1	5	48	3.4285
S1_19	1	1	5	1	3	5	1	5	5	1	1	1	1	5	36	2.5714
S1_20	1	3	3	1	3	5	1	3	5	5	1	5	1	5	42	3
S1_21	1	1	5	1	3	5	1	3	5	3	1	1	1	5	36	2.5714
S1_22	1	5	4	1	3	5	1	5	1	5	1	5	5	5	47	3.3571
S1_23	1	5	4	1	3	5	1	3	5	3	1	5	5	5	47	3.3571

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
S1_24	3	5	4	1	3	5	3.5	3	1	1	1	3	5	5	43.5	3.1071
S1_25	5	5	4	1	3	5	1	5	1	3	1	5	5	5	49	3.5
S1_26	5	1	5	2.5	3	5	3.5	3	1	3	1	5	5	5	48	3.4285
S1_27	5	3	5	1	3	5	3.5	5	1	3	1	5	5	5	50.5	3.6071
S1_28	3	5	5	2.5	3	5	3.5	5	1	3	1	5	1	5	48	3.4285
S1_29	5	3	5	1	3	5	3.5	5	5	3	1	5	5	5	54.5	3.8928
S1_30	1	5	1	1	3	5	3.5	5	1	3	1	5	5	5	44.5	3.1785
S1_31	5	5	5	1	3	5	1	3	5	3	1	3	5	5	50	3.5714
S1_32	5	1	4	1	3	5	5	5	1	3	1	3	5	5	47	3.3571
S1_33	5	5	4	1	3	5	1	3	1	3	1	5	5	5	47	3.3571
S1_34	5	3	5	1	3	5	1	5	1	3	1	3	5	5	46	3.2857
S1_61	5	3	4	1	3	5	1	3	5	3	1	3	5	5	47	3.3571
S1_63	1	5	4	2.5	3	5	1	5	5	3	1	3	5	1	44.5	3.1785
S1_64	1	1	3	2.5	3	5	1	5	1	5	1	5	5	5	43.5	3.1071
S1_65	3	3	5	3.5	3	5	1	2	5	5	1	5	5	5	51.5	3.6785
S1_66	1	1	4	2.5	3	5	1	2	1	5	3	3	5	5	41.5	2.9642
S1_71	1	1	3	1	3	5	1	5	5	3	1	5	5	5	44	3.1428
S1_72	3	3	4	2.5	3	5	5	2	1	3	1	5	1	5	43.5	3.1071
S1_73	5	5	5	1	3	5	5	2	5	3	1	3	5	5	53	3.7857
S1_74	5	5	4	2.5	3	5	1	2	1	3	1	5	5	5	47.5	3.3928
S1_75	5	5	5	1	3	5	1	3	1	3	1	5	5	5	48	3.4285
S1_76	1	1	4	2.5	3	5	1	2	1	5	1	3	5	1	35.5	2.5357
S1_77	5	5	5	1	3	5	1	2	1	3	1	3	5	5	45	3.2142
S1_81	1	3	4	1	3	5	5	4	1	3	1	5	5	5	46	3.2857
S1_82	3	3	5	1	3	5	1	4	1	5	1	5	5	5	47	3.3571
S1_83	5	1	4	1	3	5	1	4	5	3	1	5	5	5	48	3.4285
S1_93	3	3	4	1	3	5	1	5	1	5	1	3	5	1	41	2.9285
S3_39	5	5	4	2.5	5	5	1	5	1	5	1	5	5	5	54.5	3.8928
S3_40	5	3	5	1	5	5	1	5	1	3	1	5	5	5	50	3.5714

Questionnaire Number	Age	Sex	Family Size	Period of Stay	Kind of Colony	Type of House	Connection to Sewer	Source of Water	Consumption Habit	Sewage Mixing	Nearness to Open Drain	Frequency of Drain Overflow	Open Defecation and Public Washing	Physical Contact with Raw Sewage	Total Score	Exposure Index
S3_41	5	1	3	1	5	5	5	1	1	5	1	5	5	5	48	3.4285
S3_42	3	3	4	1	5	5	5	3	1	5	1	5	5	5	51	3.6428
S3_43	5	5	4	1	5	5	1	3	1	3	1	5	5	1	45	3.2142
S3_44	5	5	5	1	5	5	5	3	1	5	1	5	5	5	56	4
S3_45	5	5	5	1	5	5	5	3	1	5	1	3	5	5	54	3.8571
S3_46	5	5	4	1	5	5	5	5	1	1	1	3	5	1	47	3.3571
S3_47	5	5	3	2.5	5	5	1	5	5	3	1	5	5	5	55.5	3.9642
S3_48	3	5	5	2.5	5	5	1	5	5	5	1	3	5	1	51.5	3.6785
S3_49	5	5	4	2.5	5	5	1	5	1	5	1	5	5	5	54.5	3.8928
S3_50	5	5	4	1	5	5	1	3	1	3	1	5	5	1	45	3.2142
S3_51	3	5	4	1	5	5	1	3	1	5	3	5	5	5	51	3.6428
S3_52	3	5	4	1	5	5	1	3	1	5	3	1	5	1	43	3.0714
S3_54	5	5	2	2.5	5	5	1	5	1	3	3	1	5	1	44.5	3.1785
S3_56	3	5	5	2.5	5	5	5	5	1	5	3	3	5	1	53.5	3.8214
S3_57	3	3	5	2.5	5	5	5	5	1	5	3	3	5	5	55.5	3.9642
S3_76	1	3	5	3.5	5	5	5	5	5	5	3	5	5	5	60.5	4.3214
S3_77	5	1	5	3.5	5	5	5	5	5	3	3	5	5	5	60.5	4.3214
S3_78	1	3	5	3.5	5	5	5	5	5	5	3	5	5	5	60.5	4.3214
S3_79	5	1	5	3.5	5	5	5	5	5	5	3	5	5	5	62.5	4.4642
S3_80	5	1	4	3.5	5	5	5	5	5	3	3	5	5	5	59.5	4.25
S3_81	5	1	5	3.5	5	5	5	5	5	3	5	5	5	5	62.5	4.4642
S3_82	3	3	5	3.5	5	5	5	5	5	3	5	3	5	5	60.5	4.3214
S3_88	5	5	5	5	5	5	5	5	5	5	5	5	5	5	70	5
S3_89	3	3	5	3.5	5	5	5	5	5	5	5	3	5	5	62.5	4.4642
S3_90	3	3	5	3.5	5	5	5	5	5	5	5	3	5	5	62.5	4.4642
S3_91	1	5	4	3.5	5	5	5	5	5	5	5	3	5	5	61.5	4.3928
S3_92	5	1	4	3.5	5	5	5	5	5	5	5	3	5	5	61.5	4.3928
S3_93	3	3	4	3.5	5	5	5	5	1	5	5	5	5	5	59.5	4.25
S3_94	3	3	5	3.5	5	5	5	5	1	5	5	5	5	5	60.5	4.3214
S3_95	3	3	4	3.5	5	5	5	5	5	5	5	5	5	5	63.5	4.5357
S3_96	3	3	4	3.5	5	5	5	5	1	5	5	3	5	5	57.5	4.1071

Source: Data processed from household survey results according to the HEI key

Appendix V

Household Management Capacity Index of the Surveyed Households

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
C2_5	3.5	1	1	5	5	5	20.5	3.41667
C2_6	5	2	1	5	5	1	19	3.16667
C2_7	5	3	1	5	1	5	20	3.33333
C2_8	5	2	1	1	5	1	15	2.5
C2_9	5	3	1	1	5	1	16	2.66667
C2_10	3.5	2	1	5	1	1	13.5	2.25
C2_11	2.5	2	1	1	5	1	12.5	2.08333
C2_12	3.5	4	1	1	1	5	15.5	2.58333
C2_13	2.5	3	1	1	5	5	17.5	2.91667
C2_14	5	4	1	1	5	5	21	3.5
C2_15	2.5	4	1	1	5	1	14.5	2.41667
C2_16	5	4	1	1	1	1	13	2.16667
C2_17	5	2	1	5	5	1	19	3.16667
C2_18	5	4	1	5	5	1	21	3.5
C2_19	5	3	1	5	5	1	20	3.33333
C2_20	2.5	4	1	5	1	5	18.5	3.08333
C2_21	2.5	3	1	5	1	1	13.5	2.25
C2_22	2.5	3	1	5	5	5	21.5	3.58333
C2_23	5	4	1	1	5	5	21	3.5
C2_24	3.5	3	1	1	5	1	14.5	2.41667
C2_25	3.5	4	1	1	5	1	15.5	2.58333
C2_26	2.5	3	1	5	1	5	17.5	2.91667
C2_27	5	3	1	1	5	1	16	2.66667
C2_28	5	3	1	5	1	5	20	3.33333
C2_29	3.5	3	1	1	1	5	14.5	2.41667
C2_30	5	4	1	1	1	1	13	2.16667
C2_34	3.5	4	5	5	5	1	23.5	3.91667
C2_35	3.5	4	5	5	5	1	23.5	3.91667
C2_36	3.5	4	1	5	1	1	15.5	2.58333
C2_37	3.5	4	5	5	5	1	23.5	3.91667
C2_38	2.5	4	5	5	5	1	22.5	3.75
C2_39	5	2	1	5	5	1	19	3.16667
C2_40	3.5	1	1	5	5	1	16.5	2.75
C2_41	3.5	4	1	5	1	5	19.5	3.25
C2_56	5	3	1	5	5	1	20	3.33333
C2_66	3.5	4	1	5	5	1	19.5	3.25
C2_67	2.5	2	1	5	5	1	16.5	2.75
C2_68	3.5	4	5	5	5	1	23.5	3.91667
C2_69	5	5	5	5	5	5	30	5

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
C2_70	5	3	1	5	1	5	20	3.33333
C2_71	5	3	1	5	5	5	24	4
C2_72	3.5	2	5	5	5	5	25.5	4.25
C2_73	5	5	1	5	5	5	26	4.33333
C2_74	5	2	1	1	5	1	15	2.5
C2_75	5	1	1	1	5	1	14	2.33333
C2_76	5	3	1	1	5	1	16	2.66667
C2_77	5	3	1	1	5	1	16	2.66667
C2_78	3.5	3	1	1	1	1	10.5	1.75
C2_79	5	2	1	5	5	5	23	3.83333
C2_80	2.5	2	5	5	5	1	20.5	3.41667
C2_81	3.5	3	1	5	5	1	18.5	3.08333
C2_82	2.5	4	5	5	5	5	26.5	4.41667
C2_83	5	3	1	5	5	1	20	3.33333
C2_84	5	5	1	5	5	1	22	3.66667
C2_85	5	4	1	5	5	1	21	3.5
C2_86	5	3	1	5	5	5	24	4
C2_87	3.5	3	1	5	5	1	18.5	3.08333
C2_88	3.5	4	1	5	5	1	19.5	3.25
C2_89	3.5	3	5	5	5	1	22.5	3.75
C2_90	3.5	3	5	5	5	5	26.5	4.41667
C2_91	3.5	3	5	5	5	5	26.5	4.41667
C2_92	5	5	5	5	5	5	30	5
C2_93	5	4	5	5	5	5	29	4.83333
C2_94	3.5	4	1	5	1	5	19.5	3.25
C2_95	3.5	2	1	5	1	5	17.5	2.91667
C2_96	3.5	1	1	5	1	1	12.5	2.08333
C2_97	3.5	2	1	5	1	5	17.5	2.91667
C2_98	3.5	2	1	5	1	5	17.5	2.91667
C2_99	2.5	3	1	5	5	5	21.5	3.58333
C2_100	2.5	4	1	5	5	5	22.5	3.75
C2_101	2.5	3	5	5	1	5	21.5	3.58333
C2_102	1	2	5	5	1	5	19	3.16667
C2_103	2.5	3	5	5	1	5	21.5	3.58333
C2_104	3.5	2	5	5	1	5	21.5	3.58333
C2_105	3.5	1	5	5	5	1	20.5	3.41667
C2_106	5	3	5	1	5	5	24	4
C2_107	3.5	4	1	5	5	1	19.5	3.25
C2_108	5	1	1	5	5	1	18	3
C2_109	5	2	1	5	5	1	19	3.16667
C2_110	3.5	3	1	5	5	1	18.5	3.08333

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
C2_111	3.5	2	1	5	5	1	17.5	2.91667
C2_112	3.5	3	1	5	1	5	18.5	3.08333
C2_113	3.5	4	1	5	1	1	15.5	2.58333
C1_1	3.5	3	1	5	5	5	22.5	3.75
C1_2	5	3	1	1	5	5	20	3.33333
C1_22	5	3	5	1	5	5	24	4
C1_23	3.5	2	5	5	5	5	25.5	4.25
C1_24	5	2	5	1	1	5	19	3.16667
C1_25	5	4	5	5	1	5	25	4.16667
C1_26	2.5	4	5	5	5	5	26.5	4.41667
C1_27	3.5	4	5	5	5	1	23.5	3.91667
C1_28	3.5	1	5	5	5	1	20.5	3.41667
C1_29	3.5	3	5	1	5	1	18.5	3.08333
C1_30	5	4	5	1	5	5	25	4.16667
C1_31	3.5	3	5	5	5	1	22.5	3.75
C1_32	3.5	5	5	5	1	1	20.5	3.41667
C1_33	2.5	5	5	5	5	5	27.5	4.58333
C1_34	3.5	1	5	1	5	1	16.5	2.75
C1_35	3.5	2	5	5	5	5	25.5	4.25
C1_36	3.5	2	5	5	5	5	25.5	4.25
C1_37	5	3	5	1	5	5	24	4
C1_38	5	4	5	1	5	5	25	4.16667
C1_39	5	3	5	5	5	5	28	4.66667
C1_40	3.5	3	5	5	5	5	26.5	4.41667
C1_41	5	1	1	1	1	5	14	2.33333
C1_42	3.5	1	1	1	1	5	12.5	2.08333
C1_43	3.5	1	1	1	1	1	8.5	1.41667
C1_44	2.5	4	1	1	1	5	14.5	2.41667
C1_45	5	4	1	1	5	1	17	2.83333
C1_46	5	3	1	1	5	1	16	2.66667
C1_47	5	4	1	5	5	1	21	3.5
C1_48	3.5	4	5	1	5	1	19.5	3.25
C1_49	5	2	1	5	1	1	15	2.5
C1_50	2.5	4	1	5	1	1	14.5	2.41667
C1_51	3.5	3	5	5	1	5	22.5	3.75
C1_52	3.5	4	5	1	1	5	19.5	3.25
C1_53	5	1	5	1	1	5	18	3
C1_54	5	4	5	5	1	5	25	4.16667
C1_55	3.5	4	1	1	5	1	15.5	2.51667
C1_56	5	4	1	5	5	1	21	3.5
C1_57	3.5	5	5	1	1	5	20.5	3.41667

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
C1_58	5	3	5	1	1	5	20	3.33333
C1_59	5	2	1	5	1	1	15	2.5
C1_60	5	4	1	1	1	1	13	2.16667
C1_61	2.5	1	1	5	5	5	19.5	3.25
C1_65	3.5	3	5	1	5	1	18.5	3.08333
C1_66	5	5	1	1	5	1	18	3
C1_67	2.5	2	5	5	5	1	20.5	3.41667
C1_68	3.5	3	5	1	1	5	18.5	3.08333
C1_69	2.5	1	5	5	5	5	23.5	3.91667
C1_70	5	2	5	5	5	5	27	4.5
C1_71	3.5	2	5	5	5	5	25.5	4.25
C1_72	3.5	3	5	5	5	5	26.5	4.41667
C1_73	3.5	4	5	5	5	1	23.5	3.91667
C1_74	3.5	1	5	5	5	1	20.5	3.41667
C1_75	2.5	2	5	5	5	1	20.5	3.41667
C1_76	2.5	1	5	5	5	5	23.5	3.91667
C1_77	2.5	1	5	5	5	5	23.5	3.91667
C1_78	3.5	1	1	1	1	1	8.5	1.41667
C1_79	3.5	3	1	1	1	1	10.5	1.75
C1_80	2.5	2	1	1	1	1	8.5	1.41667
C1_81	2.5	2	5	1	1	1	12.5	2.08333
C1_82	2.5	1	1	1	5	1	11.5	1.91667
C1_83	2.5	2	1	1	5	1	12.5	2.08333
C1_84	5	1	1	1	5	1	14	2.33333
C1_85	5	2	1	5	5	1	19	3.16667
C1_86	3.5	3	1	5	5	1	18.5	3.08333
C1_87	5	1	1	1	1	1	10	1.66667
C1_88	2.5	2	5	1	5	1	16.5	2.75
C1_89	2.5	2	5	1	1	5	16.5	2.75
C1_90	3.5	1	5	1	1	5	16.5	2.75
C1_91	3.5	1	5	1	1	5	16.5	2.75
C1_92	5	1	5	1	1	5	18	3
C2_1	5	4	1	5	1	5	21	3.5
C2_2	3.5	1	1	1	1	5	12.5	2.08333
C2_3	2.5	1	1	1	1	5	11.5	1.91667
C2_4	2.5	2	1	1	1	5	12.5	2.08333
C2_31	2.5	1	1	5	5	5	19.5	3.25
C2_32	1	1	1	1	1	5	10	1.66667
C2_33	1	1	1	1	1	5	10	1.66667
C2_42	2.5	3	1	1	1	5	13.5	2.25
C2_43	2.5	3	1	1	5	5	17.5	2.91667

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
C2_44	2.5	1	1	1	5	5	15.5	2.58333
C2_45	2.5	3	1	1	5	5	17.5	2.91667
C2_46	3.5	4	1	5	1	5	19.5	3.25
C2_47	2.5	1	1	1	1	5	11.5	1.91667
C2_48	2.5	3	1	1	5	5	17.5	2.91667
C2_49	5	3	1	5	1	1	16	2.66667
C2_50	3.5	3	1	5	1	5	18.5	3.08333
C2_51	3.5	2	1	1	1	5	13.5	2.25
C2_52	3.5	2	1	1	1	5	13.5	2.25
C2_53	3.5	2	5	5	5	5	25.5	4.25
C2_54	3.5	3	1	5	5	5	22.5	3.75
C2_55	3.5	2	1	5	5	5	21.5	3.58333
C2_57	1	1	1	1	5	1	10	1.66667
C2_58	1	1	1	5	1	5	14	2.33333
C2_59	2.5	2	1	1	1	5	12.5	2.08333
C2_60	1	1	1	1	5	5	14	2.33333
C2_61	1	2	1	1	5	1	11	1.83333
C2_62	5	4	1	5	5	1	21	3.5
C2_63	5	4	1	5	5	1	21	3.5
C2_64	5	2	1	5	5	1	19	3.16667
C2_65	2.5	2	1	1	1	1	8.5	1.41667
C1_3	2.5	3	5	5	5	5	25.5	4.25
C1_4	3.5	3	1	5	5	1	18.5	3.08333
C1_5	2.5	3	1	5	5	1	17.5	2.91667
C1_6	2.5	3	1	5	5	1	17.5	2.91667
C1_7	3.5	3	1	5	5	1	18.5	3.08333
C1_8	3.5	3	1	5	1	1	14.5	2.41667
C1_9	2.5	1	1	1	1	1	7.5	1.25
C1_10	3.5	3	5	5	1	5	22.5	3.75
C1_11	3.5	3	1	5	1	5	18.5	3.08333
C1_12	5	1	5	5	5	5	26	4.33333
C1_13	5	3	5	5	2	5	25	4.16667
C1_14	2.5	3	5	5	5	1	21.5	3.58333
C1_15	2.5	5	5	5	5	1	23.5	3.91667
C1_16	3.5	3	1	5	5	5	22.5	3.75
C1_17	2.5	3	5	5	5	5	25.5	4.25
C1_18	2.5	3	5	5	1	5	21.5	3.58333
C1_19	2.5	2	5	5	1	5	20.5	3.41667
C1_20	2.5	2	5	5	1	5	20.5	3.41667
C1_21	5	4	5	5	5	5	29	4.83333
C1_62	3.5	2	5	5	5	1	21.5	3.58333

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
C1_63	3	1	5	5	5	5	24	4
C1_64	2.5	3	5	5	5	1	21.5	3.58333
C1_93	2.5	2	1	1	1	5	12.5	2.08333
C1_94	2.5	1	1	1	1	5	11.5	1.91667
E2_1	2.5	4	1	5	1	1	14.5	2.41667
E2_2	3.5	3	1	1	1	1	10.5	1.75
E2_3	3.5	1	1	1	1	1	8.5	1.41667
E2_4	5	4	1	5	1	1	17	2.83333
E2_5	2.5	1	1	5	1	1	11.5	1.91667
E2_6	2.5	1	1	5	1	1	11.5	1.91667
E2_7	2.5	1	1	5	1	1	11.5	1.91667
E2_8	2.5	3	1	1	1	1	9.5	1.58333
E2_9	2.5	2	1	5	1	1	12.5	2.08333
E2_10	2.5	3	1	5	1	1	13.5	2.25
E2_11	2.5	1	1	5	1	1	11.5	1.91667
E2_12	2.5	3	1	1	1	1	9.5	1.58333
E2_13	2.5	1	1	5	1	1	11.5	1.91667
E2_14	5	3	1	1	1	5	16	2.66667
E2_15	2.5	1	1	1	1	5	11.5	1.91667
E2_16	3.5	1	1	1	1	1	8.5	1.41667
E2_17	3.5	3	1	5	1	5	18.5	3.08333
E2_18	2.5	2	1	1	1	5	12.5	2.08333
E2_19	1	5	1	1	1	5	14	2.33333
E2_20	2.5	1	1	5	1	5	15.5	2.58333
E2_21	3.5	3	1	5	1	1	14.5	2.41667
E2_22	3.5	3	1	1	1	5	14.5	2.41667
E2_23	2.5	2	1	1	1	5	12.5	2.08333
E2_24	3.5	1	1	1	5	1	12.5	2.08333
E2_25	3.5	3	1	1	1	1	10.5	1.75
E2_26	1	3	1	5	1	1	12	2
E2_27	2.5	1	1	1	1	1	7.5	1.25
E2_28	2.5	3	1	1	1	1	9.5	1.58333
E2_29	3.5	3	1	5	5	1	18.5	3.08333
E2_30	2.5	3	1	5	1	1	13.5	2.25
E2_31	1	1	1	5	1	1	10	1.66667
E2_32	3.5	1	1	1	1	1	8.5	1.41667
E2_33	3.5	2	1	5	1	5	17.5	2.91667
E2_34	3.5	4	1	1	1	5	15.5	2.58333
E2_35	2.5	1	1	5	5	1	15.5	2.58333
E2_36	2.5	1	1	1	1	1	7.5	1.25
E2_37	1	1	1	1	1	1	6	1

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
E2_38	3.5	3	1	1	1	1	10.5	1.75
E2_39	3.5	3	1	5	1	1	14.5	2.41667
E2_40	3.5	3	1	1	1	1	10.5	1.75
E2_41	3.5	3	1	1	5	1	14.5	2.41667
E2_42	3.5	1	1	1	1	1	8.5	1.41667
E2_43	3.5	2	1	1	1	1	9.5	1.58333
E2_44	2.5	3	1	1	1	1	9.5	1.58333
E2_45	3.5	3	1	5	1	1	14.5	2.41667
E2_46	3.5	2	1	5	1	1	13.5	2.25
E2_47	3.5	1	1	1	1	1	8.5	1.41667
E2_48	3.5	1	1	5	1	1	12.5	2.08333
E2_49	3.5	3	1	5	1	1	14.5	2.41667
E2_50	5	1	1	5	1	1	14	2.33333
E1_11	1	1	1	1	1	1	6	1
E1_12	1	1	1	1	1	1	6	1
E1_13	3.5	3	1	1	1	1	10.5	1.75
E1_18	2.5	1	1	1	1	5	11.5	1.91667
E1_42	1	2	1	1	1	5	11	1.83333
E1_43	1	2	1	1	1	5	11	1.83333
E1_47	1	1	1	1	1	1	6	1
E1_48	3.5	2	5	5	1	5	21.5	3.58333
E2_51	5	2	5	5	5	1	23	3.83333
E2_52	2.5	1	5	5	1	1	15.5	2.58333
E2_53	3.5	3	5	5	1	5	22.5	3.75
E2_54	3.5	3	5	5	1	5	22.5	3.75
E2_55	2.5	3	1	1	1	1	9.5	1.58333
E2_56	3.5	3	1	1	1	1	10.5	1.75
E2_57	3.5	3	1	1	1	1	10.5	1.75
E2_58	1	2	1	1	1	1	7	1.16667
E2_59	2.5	1	1	1	1	1	7.5	1.25
E2_60	1	4	1	1	1	1	9	1.5
E2_61	1	2	1	1	1	1	7	1.16667
E2_62	1	2	1	1	1	1	7	1.16667
E2_63	3.5	3	1	1	1	5	14.5	2.41667
E2_64	3.5	3	1	1	1	5	14.5	2.41667
E2_65	5	5	1	1	1	5	18	3
E2_66	2.5	3	1	1	1	1	9.5	1.58333
E2_67	5	3	1	1	1	1	12	2
E2_68	3.5	3	5	1	1	1	14.5	2.41667
E2_69	2.5	3	1	5	1	5	17.5	2.91667
E2_70	3.5	3	1	5	1	1	14.5	2.41667

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
E2_71	3.5	3	1	1	1	1	10.5	1.75
E2_72	3.5	3	1	1	1	5	14.5	2.41667
E2_73	5	3	1	1	5	1	16	2.66667
E2_74	2.5	2	1	1	5	5	16.5	2.75
E2_75	2.5	3	1	5	1	5	17.5	2.91667
E2_76	3.5	1	1	1	1	1	8.5	1.41667
E2_77	3.5	4	1	5	1	5	19.5	3.25
E2_78	5	4	5	5	1	5	25	4.16667
E2_79	2.5	1	5	1	1	5	15.5	2.58333
E2_80	3.5	4	1	1	1	1	11.5	1.91667
E2_81	5	4	1	1	1	1	13	2.16667
E2_82	2.5	2	1	1	1	1	8.5	1.41667
E2_83	2.5	3	1	1	1	1	9.5	1.58333
E2_84	5	3	1	5	1	5	20	3.33333
E2_85	5	1	1	1	1	1	10	1.66667
E2_86	3.5	3	1	1	1	1	10.5	1.75
E2_87	5	4	1	5	5	5	25	4.16667
E2_88	3.5	3	1	5	1	5	18.5	3.08333
E2_89	3.5	3	1	5	1	5	18.5	3.08333
E2_90	3.5	3	1	1	1	1	10.5	1.75
E2_91	3.5	1	1	5	5	1	16.5	2.75
E2_92	5	3	1	5	1	5	20	3.33333
E2_93	1	1	1	1	1	1	6	1
E2_94	2.5	2	1	5	1	1	12.5	2.08333
E2_95	3.5	2	1	1	1	1	9.5	1.58333
E2_96	3.5	4	1	1	1	5	15.5	2.58333
E2_97	3.5	3	1	1	1	1	10.5	1.75
E2_98	3.5	3	1	5	1	1	14.5	2.41667
E1_1	3.5	3	1	5	1	5	18.5	3.08333
E1_2	5	3	1	1	1	5	16	2.66667
E1_3	3.5	1	1	1	1	5	12.5	2.08333
E1_4	3.5	2	1	1	1	5	13.5	2.25
E1_5	5	5	1	1	1	5	18	3
E1_6	3.5	2	1	1	1	5	13.5	2.25
E1_7	3.5	1	1	1	1	5	12.5	2.08333
E1_8	5	1	1	1	1	5	14	2.33333
E1_9	1	1	1	1	1	5	10	1.66667
E1_10	3.5	1	1	1	1	5	12.5	2.08333
E1_15	1	1	1	1	1	5	10	1.66667
E1_16	2.5	1	1	1	1	1	7.5	1.25
E1_17	2.5	1	1	1	1	1	7.5	1.25

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
E1_19	5	1	1	1	1	5	14	2.33333
E1_20	5	1	1	1	1	5	14	2.33333
E1_21	5	1	1	1	1	5	14	2.33333
E1_22	5	4	1	1	1	5	17	2.83333
E1_23	3.5	1	1	1	1	1	8.5	1.41667
E1_24	3.5	4	1	1	1	5	15.5	2.58333
E1_25	5	1	1	1	1	5	14	2.33333
E1_26	3.5	3	1	1	1	1	10.5	1.75
E1_27	3.5	2	1	1	1	5	13.5	2.25
E1_28	5	5	1	1	1	1	14	2.33333
E1_29	3.5	2	1	1	1	5	13.5	2.25
E1_30	2.5	1	1	1	1	5	11.5	1.91667
E1_31	3.5	2	1	1	1	5	13.5	2.25
E1_32	3.5	4	1	1	1	1	11.5	1.91667
E1_33	3.5	2	1	1	1	1	9.5	1.58333
E1_34	1	2	1	1	1	1	7	1.16667
E1_35	5	3	1	1	1	1	12	2
E1_36	5	1	1	1	1	5	14	2.33333
E1_37	5	4	1	1	1	5	17	2.83333
E1_38	5	3	1	1	1	5	16	2.66667
E1_39	5	2	1	5	1	5	19	3.16667
E1_40	5	3	1	1	5	5	20	3.33333
E1_41	5	4	1	1	5	5	21	3.5
E2_99	5	4	5	5	5	1	25	4.16667
E2_100	5	5	5	5	5	5	30	5
E2_101	5	5	5	5	5	5	30	5
E2_102	5	5	5	5	5	5	30	5
E2_103	5	4	5	5	5	5	29	4.83333
E2_104	5	5	5	5	5	5	30	5
E2_105	5	5	5	5	5	5	30	5
E2_106	5	5	5	5	5	5	30	5
E1_14	2.5	3	1	1	5	5	17.5	2.91667
E1_44	3.5	4	1	1	5	5	19.5	3.25
E1_45	3.5	1	1	1	5	5	16.5	2.75
E1_46	5	2	1	5	1	5	19	3.16667
E1_50	5	1	1	1	1	5	14	2.33333
E1_51	3.5	4	1	1	5	1	15.5	2.58333
E1_52	3.5	4	1	1	1	5	15.5	2.58333
E1_53	3.5	1	1	1	1	1	8.5	1.41667
E1_54	5	4	1	5	5	1	21	3.5
E1_55	5	1	1	1	1	5	14	2.33333

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
E1_56	5	3	1	1	1	5	16	2.66667
E1_57	5	1	1	1	1	5	14	2.33333
E1_58	5	1	1	1	1	5	14	2.33333
E1_59	5	4	1	1	1	5	17	2.83333
E1_60	5	3	1	1	1	5	16	2.66667
E1_61	1	1	1	1	1	5	10	1.66667
E1_62	3.5	2	1	5	1	5	17.5	2.91667
E1_63	2.5	2	1	5	1	5	16.5	2.75
E1_64	2.5	2	1	5	5	5	20.5	3.41667
E1_65	3.5	2	1	5	5	5	21.5	3.58333
E1_66	3.5	2	1	5	5	5	21.5	3.58333
E1_67	3.5	2	1	5	5	5	21.5	3.58333
E1_68	5	4	1	5	5	5	25	4.16667
E1_69	3.5	3	1	5	5	1	18.5	3.08333
E1_70	2.5	2	1	5	5	1	16.5	2.75
E1_71	3.5	2	1	5	5	1	17.5	2.91667
E1_72	3.5	3	1	5	5	1	18.5	3.08333
E1_73	3.5	2	1	5	5	5	21.5	3.58333
S2_76	3.5	3	1	5	1	1	14.5	2.41667
S2_77	3.5	3	1	5	1	1	14.5	2.41667
S2_72	3.5	4	1	5	1	1	15.5	2.58333
S2_73	5	3	1	5	1	1	16	2.66667
S2_74	5	2	1	5	1	5	19	3.16667
S2_75	3.5	3	1	5	1	5	18.5	3.08333
S2_126	3.5	1	1	1	1	5	12.5	2.08333
S2_127	2.5	1	1	1	1	5	11.5	1.91667
S2_128	3.5	1	1	1	1	5	12.5	2.08333
S2_129	5	4	5	1	1	5	21	3.5
S2_130	5	4	1	1	1	1	13	2.16667
S2_131	5	4	1	1	1	5	17	2.83333
S2_132	5	1	1	5	1	5	18	3
S2_133	3.5	2	1	5	1	1	13.5	2.25
S2_134	3.5	2	1	5	1	1	13.5	2.25
S2_135	3.5	3	1	5	1	1	14.5	2.41667
S2_136	3.5	4	1	5	1	1	15.5	2.58333
S2_137	3.5	4	1	5	1	1	15.5	2.58333
S2_138	2.5	3	1	5	1	1	13.5	2.25
S3_53	3.5	3	1	1	1	1	10.5	1.75
S3_55	2.5	3	1	1	1	1	9.5	1.58333
S3_86	2.5	2	1	1	1	1	8.5	1.41667
S3_87	2.5	2	1	1	1	1	8.5	1.41667

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
S1_84	5	4	1	1	1	5	17	2.83333
S1_85	3.5	3	1	1	1	5	14.5	2.41667
S1_86	3.5	2	1	1	1	5	13.5	2.25
S1_87	2.5	2	1	1	1	5	12.5	2.08333
S1_88	3.5	1	1	1	1	1	8.5	1.41667
S1_89	2.5	1	1	1	1	5	11.5	1.91667
S1_90	3.5	1	1	1	1	1	8.5	1.41667
S1_91	3.5	1	1	5	1	1	12.5	2.08333
S1_92	2.5	2	1	1	1	1	8.5	1.41667
S1_78	3.5	3	1	1	1	1	10.5	1.75
S1_79	3.5	2	1	1	1	5	13.5	2.25
S1_80	3.5	2	1	1	1	5	13.5	2.25
S1_67	5	2	1	1	1	5	15	2.5
S1_68	5	1	1	1	1	5	14	2.33333
S1_69	3.5	2	1	1	1	5	13.5	2.25
S1_70	3.5	2	1	1	1	1	9.5	1.58333
S1_62	2.5	2	1	5	1	1	12.5	2.08333
S2_1	3.5	2	5	1	1	1	13.5	2.25
S2_2	3.5	1	1	5	1	1	12.5	2.08333
S2_3	3.5	1	1	1	1	1	8.5	1.41667
S2_4	2.5	1	1	1	1	5	11.5	1.91667
S2_5	2.5	2	1	1	1	1	8.5	1.41667
S2_6	2.5	3	1	5	1	5	17.5	2.91667
S2_7	2.5	3	1	1	1	5	13.5	2.25
S2_8	2.5	1	1	1	1	5	11.5	1.91667
S2_9	1	1	1	1	1	5	10	1.66667
S2_10	2.5	2	1	1	1	1	8.5	1.41667
S2_11	1	3	1	5	1	1	12	2
S2_12	2.5	2	1	5	1	1	12.5	2.08333
S2_13	2.5	3	1	5	1	1	13.5	2.25
S2_14	1	1	1	5	1	1	10	1.66667
S2_15	2.5	2	1	1	1	5	12.5	2.08333
S2_16	2.5	1	1	1	1	5	11.5	1.91667
S2_17	1	1	1	5	1	1	10	1.66667
S2_18	2.5	2	1	1	1	1	8.5	1.41667
S2_19	2.5	2	1	1	1	1	8.5	1.41667
S2_20	2.5	1	1	5	1	1	11.5	1.91667
S2_21	5	1	1	5	1	1	14	2.33333
S2_22	2.5	1	1	5	1	1	11.5	1.91667
S2_23	2.5	1	1	1	1	5	11.5	1.91667
S2_24	2.5	2	1	1	1	5	12.5	2.08333

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
S2_81	3.5	4	1	1	1	5	15.5	2.58333
S2_82	3.5	4	5	1	1	5	19.5	3.25
S2_83	3.5	1	5	1	1	5	16.5	2.75
S2_84	3.5	1	1	1	1	1	8.5	1.41667
S2_85	2.5	1	1	5	1	5	15.5	2.58333
S2_86	2.5	3	1	5	1	5	17.5	2.91667
S2_87	2.5	1	1	5	1	5	15.5	2.58333
S2_88	2.5	1	1	5	1	1	11.5	1.91667
S2_89	2.5	2	1	5	1	1	12.5	2.08333
S2_90	1	1	1	5	1	5	14	2.33333
S2_91	3.5	3	1	1	1	5	14.5	2.41667
S2_92	1	2	1	1	1	5	11	1.83333
S2_93	3.5	2	1	1	1	1	9.5	1.58333
S2_94	2.5	3	1	1	1	5	13.5	2.25
S2_95	2.5	3	1	1	1	5	13.5	2.25
S2_96	2.5	1	1	1	1	5	11.5	1.91667
S2_97	2.5	2	1	1	1	5	12.5	2.08333
S2_98	5	1	1	1	1	5	14	2.33333
S2_99	5	3	1	1	1	5	16	2.66667
S2_121	2.5	1	1	5	1	1	11.5	1.91667
S2_122	2.5	3	1	5	1	1	13.5	2.25
S2_123	2.5	3	1	5	1	1	13.5	2.25
S2_124	2.5	3	1	5	1	1	13.5	2.25
S2_125	2.5	1	1	5	1	1	11.5	1.91667
S3_1	3.5	4	1	1	1	1	11.5	1.91667
S3_2	3.5	4	1	1	1	5	15.5	2.58333
S3_3	3.5	1	1	1	1	5	12.5	2.08333
S3_4	3.5	2	1	5	1	5	17.5	2.91667
S3_5	3.5	1	1	1	1	5	12.5	2.08333
S3_6	1	1	1	1	1	1	6	1
S3_7	2.5	1	1	1	1	1	7.5	1.25
S3_8	2.5	1	1	1	1	5	11.5	1.91667
S3_9	2.5	3	1	5	1	1	13.5	2.25
S3_10	2.5	3	1	1	1	1	9.5	1.58333
S3_11	3.5	2	1	1	1	5	13.5	2.25
S3_12	2.5	1	1	1	1	1	7.5	1.25
S3_13	1	3	1	1	1	1	8	1.33333
S3_14	1	1	1	1	1	5	10	1.66667
S3_15	2.5	2	1	1	1	5	12.5	2.08333
S3_16	3.5	3	1	1	1	1	10.5	1.75
S3_17	1	1	1	1	1	1	6	1

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
S3_18	2.5	2	1	1	1	1	8.5	1.41667
S3_19	2.5	1	1	1	1	1	7.5	1.25
S3_20	1	3	1	1	1	5	12	2
S3_21	2.5	3	1	1	1	5	13.5	2.25
S3_22	3.5	3	1	1	1	1	10.5	1.75
S3_23	2.5	1	1	1	1	5	11.5	1.91667
S3_24	3.5	1	1	1	1	5	12.5	2.08333
S3_25	1	2	1	1	1	1	7	1.16667
S3_26	2.5	3	1	1	1	1	9.5	1.58333
S3_27	2.5	3	1	1	1	5	13.5	2.25
S3_28	3.5	3	1	1	1	1	10.5	1.75
S3_29	2.5	1	1	1	1	5	11.5	1.91667
S3_30	2.5	3	1	1	1	1	9.5	1.58333
S3_31	3.5	3	1	1	1	5	14.5	2.41667
S3_32	2.5	1	1	1	1	1	7.5	1.25
S3_33	2.5	1	1	1	1	1	7.5	1.25
S3_34	2.5	3	1	1	1	1	9.5	1.58333
S3_35	1	3	5	1	1	1	12	2
S3_36	1	3	5	1	1	5	16	2.66667
S3_37	2.5	1	1	1	1	5	11.5	1.91667
S3_38	1	2	5	1	1	1	11	1.83333
S3_83	3.5	2	5	1	1	5	17.5	2.91667
S3_84	2.5	1	5	1	1	5	15.5	2.58333
S3_85	2.5	3	1	1	1	5	13.5	2.25
S2_25	5	1	1	1	5	1	14	2.33333
S2_26	3.5	4	1	1	5	1	15.5	2.58333
S2_27	1	1	1	1	1	1	6	1
S2_28	3.5	2	1	5	1	1	13.5	2.25
S2_29	5	4	1	5	1	1	17	2.83333
S2_30	5	3	1	1	5	1	16	2.66667
S2_31	2.5	1	5	5	1	1	15.5	2.58333
S2_32	1	2	5	5	1	5	19	3.16667
S2_33	2.5	1	1	5	1	1	11.5	1.91667
S2_34	3.5	1	5	5	1	1	16.5	2.75
S2_35	3.5	3	5	5	1	5	22.5	3.75
S2_36	2.5	2	1	5	5	5	20.5	3.41667
S2_37	2.5	3	1	5	5	5	21.5	3.58333
S2_38	2.5	2	1	5	5	1	16.5	2.75
S2_39	5	5	1	5	5	1	22	3.66667
S2_40	5	5	1	5	5	1	22	3.66667
S2_41	3.5	3	5	1	1	5	18.5	3.08333

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
S2_42	3.5	2	5	1	1	5	17.5	2.91667
S2_43	3.5	1	5	1	1	5	16.5	2.75
S2_44	3.5	2	5	1	1	1	13.5	2.25
S2_45	3.5	2	5	5	1	5	21.5	3.58333
S2_46	5	1	1	1	1	1	10	1.66667
S2_47	2.5	3	1	5	1	5	17.5	2.91667
S2_48	5	3	1	5	1	5	20	3.33333
S2_49	1	3	5	5	1	1	16	2.66667
S2_50	5	2	1	5	1	5	19	3.16667
S2_51	3.5	3	5	1	1	5	18.5	3.08333
S2_52	3.5	3	5	5	1	5	22.5	3.75
S2_53	5	1	1	1	1	1	10	1.66667
S2_54	3.5	1	1	1	1	1	8.5	1.41667
S2_55	5	1	1	1	5	1	14	2.33333
S2_56	2.5	2	1	1	5	1	12.5	2.08333
S2_57	2.5	2	1	1	1	1	8.5	1.41667
S2_58	3.5	1	1	5	1	5	16.5	2.75
S2_59	5	3	1	5	1	5	20	3.33333
S2_60	2.5	1	1	1	1	1	7.5	1.25
S2_61	3.5	3	1	1	1	5	14.5	2.41667
S2_62	3.5	2	1	1	1	5	13.5	2.25
S2_63	2.5	3	1	5	1	5	17.5	2.91667
S2_64	5	3	1	5	1	5	20	3.33333
S2_65	2.5	1	1	1	1	1	7.5	1.25
S2_66	2.5	2	1	1	1	5	12.5	2.08333
S2_67	2.5	3	1	1	1	1	9.5	1.58333
S2_68	5	2	1	5	1	1	15	2.5
S2_69	2.5	3	1	1	1	1	9.5	1.58333
S2_70	3.5	3	1	1	5	1	14.5	2.41667
S2_71	3.5	4	1	1	1	1	11.5	1.91667
S2_100	3.5	2	1	5	1	5	17.5	2.91667
S2_101	2.5	1	1	5	1	1	11.5	1.91667
S2_102	3.5	3	1	5	1	1	14.5	2.41667
S2_103	3.5	3	1	5	1	5	18.5	3.08333
S2_104	1	3	1	1	1	1	8	1.33333
S2_105	5	1	1	1	1	1	10	1.66667
S2_106	2.5	1	1	1	1	1	7.5	1.25
S2_107	5	2	1	1	1	1	11	1.83333
S2_108	5	2	1	1	1	1	11	1.83333
S2_109	3.5	3	1	1	1	5	14.5	2.41667
S2_110	2	3	1	5	5	5	21	3.5

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
S2_111	2	3	1	5	5	5	21	3.5
S2_112	2	1	1	5	1	5	15	2.5
S2_113	2	4	1	1	1	1	10	1.66667
S2_114	2	3	1	1	1	1	9	1.5
S2_115	2	1	1	1	1	1	7	1.16667
S2_116	2	3	1	1	1	1	9	1.5
S2_117	5	3	1	1	1	5	16	2.66667
S2_118	5	1	1	1	1	5	14	2.33333
S2_119	5	1	1	1	1	5	14	2.33333
S2_120	5	1	1	1	1	5	14	2.33333
S3_58	3.5	2	1	1	5	1	13.5	2.25
S3_59	2.5	3	1	1	5	1	13.5	2.25
S3_60	3.5	3	1	5	5	1	18.5	3.08333
S3_61	5	3	1	1	5	1	16	2.66667
S3_62	3.5	4	1	1	5	5	19.5	3.25
S3_63	3.5	1	1	5	5	1	16.5	2.75
S3_64	5	5	1	5	5	1	22	3.66667
S3_65	5	2	1	5	5	1	19	3.16667
S3_66	5	5	5	5	5	5	30	5
S3_67	5	4	1	1	5	5	21	3.5
S3_68	5	3	1	1	1	5	16	2.66667
S3_69	5	3	5	5	1	5	24	4
S3_70	3.5	2	1	1	5	5	17.5	2.91667
S3_71	3.5	3	1	1	5	1	14.5	2.41667
S3_72	5	2	1	1	5	5	19	3.16667
S3_73	5	3	1	1	5	1	16	2.66667
S3_74	3.5	1	1	1	5	1	12.5	2.08333
S3_75	5	5	1	1	5	1	18	3
S2_78	5	5	1	5	5	5	26	4.33333
S2_79	5	5	1	5	5	5	26	4.33333
S2_80	5	1	1	5	5	1	18	3
S2_139	2.5	2	1	5	1	5	16.5	2.75
S2_140	3.5	3	1	5	1	1	14.5	2.41667
S2_141	3.5	3	1	5	1	5	18.5	3.08333
S2_142	5	4	5	5	1	5	25	4.16667
S2_143	3.5	4	1	1	1	5	15.5	2.58333
S2_144	3.5	3	5	5	1	5	22.5	3.75
S2_145	5	3	1	1	1	5	16	2.66667
S2_146	3.5	1	1	1	1	1	8.5	1.41667
S2_147	3.5	2	1	1	1	5	13.5	2.25
S2_148	5	3	1	1	1	1	12	2.00

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
S1_1	3.5	2	1	1	1	1	9.5	1.58333
S1_2	3.5	3	1	1	1	1	10.5	1.75
S1_3	5	3	1	1	1	1	12	2
S1_4	5	4	1	1	1	1	13	2.16667
S1_5	5	3	1	1	1	5	16	2.66667
S1_6	3.5	3	1	1	5	5	18.5	3.08333
S1_7	3.5	2	1	1	1	5	13.5	2.25
S1_8	2.5	2	1	1	1	5	12.5	2.08333
S1_9	3.5	3	1	1	1	5	14.5	2.41667
S1_10	5	4	1	1	1	1	13	2.16667
S1_11	5	4	1	1	1	5	17	2.83333
S1_12	5	4	1	1	1	1	13	2.16667
S1_13	5	2	1	1	1	1	11	1.83333
S1_14	5	5	1	1	1	5	18	3
S1_15	3.5	3	1	1	1	1	10.5	1.75
S1_16	5	1	1	5	1	5	18	3
S1_17	3.5	1	1	1	1	1	8.5	1.41667
S1_18	3.5	1	1	1	1	1	8.5	1.41667
S1_19	5	3	1	1	1	5	16	2.66667
S1_20	5	2	1	1	1	1	11	1.83333
S1_21	2.5	3	1	1	1	5	13.5	2.25
S1_22	3.5	2	1	1	1	1	9.5	1.58333
S1_23	3.5	3	1	5	1	1	14.5	2.41667
S1_24	5	4	1	1	1	5	17	2.83333
S1_25	3.5	1	1	1	1	5	12.5	2.08333
S1_26	3.5	4	1	1	1	1	11.5	1.91667
S1_27	5	1	1	1	1	1	10	1.66667
S1_28	2.5	3	1	5	1	5	17.5	2.91667
S1_29	5	3	1	1	1	1	12	2
S1_30	5	1	1	1	1	1	10	1.66667
S1_31	3.5	3	1	1	1	1	10.5	1.75
S1_32	3.5	1	1	1	1	5	12.5	2.08333
S1_33	5	2	1	1	1	1	11	1.83333
S1_34	3.5	2	1	5	1	5	17.5	2.91667
S1_61	5	4	1	1	1	5	17	2.83333
S1_63	2.5	2	1	1	1	1	8.5	1.41667
S1_64	2.5	2	1	1	1	5	12.5	2.08333
S1_65	3.5	3	1	1	1	1	10.5	1.75
S1_66	3.5	3	1	1	1	5	14.5	2.41667
S1_71	5	2	1	1	1	5	15	2.5
S1_72	5	3	1	1	1	1	12	2

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
S1_73	5	5	1	5	1	1	18	3
S1_74	3.5	1	1	1	1	5	12.5	2.08333
S1_75	5	5	1	1	1	1	14	2.33333
S1_76	2.5	2	1	1	1	1	8.5	1.41667
S1_77	3.5	3	1	1	1	5	14.5	2.41667
S1_81	3.5	2	1	1	1	1	9.5	1.58333
S1_82	2.5	4	1	1	1	5	14.5	2.41667
S1_83	3.5	2	1	1	1	1	9.5	1.58333
S1_93	5	4	1	1	1	5	17	2.83333
S3_39	3.5	1	1	1	1	1	8.5	1.41667
S3_40	3.5	3	1	1	1	1	10.5	1.75
S3_41	5	4	1	1	5	5	21	3.5
S3_42	3.5	3	1	1	5	5	18.5	3.08333
S3_43	5	4	1	1	5	1	17	2.83333
S3_44	3.5	3	5	1	1	5	18.5	3.08333
S3_45	2.5	3	1	1	5	1	13.5	2.25
S3_46	5	3	1	1	1	1	12	2
S3_47	5	2	1	1	1	5	15	2.5
S3_48	2.5	3	1	1	1	1	9.5	1.58333
S3_49	5	3	1	1	1	1	12	2
S3_50	3.5	3	1	1	5	1	14.5	2.41667
S3_51	5	1	1	5	5	1	18	3
S3_52	5	3	1	5	1	1	16	2.66667
S3_54	5	3	1	5	1	1	16	2.66667
S3_56	5	2	1	5	5	1	19	3.16667
S3_57	5	3	1	1	5	1	16	2.66667
S3_76	5	4	1	1	5	1	17	2.83333
S3_77	5	5	1	1	5	1	18	3
S3_78	5	5	1	1	5	1	18	3
S3_79	5	5	1	1	5	5	22	3.66667
S3_80	5	4	1	5	5	5	25	4.16667
S3_81	5	5	1	1	5	5	22	3.66667
S3_82	5	5	5	5	5	5	30	5
S3_88	5	4	5	5	5	5	29	4.83333
S3_89	5	5	5	5	5	5	30	5
S3_90	5	5	5	5	1	5	26	4.33333
S3_91	5	5	5	1	1	5	22	3.66667
S3_92	5	4	5	1	5	5	25	4.16667
S3_93	5	5	5	1	5	5	26	4.33333
S3_94	5	5	5	1	1	5	22	3.66667
S3_95	5	5	5	5	1	5	26	4.33333

Questionnaire Number	Income Level	Educational Level	Existence of Resident Welfare Association or other Unions or Organizations	Awareness of Responsible Authority	Response to the Reporting	Possibility of Community Participation	Total Score	Coping Capacity Index
S3_96	5	5	5	5	1	5	26	4.33333

Source: Data processed from household survey results according to the HRCI key

<u>Appendix VI</u>

Water Quality Criteria

DESIGNATED BEST USE	**CLASS OF WATER**	**CRITERIA**
Drinking water source without conventional treatment but after disinfection	**A**	1. Total Coliforms OrganismMPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20oC 2mg/l or less
Outdoor bathing	**B**	1. Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20^{o}C 3mg/l or less
Drinking water source after conventional treatment and disinfection	**C**	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 to 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20^{o}C 3mg/l or less
Propagation of wild life and fisheries	**D**	1. pH between 6.5 to 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, controlled waste disposal	**E**	1. pH betwwn 6.0 to 8.5 2. Electrical Conductivity at 25oC micro mhos/cm Max.2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

Source: Central Pollution Control Board.

URL http://tempweb93.nic.in/Water_Quality_Criteria.php (Last accessed on 3.6.8)

<u>Appendix VII</u>

Classification of Water-Related Diseases and Preventive Strategies

Category	**Disease or syndrome**	**Preventive strategy**
Waterborne Microbiological	Diarrheas and dysenteries Amoebiasis Campylobacter enteritis Cholera E.coli diarrhea Giardisis Rotavirus diarrhea Salmonellosis Shigellosis Enteric fevers Typhoid Paratyphoid Poliomyelitis Hepatitis A	Improve quality of drinking water. Prevent casual use of unprotected sources.
Water hygiene diseases	Infectious skin diseases Infectious eyes diseases (conjunctivitis, trachoma)	Increase water quality used. Improve accessibility and reliability of domestic water supply. Improve hygiene.
Water contact diseases	Schistosomiasis Leptospirosis	Reduce the need for contact with infected water. Reduce contamination of surface waters.
Water habitat vector-borne diseases	Malaria Yellow fever Dengue Onchocerciasis (river blindness)	Improve surface water management. Destroy breeding sites of insects. Reduce need to visit breeding sites.
Waterborne chemical diseases	Methemoglobinemia (nitrates) Cancer (organic chemical radionuclides) Mutations (organic chemicals) Birth defects (organic chemicals) Tosixcoses (metals)	Protect drinking water sources. Prevent casual use of Unprotected sources. Improve surface water management

Source: Porto, 2004: 10

Appendix VIII

Contingency Coefficient Analysis

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Exposure_Category* Disease_Category	696	100.0%	0	.0%	696	100.0%

Exposure_Category * Disease_Category Crosstabulation

			Disease Category			Total
			1.00(L)	2.00(M)	3.00(H)	
Exposure Category	1.00 (H)	Count	18	37	28	83
		Expected Count	25.9	41.3	15.9	83.0
		Adjusted Residual	-2.0	-1.0	3.6	
	2.00 (M)	Count	115	219	84	418
		Expected Count	130.3	207.8	79.9	418.0
		Adjusted Residual	-2.6	1.7	.8	
	3.00 (L)	Count	84	90	21	195
		Expected Count	60.8	96.9	37.3	195.0
		Adjusted Residual	4.2	-1.2	-3.5	
Total		Count	217	346	133	696
		Expected Count	217.0	346.0	133.0	696.0

H-High; M- Moderate; L-Low

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Contingency Coefficient	.207	.000
N of Valid Cases		696	

Appendix IX

Photographic Elaboration of the Study Area: Delhi

A Newly developed squatter with temporary hutments. These are inhabited by migrant labours from neighbouring states.

(Location: Central Delhi)

An informal colony (*Jhuggi Jhompri* cluster) in the midst of planned area. It is an old colony located there since more than 20 years.

(Location: Central Delhi)

New construction of houses in densely packed residential areas and further mushrooming of unauthorised colonies.

(Location: East Delhi)

Co-operative housing: Example of a gated community inhabited by upper middle class people.

(Location: East Delhi)

A typical farm house bungalow in the outskirts of Delhi.

(Location: South Delhi)

Administrative area of New Delhi.

(Location: Central Delhi)

Congested narrow lane of a typical unauthorised colony.

(Location: South Delhi).

Poorly maintained open drain running through the colony. It is conducive habitat for breeding of mosquitoes and flies as the grasses along the drain is also not cleared regularly.

(Location: East Delhi)

Open canal carrying polluted water is also not bothersome for local children interested in swimming and fishing for small items.

(Location: East Delhi)

Women engaged in everyday household chores in the morning at a surveyed unauthorised colony.

(Location: East Delhi)

Uncovered water tank levelled with the ground; vulnerable to surface pollutants and wastewater mixing.

(Location: South Delhi)

Garbage and solid waste is a severe problem causing blockage in the drains. A cart used to carry away the mucks and garbage removed from them.

(Location: South Delhi)

Temporarily constructed public toilet for the neighbouring JJ clusters.

(Location South Delhi)

Overcrowded public water tank provided by the local leader for the inhabitants of nearby JJ cluster.

(Location: South Delhi)

Bottled water sold by road side. (Location: South Delhi)

A private sewer cleaning service "Kunwar Pal Enterprise", in an unauthorised colony available at an average cost of 600 INR for one time cleaning.

(Location: East Delhi).

Water supply pipeline running close to raw sewage which frequently suffers leakages.

(Location: East Delhi).

Household hand pumps painted red by the pollution control board after inspection, indicating contaminated water unsafe for consumption.

(Location: East Delhi).

Open area with stagnant wastewater and solid wastes lying over for months.

(Location: East Delhi)

Open manhole clogged with plastics and solid waste at a resettlement colony.

(Location: East Delhi)

Clogged drains in the colony being cleaned by local sweepers “Safaikarmachari”.

(Location: East Delhi)

Human exposure to sewage: Muck from the drains being manually removed at a resettlement colony.

(Location: East Delhi)

A women manually draining out the wastewater entering her household.

(Location: South Delhi)

Lanes getting flooded with sewage water in the absence of proper sewage facility at an unauthorised colony.

(Location: East Delhi)

Source: Own photos, 2005-2006

Declaration

I assure that I wrote the submitted thesis on my own. Furthermore, I confirm that the sources and means I reverted to are cited completely. Those parts of the thesis – including tables, maps and figures – that I took from other publications, as quotation or figuratively, are indicated as borrowings in every single case. I assure that this thesis was not submitted to a different faculty or university before and that – apart from the stated publications given below – nothing else has been published yet and will not be published before the *Promotionsverfahren* is finished. I know about the regulations of this *Promotionsordnung*. The submitted dissertation has been supervised by Prof. Dr. Frauke Kraas.

Publication(s)

SINGH, R. (2008): Social Vulnerability and Wastewater Related Risks: A Case Study of Delhi. In Bohle, H.G and Warner, K. (Eds) Megacities: resilience and social vulnerability. SOURCE 10/2008, publication series of UNU-EHS, Bonn, pp. 121-131.

SINGH, R., et.al. (2006): A New Approach to Analyse Water Related Vulnerability in Megacities: Case Study of Delhi. In: WHOCC Newsletter No. 10, Bonn, pp. 4-7.

MAUSER, W., KRAAS, F., KRAFFT, T., LÖW, A., NIEBERGALL, S., SELBACH, V. and **R. SINGH** (2006): Vulnerability in Megacities: An Integrated Approach Using High Resolution Satellite Data and Social Analysis. In*:* Wuyi, W., Krafft, T., and Kraas, F., (Eds.) (2006): Global change, Urbanisation and Health. China Meteorological Press. Beijing, pp. 225-239.

I assure that the above mentioned publications together present only a small section of the submitted thesis.

Cologne,

Reena Singh