CHAPTER I

Cholera and Urbanisation:
Conceptual Framework and Design
With the help of a review of literature, the effort here is to articulate the problem and evolve a suitable design for the study. Understanding of epidemiological methods is necessary to choose appropriate models for designing the study. However, our emphasis is to review epidemiological literature itself to emphasize the fact that is as crucial at the conceptual level as the level of methods. Today, cholera is now largely seen as an urban disease, perhaps due to non-availability of surveillance in rural areas. In urban areas the disease exists primarily as endemic foci among the urban poor living in infrastructure deficient settlements. Issues of urbanisation, the urban poor, their lack of access to civic services and its consequent health impacts are our primary focus and have been reviewed. The chapter therefore is divided into two main sections – one that reviews the importance of epidemiology, urbanisation and cholera transmission processes. The other deals with issues of methodology.

I
Reviews

EPIDEMIOLOGICAL APPROACH TO CHOLERA

While in one sense epidemiology is almost as old as medicine itself, in another sense it is a very young discipline (Mac Mahon, 1996). Although Hippocrates spoke in terms that have meaning to epidemiologists today, only in the last few decades has epidemiology become recognisable as a named discipline with which research groups and academic departments are identified. Since the 1960's, the discipline has featured regularly in regulatory, legal and media contexts. The essential purpose of epidemiology has been to identify things in people and their surroundings that affect the occurrence of diseases. Medical epidemiologists are therefore "doctors who don't care about a single person!" (Vetter, 1999).

Frost (1941) considered epidemiology essentially as an inductive science, concerned not merely with describing the distribution of disease, but equally importantly fitting it into a consistent philosophy. As a scientific discipline matures, he pointed out, "a desire develops
among scientists in the field to express the phenomena they are studying in mathematical terms. If the deduction from the mathematical model correspond to the observations, the underlying hypothesis is strengthened, resulting in a better understanding of the phenomenon."

The scope of observational epidemiology has been summarised by Mac Mahon, (1996):

- Understanding the cause of disease
- Explaining local disease patterns
- Describing the natural history of diseases, and,
- Applying this knowledge for solving administrative and health services solutions

Classically, the epidemiologist develops hypotheses and tests them and classifies individuals with disease or health problems into groups that appear to have etiologic features in common. The epidemiologist of today is concerned not so much with the acquisition of new knowledge about the origin of diseases as with applying the existing knowledge about the causes of diseases to understand patterns that diseases exhibit in a local area or community. The emphasis of the reasoning process is deductive rather than inductive, the latter attempting to utilise information from a single set of observations to derive principles that have greater generality. However, generalisable knowledge may also be derived during the course of any routine study (Mac Mahon, 1996).

Rothman (1988) has outlined the difficulties of conducting epidemiological research. The basic building blocks for epidemiological influences are incidence rates. This involves counting disease occurrence in relation to the people and time spans in which they occur. They are not easy to obtain. Such difficulties have in fact discouraged epidemiological research and will continue to do so. Economies of scale resulting from these observational problems have favoured epidemiological research in settings where medical records and vital statistical records are carefully collected and available for use or where the wealth of society can support these expensive efforts.
Until the 1970s, virtually all epidemiologists were physicians and their interest was typically focussed on the incidence patterns of a particular disease. There was no movement to pursue the development of a theory of epidemiological investigation. The physicians collaborated with the statisticians who constituted expertise in making observations on large populations as well as in data analysis. The influence of statistical thinking in epidemiology has been considered not to be wholly positive (Rothman 1988). It was natural for some statisticians, bringing their skills to bear on epidemiological problems, to borrow methods with which they were familiar in other areas of application. These methods often became incorporated into epidemiological practices, not always with a sound basis. The notion of statistical significance came to pervade epidemiological thinking. Statistical hypothesis testing as a mode of analysis has been criticised as it offers less insight into epidemiological data than alternative methods that emphasise estimation of interpretable measures.

Analysing the history of epidemiology, Susser and Susser (1996) grouped them into three main historical eras:

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<th>Era</th>
<th>Paradigm</th>
<th>Analytical Approach</th>
<th>Preventive Approach</th>
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<tr>
<td>I Sanitary statistics</td>
<td>Miasmatic</td>
<td>Demonstrate clustering and patterns of morbidity and mortality</td>
<td>Drainage, sewage and sanitation</td>
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<td>II Infectious Diseases</td>
<td>Germ theory</td>
<td>Laboratory isolation of pathogenic organisms</td>
<td>Interrupt disease transmission through technological intervention on mass scale including drugs and vaccines</td>
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<td>Epidemiology</td>
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<td>III Chronic Diseases</td>
<td>Causality due to exposures other than infection</td>
<td>Risk ratio of exposure to outcome at individual level</td>
<td>Control risk factors by modifying lifestyle</td>
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The Hippocratic School of Ancient Greece was the earliest proponent of the concept that environmental factors could influence the occurrence of diseases (Rosen, 1958). The work of British sanitarians like Chadwick and Smith reinforced the environmentalist approach and
provided impetus for solving public health problems through sanitary reform in the early 19th century. Chadwick's report published in 1842 established that diseases originated from filthy environmental conditions, accumulated garbage and polluted water supplies (Fee, 1993).

Statistical approach in public health research began with the work of the French physician Louis in his paper on blood letting in which he demonstrated that there was little merit in that therapy. Though this was rejected by the French Academy of Medicine, the application of numerical methods to studying disease at the population level gained acceptance with the works of Farr and Guy in England who were both students of Louis. Farr established that for analysis of disease aetiologies understanding the population perspective was crucial (Lillienfield, 1979).

In the first half of the 19th century two landmark studies were undertaken by Villerme in France and Snow in England. Villerme's epidemiological studies on mortality patterns of different communities in Paris established for the first time that poverty was a major cause of disease and death. This work influenced further research in different countries like Alison in Scotland, Engels in England, Virchow in Germany that emphasised the role of social and economic factors in disease aetiology (Smith, 1996).

In 1849, John Snow, while investigating cholera in London, observed that cholera rates were particularly high in areas supplied with water by Lambeth Company compared to areas that were supplied by Vauxhall Company. This marked the beginning of modern observational epidemiology. Snow's studies confirmed his earlier hypothesis that cholera was a communicable disease and also that the mode of transmission was through polluted drinking water. He applied statistical measures to count and compare the number of cholera deaths in different London districts with different water supplies. Thus, Snow established through epidemiological studies that cholera was probably transmitted through contaminated water, much before bacteriologists discovered the _Vibrio cholerae_.

The foundation of the London Epidemiological Society in 1850 indicated that the discipline existed by mid-19th century. It is interesting that the Society was initially proposed to study
anti-cholera activities – and was to be named the Epidemic Medical Society – and also to explore issues that today would be considered as health services research (Smith and Ebrahim 2001). The term epidemiologist was apparently not used until the 1860's and the profession only emerged in the early part of the 20th century.

The decline of communicable diseases and the rise in relative importance of non-communicable diseases led to the development of a new epidemiological paradigm in the mid-20th century. This involved the recognition of role of multiple causes and also led to the development and application of new techniques of study design and tools of analysis (Pearce, 1996). Risk factor epidemiology thus emerged as a strong discipline since the 1950's and entails the use of statistical tools to identify factors having damaging or protective effect on health i.e. risk factors. High risk behaviours are increasingly been incriminated for a number of diseases including personal and household level factors in the aetiology of diarrhoeal diseases. The notion of risk factor was not used by the earliest epidemiologists who relied on simple but powerful associations between environment and disease (Qadeer, 1988). With discovery of specific causal microbiological agents of prevalent communicable diseases there was optimism in the medical community for overcoming the challenges. However, epidemiologists recognised that this over simplified approach ignored the complex realities of disease epidemiology. There were efforts for developing alternative approaches to epidemiology that re-emphasised the interplay of multiple factors in disease epidemiology.

Modern epidemiology often seems more concerned with modelling complex relationships among risk factors than with understanding their origins and implications for public health. Web of causation was first mentioned in 1960. It sought to move beyond the germ theory and advocated replacing single agent germ theories of disease by more complex models of host, agent and environment. Social determinants of health were also explored. Epidemiologic thought was also influenced in that period by two more events – discovery of the double helix structure of DNA in 1953 and the growing use of computers to store and analyse large datasets specially using multivariate techniques.
Driven by germ theory, and the linear causal understanding the designs within epidemiology took a specific direction and risk factor epidemiology became central. Risk factor epidemiology undoubtedly provided useful insights into disease processes, but, was based on narrow definition of individual risks with little emphasis on social and environmental factors. Risk factor epidemiology reduced the discipline of epidemiology to the role of identifying, measuring, ranking and predicting risk factors related to individual behaviours and practices. Though specific risk factors may appear to operate at the individual level, exposure and susceptibility may occur due to a wide range of political, economic and social factors (Pearce, 1996). Risk factor epidemiology has thus been considered not to be a sound basis for public health action as it essentially ignores population perspectives on health and disease (Smith, 1996). Those who were grappling with multi-causality evolved the notion of web of causation to reflect complexities. A web theory only expresses complexity but does not expose causality. It was critiqued by epidemiologists who asked the question, "Has anyone seen the spider?" (Krieger, 1994)

"Multiple causation is the canon of contemporary epidemiology, and its metaphor and model is the web of causation" (Kreiger, 1994). The belief that population patterns of health and disease can be explained by a web of inter connected risk and preventive factors has become a central theme of epidemiology and is embedded in the statistical techniques of multivariate analysis. Its corollary is that epidemiology's role in improving public health rests upon its ability to identify and predict the results of breaking selected strands of this causal web.

Within risk factor epidemiology molecular biology and genetics is acquiring a major space due to its therapeutic, preventive and profit potentials. Just as the occurrence of diseases within a population can be studied at multiple levels – populations, individuals, organs, tissues, cells and molecules, the causality can also be studied at these different levels – socioeconomic factors, lifestyle, organ burden of a carcinogen and DNA adducts. 26th June, 2000 – the date on which DNA sequencing of the human genome was announced – has been hailed as a landmark in the history of human knowledge. Smith and Ebrahim (2001) questioned whether, "viewed through DNA-tinted spectacles", epidemiology was to be considered
merely as a discipline with a glorious past? The challenge before epidemiology, said the authors, was to shift the focus from mere description to explanation (gene expression).

The increasing dominance of risk factor epidemiology and molecular epidemiology in current epidemiological approaches has been recently questioned by some authors (Pearce, 1996). Pearce (1996) also pointed out that there was a shift in the level of analysis from population to individuals in modern epidemiology. This is marked by the current lack of interest in population factors as causes of disease, the lack of interest in history of epidemiology and the lack of integration with other public health services. While traditional epidemiology used a wide variety of approaches, modern epidemiology focussed primarily on statistical issues and was primarily concerned with measurements of disease incidence and a lack of understanding of population patterns of disease occurrence. Governments and funding agencies focussed on lifestyle diseases and epidemiologists out of choice or necessity gravitated to "where the money is." Epidemiology was "inevitably entangled with society" and it was not desirable to study disease causality in the abstract. The Leeds Declaration therefore called for a need to refocus upstream and to use research methods that are appropriate to the level at which intervention could take place (Pearce, 1996).

It is in this backdrop that Susser and Susser (1996) termed the emergent era of epidemiology as eco-epidemiology on the track of ecologism. Noting that exclusive focus on risk factors at individual levels within population will not serve the purpose, they advocated the need to be concerned with causal pathways at the societal level and with pathogenesis and causality at the molecular level. A fully adequate causal model for public health must therefore be able to explain the disease at the ecological level. In contrast with universalism (of natural sciences), ecologism of biological sciences entails localisation and attention to the bounds that limit generalisations about biological, human and social systems. Ecological constructs try to deal with true complexity of the biological world. The authors proposed a "Chinese Box" model – a conjurer's nest of boxes, each containing a succession of smaller ones within localised structures and successive levels of organisation, each of which encompasses the next and simpler level, all with intimate links between them. The epidemiological approach advocated by the authors was thus to analyse determinants and outcomes at different levels of
organisation – a contextual analysis. The shortcoming of this model is that the linkages between each of the levels has not been given due recognition.

As a hindsight, theoretical conclusions born out of certain empirical observations in the past can now be considered wrong, yet, their empirical basis at the population level remains irrevocable. It was this observed relationship that was behind the positive public health effects of strategies based on dealing with the relationship. For example, those who thought cholera was air-borne miasma were as likely to demand appropriate sanitary reform as those who saw it as a contagious disease (Smith and Ebrahim 2001). Snow recognised this, accepting that anti-contagionist theories of cholera causation were "in a hygienic sense as useful as that I believe to be the real truth (Snow, 1849)." Thus miasma as opposed to simple contagionist theories of cholera prompted interventions that reduced the severity of future cholera outbreaks. John Snow was right for the right reason – and that marks his relevance to epidemiological understanding and public health measures.

Pearce (1996) pointed out that any meaningful analysis of the causes of disease in populations should integrate the individual-biologic and population levels of analysis without collapsing one into the other or denying the existence of either. He advocates that the top-down approach, that stems in part from the demographic tradition, starts at the population level in order to ascertain the main factors that influence health status within the population. It therefore implicitly uses a structural model of causation rather than a behavioural model or a biomedical model. The object of scientific enquiry is not patterns of events but rather the underlying processes and structures that cause these events to occur. Causation is seen as resulting from mechanisms that are internal to the population under study and that operate dialectically, rather than involving associations between externally related independent objects. Since the goal of epidemiological studies is to understand and prevent the causation of disease in populations, the studies should start at the population level and should address the major determinants of health or disease at this level by exploring the structure of population.
It is therefore important to recognise that populations are not just collections of individuals that are conveniently grouped for the purposes of study. Every population has its own history, culture, organisation and economic and social divisions that influence how and why people are exposed to particular factors. It is therefore essential to understand the historical and social context and to emphasise the importance of diversity and local factors rather than search for universal relationships. Studying these phenomena will require the study of the above factors including environment and group variables apart from individual level variables. It is within this emerging frame of social epidemiology that is more contextual and holistic and, also uses statistics wherever necessary, that it is proposed to examine disease profile of cholera in the fast urbanising city of Delhi. This calls for an understanding of the process of urbanisation itself.

URBANISATION IN DEVELOPING COUNTRIES

While classical cholera was primarily a rural disease, the El tor biotype entrenched itself firmly in urban areas and more specifically among the urban poor in developing countries. It is therefore necessary to review the process of urbanisation and the state of the urban poor in the context of lack of access to civic infrastructure and the consequent health impacts.

The causative factors behind urbanization has varied from time to time. Ramachandran (1989) observed that in the prehistoric period, urbanization was synonymous with the origin and rise of civilization itself and was thus essentially a cultural process. In the historical period, urbanization was linked to the rise and fall of kingdoms, dynasties and empires. Urbanization during this period was a political process. In recent times urbanization is associated primarily with industrialization and economic development and is therefore essentially an economic process.

It has been recognised that the historical process of urbanisation in developing countries is different from that in advanced industrial societies (Safa 1982). The rapid growth of cities and urbanisation in the developing countries has been explained by two major hypotheses –
unusually rapid rates of population growth *vis a vis* limited farm acreage, forcing landless labour into cities ('push factor'), and, various economic forces attracting migrants ('pull factor') into the cities. The various forces exerting the 'pull factor' include domestic terms of trade squeezing agriculture, diffusion of technology from advanced economies favouring setting up of large scale urban industries, foreign capital inflow into urban infrastructure, housing, power, transportation and large scale manufacturing (Mitra, 1994). The resultant of all these forces has been a process of rapid industrialisation and concomitant demand for labour. The literature on new urban economics therefore explains the existence, size and structures of urban areas viewing cities as market responses to opportunities for production and incomes (Mitra, 2003). Further, in the current times, the impact of information and communication technology on human settlement has manifested itself in what is called a "divided city" where, new landscapes of innovation, economic development, cultural exchanges, political dynamics and social inequalities within cities and urban regions are emerging (Global Report on Human Settlements, 2001).

Safa (1982) explained that difference in patterns of urbanisation are due primarily to the late entry of the Third World countries in the global capitalist economy and their dependence on advanced economies for capital, technology and export markets. This dependency started during the colonial period and has resulted in undermining traditional modes of production and precipitated major changes in the organisation, structure of production and distribution and therefore in the labour force. Urbanisation has been viewed as a reflection of the overall socio-economic development of a society and consequently its attainment has been regarded as a critical determinant to the strategy of progress (Kundu, 1980 and McGee, 1971).

Economists have viewed problems of development in the Third World as a division of the economy into dual sectors – a modern, expansive capitalist sector with large scale production and orientation towards export and a traditional, subsistence sector for the domestic market. The failure to integrate these two sectors has been assumed to be a major deterrent in the countries' trajectory of growth and development. The dual sector approach has been criticised by several authors [Hart, (1973), McGee (1971) and Souza and Tokman (1976)]. Rather than being an impediment in the expansion of a modern capitalist economy, the informal sector
has been considered to be the major means of survival to those not directly employed by the formal modern sectors. Most of the urban poor work in small scale enterprises requiring a low level of skill and capital investment and often utilising the labour of unpaid family members to cut down on production costs, in Third World cities across the world. Because of labour-absorptive capacities of the informal sector, it is capable of sustaining large numbers of urban poor at low standards of living and infrastructure. They inhabit squatter settlements built with their own labour and often do not get access to basic facilities including water supply, sanitation, electricity, transport, education and health services. Squatter settlements are a survival strategy of the urban poor – at times the focal point for political unrest and at the same time "constituting a subsidy" by cutting down on the need for provision of urban infrastructure and providing low-cost housing to the poor (Safa, 1982).

Contrary to earlier notions of the formal and informal economies being discrete, they have been increasingly recognised to be inter-dependent; the formal sector being dependent on the informal for cheap labour, goods and services and the informal sector dependent upon the formal for its clientele and source of new income-generating activities. In contrast to the previous notion of the informal sector being a residual one, it is now considered to be dynamic and continuously reconstituting itself to the challenges of the 'modern' sector (Safa, 1982).

During the 1980s and 1990s poverty has become increasingly concentrated in urban settlements for economic and demographic reasons (Wratten, 1995). Structural adjustment policies introduced in the Third World have further accentuated this problem owing to rising food prices, declining real wages, redundancy in the formal labour market and reduced public expenditure on basic services and infrastructure (Moser et al, 1993 and World Bank, 1991). The global demographic shift to urban areas is undisputed. It had been projected that in the next two decades the world's population living in urban areas will overtake the proportion living in the rural areas for the first time. Globally, the urban poor have been considered to grow at a faster rate than the numbers of rural people. In 1980, there were twice as many poor rural households than poor urban ones; by 2000, more than half of the absolute poor are considered to be located in urban areas. It is also of concern that in many parts of the
developing world urban poverty has been growing faster than rural poverty due to macroeconomic adjustment, inefficiencies in the urban economy, and misapplication of public resources. While examining the sustainability of cities of developing countries, one trend is to emphasise the basic problem of rapidly increasing numbers, both due to intrinsic growth and due to extrinsic migration, predominantly of the rural poor.

However, this is not the uniform pattern across all countries. The critical factors of urban change in the Third World nations are changes in their economic and employment base. In nations with weaker economies, population movements are oriented towards where employment (and to a less extent educational) opportunities are located (Hardoy and Satterthwaite, 1989). Cities like Dhaka, Lagos, Lima, Manila, Rangoon and Sao Paulo accounted for significant proportions of industry and contributions to national GDP and that in turn is linked to the rapid growth of population in these urban centres. The movement of people to these cities that attract large number of migrants is also because the uncertainties of survival are less.

The level of urbanisation, is measured as the proportion of urban population to the total population (McGee, 1971). China and India together represent more than two-thirds of Third World Asia's population. In Asia, the richer nations experienced the largest growth of urban population during 1960s and 1970s. Between 1960-82, the level of urbanisation grew from 30% to 69% in Saudi Arabia, from 43% to 70% in Iraq and from 28% to 61% in South Korea. In contrast, in Pakistan and Bangladesh, there was little change in the proportion of labour force employed in agriculture.

The percentage of population that is urban always accompanies sustained economic growth (Mills and Becker, 1986). India's economic growth has been modest but sustained; one would thus expect a similar pattern of urbanisation. The urban population grew at an average annual compound rate of 2.26% during 1901-1981 – that was 1.74 times the 1.30% growth rate of the total population. The urban growth rate was zero or negligible until 1921. Then it accelerated rapidly during 1931-41 and 1941-51. Mills and Becker (1986) have demonstrated a correlation between real income growth and urbanisation in the later decades than the
earlier decades for most of the twentieth century in India. Given this pace of urban migration, it was inevitable that pressure on services and housing would increase. It is therefore pertinent to examine if the urban planners were conscious of the needs of the urban poor.

For people with low incomes, living on cheap land adjacent to employment opportunities is a rational choice, the risks notwithstanding. These vulnerable communities lose their homes, belongings, source of income and previous social networks when they are relocated (Hardoy, Mitlin and Satterthwaite, 1992). At least 600 million urban residents of the Third World live in "life and death threatening homes and neighbourhoods" (Hardoy, Cairncross and Satterthwaite, 1990). Risks include diseases associated with contaminated water and food, poor drainage and garbage collection, vectors, overcrowding and poor ventilation. The quality of environment has been deteriorating in many Third World countries. For Lusaka, during 1978-88, the proportion of population with access to piped water supply actually declined from 99% to 83% while those having access to waste disposal services dropped from 11% to just 4%. About 30% to 45% of the urban centres in India consist of slums and squatter colonies (National Commission for Urbanisation, 1988).

Hardoy and Satterthwaite, (1989) pointed out that most of new housing and new neighbourhoods in the Third World cities were organised and built outside the legal framework. 30-60% of the urban population in these cities, across countries live in houses and colonies that are developed illegally and also that 70-95% of all new housing colonies are built illegally. Residents of these colonies are naturally subject to exploitation by landowners, business interests and the police. Poor people make such constructions with great ingenuity – in matters of design and construction materials that are suited to local needs, local climatic conditions and local resources. In sharp contrast, the official (legal) standards and specifications, generally derived from western models, often do not take care of such felt needs.

The colonial legacy in urban planning and architecture is conspicuous in Third World cities across Asia, Africa and Latin America. The colonial form of administration and mindset has influenced the contemporary city, its institutions, laws and regulations and particularly the
attitudes of those governing it towards the poor. The *cordon sanitaire* segregated the Europeans from epidemic and diseases of poverty that affected the natives. In keeping with that mindset and sense of priorities most urban planning and state investment in water supply, sanitation, drainage and roads take place in high and middle income localities that, overall, house a minority of the population. Hospitals and health services also follow the pattern of serving the elite. The spatial distribution of medical institutions in a city follow predictable patterns in the favour of privileged sections of the society. Medical research during the colonial period paid attention to diseases that affected the rulers and troops (like malaria and sleeping sickness) rather than those that ravaged the native population. (Doyal, 1981).

Urban settlements develop in a way that groups capitalist enterprises in a cost-effective spatial configuration (Harvey, 1975). Environmental health problems faced by the urban poor result from spatial juxtaposition of industrial/livelihood and residential functions, marked by competition for land, high population densities and residential settlements in hazardous areas. Most people are attracted to cities for opportunities of work. The externalities of urban production are unfortunately borne disproportionately by the poor. Cheap housing areas and industries often tend to be located close to each other on lands not designated for these purposes. In the absence of strict regulations, this proximity can cause special environmental problems, the Bhopal gas tragedy being a case in point.

**Urban Poverty and Environmental Health**

40% of the global population was located in urban centres during the 1980's. Also, most of them were living in the developing countries. It is predicted that by 2025, 80% of the global urban population would belong to the smaller and larger urban centres of the developing countries. This would be in the backdrop of the fact that, overall, 60% of the world's population will be urban. The Government of India (1996) estimated that by 2020 half of India's population will be 'urban'.
The World Development Report (WDR) 1990, estimated that about a quarter of the world's urban population lives in absolute poverty - and many more live in substandard conditions. The poorer sections are hit the hardest as environment and infrastructural services deteriorate. Consequent to their lack of access to basic services the urban poor are the most vulnerable to natural and man-made environmental hazards including health hazards. The WDR (1990) defined poverty as inability to attain a minimum standard of living as measured by household incomes and expenditure. Ownership or access to physical facilities is often used as a proxy for measuring poverty, particularly where data on income is weak. The WDR 1990 had stressed that in order to ensure that growth is consistent with poverty reduction, access to these basic services is essential.

There has been a lot of debate on urban poverty and environment and health impact links in developing countries. An estimated 30-70% of urban populations in developing countries are living in conditions of extreme poverty. The deteriorating environment leaves its health impacts on the urban poor. At the same time there is an urgent need to recognise the social dimension of being poor within the overall urban society. Neighbourhood factors play significant roles in the case of child health over individual household characteristics like parental education, income and feeding practices. Thus, while a poor household struggles to get its own facilities, the benefits may elude the health of their children if the surrounding environment is poor, as is so often the case in underdeveloped countries. A 1992 study by the World Bank and UKODA in Ghana and Brazil, involving systematic analysis of environment and health differentials confirmed the complexity of the underlying factors in developing countries. In terms of urban child health, the results confirmed that sanitary household and neighbourhood environment were both very critical factors in the control of morbidity and mortality from infections and parasitic diseases. Thus, improvements in living standards and public health considerations, both require policies that would achieve poverty reduction in a manner consistent with a concern for environmental resources.

Baker's report on 'endemic colic' of Devonshire (lead poisoning) was one of the earliest published environmental epidemiology studies. Environment was defined as exogenous to and non-essential for the functioning of human beings and that altered patterns of disease and
health. Environment includes not only physical, chemical and biological agents but also social, political, cultural, engineering and architectural factors (Rothman 1988). Exposure to environmental agents is frequently determined by social factors – where one lives, works, socialises or buys food. That the social, political and economic context is integral to most environmental epidemiological problems has not been fully appreciated. Environmental exposure is also largely involuntary.

Environmental health problems of developing countries are wide ranging and far reaching. In addition to the problems of industrialisation, there are certain other distressing problems which are peculiar to our circumstances. Poor collection and disposal of solid and liquid wastes, unsafe and inadequate drinking water, deforestation and indoor pollution due to unclean fuels are some of the critical problems that will be challenges of the current millennium. In most low income communities, the pollutant of primary concern is human excreta.

The WHO (1992) classified diseases associated with water into the following groups:

- Waterborne diseases: caused by the consumption of water contaminated by pathogenic viruses or bacteria from human or animal faeces or, urine. Acute diarrhoeal diseases including cholera are important waterborne diseases in the developing country context.
- Water washed diseases: caused by infection arising from the lack of personal hygiene due to inadequacy of water.
- Water based and water related diseases: caused by ingestion of intermediate hosts or insect vectors.

Prevention of waterborne and waterbased diseases require improvements in the quality of water while the prevalence of water washed diseases in a community would indicate the need for improving the total quantity of water that an affected population can access. Maintaining adequate and safe water sources is therefore of paramount importance for public health considerations. The old agenda of providing sanitation services to all urban households
remains an unfinished task. The new agenda meanwhile demands that urban wastewater be safely managed and the quality of vital water resources be protected for present and future populations. The urban sanitation sector thus faces a dual environmental health challenge. The underprivileged urban poor are concentrated in settlements that are subject to insanitary conditions, hazardous emissions and accident risks and therefore are in acute need for improvements in these services. It is however often the case that these are the very segments that are conveniently overlooked during the development process. The provision of sanitation services, including sewerage has failed to keep pace with population growth in urban areas. The health consequences of the service shortfalls are enormous and fall most heavily on the urban poor though not necessarily sparing the privileged sections.

The WHO identified poor sanitation, contaminated drinking water and lack of food hygiene as the key problem areas in the context of the diarrhoeal diseases situation in the developing countries. A study (WHO, 1999) reported that 3 million children under the age of five die each year in the developing world from diarrhoeal disease. Infectious and parasitic diseases specifically linked to contaminated water are the third leading cause of productive years lost to morbidity and mortality in the developing world. Diarrhoeal death rates are typically about 60% lower among children living in households with adequate water and sanitation facilities than those in households without such facilities.

An increasing share of urban sanitation services are being provided by sewerage, especially in middle income countries. User contributions have however been low, and public subsidies on these household services have benefited primarily the middle class and the rich. This has left little public resources to be spent on sewage treatment and safe disposal. This concern is manifest in terms of the quality of the water environment which is seen as a global concern about sustainable water resources development. The costs of water resources degradation can be seen in many ways. The majority of rivers in the cities and towns of developing countries are virtually open, stinking sewers. Apart from degrading the aesthetic life in the city, they constitute a reservoir for a large number of water borne diseases. The outbreak of cholera in Peru in 1991, has been traced to inadequate urban sanitation and water contamination. The
In almost all countries, governments first came to deal with problems of pollution in the context of public health concerns, sewage disposal, and other related issues. With increasing urbanisation and population pressures, developing countries face major challenges as they seek to meet the demand for sanitation and sewage services, particularly for the poorer sections. Simultaneously, there is the dual challenge of protecting needed water resources from the polluting impacts of wastewater discharges and handling of solid waste disposal problems.

Inadequate Infrastructure for the Urban Poor

The term "fourth world" (Tabibzadeh et al 1989) has been used to describe a sub-proletariat with inadequate housing, sanitation, clothing and food; lack of support from politicians and unions; limited information, education and voice; and, are systematically prevented from exercising their rights that other people take for granted. From the economic point of view they are a 'burden' and from the health point of view – a 'danger'. As policies and programmes aim to prevent malnutrition, supply safe water, provide shelter and environmental services and provide health care and education, deprivation should be stated in terms of these factors as well as in terms of income.

The poorer areas of cities of developing countries are marked by lack of safe drinking water and safe disposal of solid and liquid wastes, with its consequent impacts on human health. The sewage system in cities invariably serve richer residential, government and commercial areas. Untreated human excrement and household wastewater end up in rivers, streams, canals and ditches. Diarrhoeal diseases, typhoid, intestinal parasites and food poisoning thus tend to be endemic problems.
Hardoy and Satterthwaite (1989) had studied inadequacies in water supply and sanitation services in some of the major urban centres of the Third World. About a third of the total population of Bangkok had no access to public water supply systems and bought water from vendors. Only 2% of the population was connected to sewer system. Wastewater was generally discharged into stormwater drains and canals. Less than 25% of Jakarta's population had direct connections to a piped water supply system. 30% of the population relied on water vendors that costed 5 times more than piped supply. Septic tanks served about 25% of the population; others used pit latrines, cesspools and roadside ditches. 15% of the population of metropolitan Manila had access to sewers or individual septic tanks. Nearly two-thirds of the population were lacking sewage system and a small proportion of the sewage collected was treated properly.

Only a third of the population of Colombo had piped water supply inside the household. Another fifth have it outside their homes. Half the population had no access to safe water sources and sewage services. Only a third of the households in Karachi had piped water connections that provided supply for few hours a day. Slum dwellers and squatters either accessed water from public standposts or bought them from vendors at inflated prices.

A 1986-87 survey in Dar Es Salaam found that almost half the households did not have piped water supply either inside or immediately outside; one-third had shared piped supply. Of households without piped water supply, 67% bought water from their neighbours and 26% drew water from public standposts. Only 13% of wastewater was disposed of safely. 4.5% of the toilets were connected to septic tanks or sewers. A 1980-81 survey in Dakar reported that 28% of the households have private water connection, 68% are dependent on public standposts and another 4% buy water from carriers.

Though "health risks inside the home" i.e. behavioural factors and practices are often highlighted as key factors for determinants of diarrhoeal diseases. The dangers in the neighbourhood in which poorer households are located that are no less critical (Hardoy and Satterthwaite 1989). The deficiencies impact on each other. The most critical neighbourhood factors are ~
• Dangerous sites – large clusters of illegal housing are often located on steep hillsides, floodplains or desertland. They may also be located on unhealthy and polluted landsites; around solid-waste dumps, beside open drains and sewers or around industrial areas. Such sites are often the only locations where the poor can build or rent accommodation. Industrial areas provide employment. They are thus rational choices for reasons of survival.

• No collection of household garbage – about 30% to 50% of solid waste generated in these urban areas remain uncollected and accumulate in the neighbourhood. This results in proliferation of disease vectors and also constitute fire risk.

• Inadequate site infrastructure – particularly lack of transport and health services

Many of the health problems of the urban poor in the Third World cities are related to water. The main constraints related to access of adequate quantity of safe water include –

• Quality – either frankly contaminated or of unreliable quality

• Available quantity

• Cost of accessing water\(^1\) including time and travel costs

• The number of households served per public standpost

• Improper disposal facilities for wastewater\(^2\)

The expectation that improvements in water supply and excreta disposal facilities would play a major role in controlling diarrhoea in developing countries formed the motivating force for the International Water Supply and Sanitation Decade (1981-90). Set against this background Esrey et al (1985) reviewed the findings of 67 studies from 28 countries on the effectiveness of water supply and excreta disposal improvements for reducing diarrhoea rates in young children in developing countries. The median reduction in diarrhoea morbidity rates were 22% from all studies and 27% from the better designed ones. The study concluded that

\(^{1}\) The poor (in illegal settlements) may pay up to 20-30 times the cost per litre paid by richer groups with piped supplies; water vendors have been estimated to serve between 20-30% of the Third World's urban population (Hardoy and Cairncross 1990).

\(^{2}\) About two-thirds of the Third World's urban population have no hygienic means of disposal of excreta and wastewater (Hardoy and Cairncross 1990).
improvements in water quality have less of an impact than improvements in water availability or excreta disposal.

Briscoe's study (1984) focussed on assessing the impact of any single intervention given the complexity of transmission routes of diarrhoeal diseases. He cautioned that where multiples routes were involved in disease transmission, one had to be careful while assessing the impact of an intervention to eliminate any one of these transmission routes. Where dose-response relationships between the ingestion of a pathogen and the incidence of disease are non-linear, the reduction in incidence due to the elimination of a particular transmission route may be an incorrect indicator for measuring the importance of a particular route. Improvements in the bacteriological quality of drinking water have played a central role in most discussions on reducing the incidence or eliminating diarrhoea. This has been strengthened by the experience in Europe and North America in the nineteenth century where improvements of drinking water quality played a central role in controlling diarrhoea and cholera. Improvements in drinking water quality are also relatively easier to monitor and bacteriologic examination less expensive than say the monitoring of food quality or person-to-person contact.

Microbiological data collected on each of the possible transmission routes of cholera in Matlab, Bangladesh left little doubt that most transmission was through drinking water. However, because of the existence of secondary transmission routes such as contaminated water during bathing, and because the dose-response relationship is approximately log-linear, elimination of the main route did not get reflected through large reductions in incidence of diarrhoea. However, Briscoe pointed out that it would be erroneous to conclude that improvements in drinking water are not an important intervention strategy for controlling cholera. Rather it has to be understood that improvements in the secondary routes of transmission would have dramatic effects on incidence of cholera if prior improvements in drinking water quality had been made.

Esrey et al (1991) reviewed 144 studies to examine the impact of improved water supply and sanitation on the incidence of diarrhoea and other water borne diseases including
schistosomiasis, dracunculiasis and hookworm infestation. These diseases are widespread in developing countries and illustrate the variety of mechanisms through which water and sanitation can protect the health of the people. The review concluded that it was difficult to distinguish between health improvements due to improvements in water quality and those due to improvements in water quantity. While considering diarrhoeal diseases, therefore, the reduction in morbidity due to improvements in water supply clubbed both the quality and quantity aspects. Further, out of 15 studies that examined the effects of increased amounts of water specifically and independently of water quality, all but one have reported a positive impact on reducing morbidity from diarrhoeal disease. The paper concluded that interventions that improved water quantity and excreta disposal along with better hygiene practices produced greater impact than improvements in water quality. This is particularly true of highly contaminated environments with high diarrhoea rates.

Cairncross (1989) reviewed the progress made during the International Water Supply and Sanitation Decade (1981-90). He observed that problems regarding water supply systems were generally regarded as technical and economical, with no reference to social or institutional aspects. Water supply in developing countries had hardly ever been addressed from the users' point of view. Investment in water was generally a function of three forces, in isolation or in combination – accelerating urbanisation, political pressure or international aid. Globally, by the late 1970s, the rate of water supply provision was hardly keeping pace with population growth. Sanitation was more neglected. Urban sanitation was usually understood to mean sewerage. Therefore the majority of the low income group families were actually excluded as it was neither found to be 'feasible' nor 'affordable'. Storm water drainage and solid waste disposal, basic environmental health interventions were conspicuous by their neglect.

A mid-term review (Cairncross, 1989) of the decade reported the proportion of population in developing countries with adequate access to facilities. As per the figures reported, water supply coverage was projected to be reasonably complete in urban and rural areas in 2-3 more decades. Sanitation would obviously take much longer. Cairncross (1989) commented that "it is no coincidence that the sector in which implementation is most affected by social
and cultural factors would be the one to lag behind." In many new project areas, the issue was, who would benefit from the improved water supply? Often new and old water systems were next to each other and communities did not prefer to use the new sources.

The issue whether water supply and sanitation could be combined in a single programme was also examined. In the context of low income groups of households in the developing economies improved water supply meant a tap in the street – an infrastructure in the public domain. Sanitation implied a toilet with on-site disposal system – a part of the owner's house, his land, at his expense and not infrequently with his own hands. Administrators considered both as an issue of laying pipelines beneath the street. However, an agency that could implement one of these efficiently was unlikely to be suited to the other. Hygiene education, a critical component, could neither be delivered by these agencies nor was envisaged in these programmes (Cairncross, 1989).

There were examples of self-help construction of water supply systems in many African nations. It was also suggested by several international agencies that governments avoid being providers of these services. However, by and large, governments did provide for the well off and privileged sections of the society. If local communities invested on local infrastructure it would also imply local control; often politicians, technocrats and experts with their own models of urban development were reluctant to such shifts of patronage.

**URBANISATION IN INDIA**

The British period in India witnessed urban stagnation except for the administrative centres including the cantonments and the railway-towns. The post independence period is notable for rapid urbanisation. The major changes that have occurred in the context of urbanisation in the post independence period are:

- Influx of refugees and their settlement primarily in urban areas in Northern India
- Construction of new industrial cities and industrial townships near existing cities
- Stagnation and in some cases decline of small towns
• Massive increase in squatters and proliferation of slums in major cities
• Emergence of rural–urban fringe
• Introduction of city planning and general improvement in city amenities

In India (and China) it has been observed that a large proportion of the urban population resides in cities with population of 500,000 and above (Amjad. 1990). In the Indian context, class I cities (those with a population of 100000 and above) account for about 60% of the urban population.

Mitra (1994) observed that rural-urban migration even in the metropolitan cities (except Mumbai) contributed less than 35% of the total growth of population growth for the decade 1971-81. The migrants in search of urban employment did not account for a significant percentage of the urban labour force growth. Gugler (1988) pointed out that for developing countries, the rural-urban differentials in natural growth rates are not significantly different in contrast to that of the developed countries. Mitra (1994) however analysed that, for India, though the urban birth and death rates were lower than the rural figures, the urban rates of natural increase were only marginally lower than the rural rates. Another contributory factor to labour force growth has been hypothesised to be due to increasing participation of women in the labour market (Jose, 1990).

Apart from the forces of rural-urban migration and natural growth of population, the relocation of areas as urban between two points of time is a significant factor in the increase of urban population. The rural areas adjacent to cities or towns are earlier reclassified as 'urban' than the relatively remote rural areas that are also growing rapidly. The 'development pole' theory (Datta-Chaudhri, 1980) explained how economic activities get concentrated in a limited number of cities to maximise the advantages of interdependence of industries in terms of input-output linkages, availability of infrastructure and marketing. Therefore, groups of industries cluster around a core of industries and growth impulses are transmitted through both forward and backward linkages. As income levels of these areas are high, they create higher demands for other products and services leading to further overall growth of these
centres. The adjoining semi-urban and/or rural areas also get involved in this process, giving rise to further urban agglomerations.

It has been observed that the rural-to-urban migration rates are generally higher than the urban-to-urban rates. The exceptional cases are – Delhi (for females), Madras, Bangalore and Jaipur. Sundaram (1986) observed that with the exception of Bombay for all the other cities, inter-state and intra-state migrants from rural areas accounted for less than a third of the total decadal increase in the population of these cities. Mitra (1994) in an analysis of the factors relating to the causes for migration attribute economic factors as the cause responsible for rural male migrants in about 50% of cases. Among the females it is less than 10%. It is also pertinent to point out that the distinction between economic and non-economic factors is not very clear. It has been argued that persons who have migrated for non-employment reasons (like education, marriage, etc.) may also have subsequently entered the urban labour market. In the backdrop of increasing rural-to-urban migration, the supply of labour in the urban segment grows further. With employment opportunities in the high productivity sector being limited, the migrant groups generally get residually absorbed into low productivity activities. Two key factors that play a role in this is the poor asset base and the lack of specific skills of these population groups in search of employment. As a result, a large proportion of these activities are in the tertiary sector; rural-to-urban migrated labour raises the share of service (tertiary) sector in the total workforce.

Short duration migrants have been defined as having duration of residence less than one year. The unemployment rate is very high for the short duration migrants. It has been observed to decline sharply with an increase in the duration of residence, more so for the male migrants. Among the long duration migrants (equal to or more than 5 years), the unemployment rates are lower than the those of the city population (for both sexes). Mitra (1994) however cautioned against the notion that the large share of tertiary activities in the total workforce is a measure of the excess supply of labour in the urban centres. Though there is positive association between rural-to-urban migration rate and the share of tertiary activities, it is to be noted that the skill levels required may be lacking in the migrants. The natural growth of
urban population contributes to a large extent in sustaining the growth of the tertiary sectors and not just the rural migrants.

Among the largest Indian cities, the population of Delhi grew the fastest during the 1961-81 period and Calcutta the largest of the four metros grew the slowest. Some studies (Mills and Becker. 1986) have divided India into five regions – North, East, South, West and Central, dominated by Delhi, Kolkata, Chennai, Mumbai and Kanpur respectively. From 1931-61, the eastern region was the most primate of the five regions dominated by Kolkata till 1971. The western region has remained the second most primate region. Delhi's domination of the northern region has increased over the decades. The central region has remained the least primate of all the regions.

In India, among the 12 million-plus cities, in 1981, Lucknow, Kolkata and Kanpur were experiencing net out-migration while Bangalore and Delhi were growing rapidly (Hardoy and Satterthwaite, 1989). Most of the rapidly growing cities in the 1970s had less than 500,000 population in 1971 and were typically single-industry cities, centres for raw material extraction or state capitals. Many of them were located away from densely populated areas. Cities close to Mumbai (Nasik and Khopoli) and Kolkata (Asansol and Durgapur) grew more rapidly than these metropolitan cities. These single-industry cities and centres for raw material extraction were also essentially public sector enterprises and by the turn of the century, some of them had begun to decline with the industries going sick resulting in out-migration.

In India, the proportion of the urban population living in slum areas grew during 1981-91, while the share of the population living in poverty declined. Thus, it must be realised that the lack of access to such facilities is really a welfare issue. Concern for poverty has always been at the centre of Indian socio-economic thinking. The Perspective Plan of 1961-75, had removal of poverty as a major objective. All subsequent planning in the Indian economy has focused on poverty removal as a key objective of the development process. And yet, the problem of poverty persists, and India's performance with human development (vis-à-vis other nations) leaves a lot to be achieved.
Slums

Settlements and infrastructure and services that go with it are always key issues that have to be considered while discussing the living conditions of migrants, most of them poor. The rapid growth of urban poor in cities is almost synonymous with the growth of slums. The definition of 'slum' varies widely from study to study. Ordinarily a slum refers to mud-structures, over-crowded or dilapidated dwelling units. The 'Slum Areas (Improvement and Clearance) Act' was enacted in Delhi in 1956 and was later extended to eleven other states. Under this act the slum was defined as areas where buildings that

- are in any respect unfit for human habitation
- are by reason of dilapidation, overcrowding, faulty arrangements and design of such buildings, narrowness or faulty arrangement of streets, lack of ventilation, light or sanitation facilities, or,
- any combination of these factors are detrimental to safety, health or morale

The Bharat Sevak Samaj (1958) used the following definition of slum in Delhi – "the term 'slum' should be applied to those parts of the city which may (on the face of it) be considered unfit for human habitation either because the structures therein are old, dilapidated grossly congested and out of repairs, or because it is impossible to preserve sanitation for want of sanitary facilities including ventilation, drainage, water supply etc., or because the sites themselves are unhealthy." 'Katras' or slum tenements referred to a group of single room tenements that were constructed generally in rows within a compound or enclosure having a single common entrance. 'Bastis' on the other hand were described as a "thick cluster of small kutchha houses or huts built on open land, often in an unauthorised manner".

The 1961 Census also adopted a similar definition to “include such dwellings which on account of such over-crowding, dilapidation and lack of ventilation are detrimental to safety, health and social morale.” The Madras Corporation used this definition as well.
The Bombay Municipal Corporation uses a three-tier definition of slums:

- **Chawls**: areas with permanent multi-storeyed buildings built long ago according to the then prevailing standards but currently in a deteriorated condition.
- **Patrachawls**: areas with semi-permanent structures – both authorised and unauthorised, often built of tin (*patra*) sheets.
- **Zopadpattis**: squatter settlements, shanty towns or hutment colonies

The Calcutta Corporation registered those slums whose "total area must not be less than 1/6th hectare, and the structures must be *kutcha*, that is, they should have a roof built without cement, with not more than 18 inches of the wall of *pucca* construction" (Singh and D'souza, 1980). Taxes are collected from these registered slums.

The Environmental Improvement Programme of Urban Slums began in 1972 and a slum was defined in greater detail. Slums were defined as any area where such dwellings predominate which by reason of dilapidation, overcrowding, faulty arrangement of design of building, narrowness or faulty arrangement of street, lack of ventilation, light or sanitation facilities, inadequacy of open spaces and community facilities, or any combination of these factors, are detrimental to safety, health or morale. While this part of the definition was a continuation of the previous versions, certain criteria were added in order that the slum be selected for improvement. The most important of them was that the slum should have at least two-thirds of its families with an income of less than Rs. 250 per month.

Most of these definitions are often not adequately for application and leave a lot of room for variation. Further, none of these definitions seek to define the basic minimum criteria for the dwelling units of the poor in an urban setting. The loose nature of the definitions are also impediments for estimation of slum populations and therefore of subsequent plans for their improvement.

The highest incidence of slums is found to be in Bombay, Calcutta, Delhi, Madras, Kanpur, Nagpur and Lucknow, ranging between 30 to 40 percentage points. For Jaipur and Lucknow there are variations in the National Buildings Organisation (NBO) and Town and Country
Planning Organisation (TCPO) estimates as NBO figures refers to the urban agglomeration while the TCPO estimate refers to the metropolitan Corporation only. The National Sample Survey (NSS) estimates are rather low as the 'undeclared slums' are not included. The 1981 census data also suffers from two major deficiencies on account of which the figures are really under-estimates. The first is that the information on slum population is provided by the municipal authorities and not through any surveys. Secondly, the information on slum population is not available for each and every slum pocket.

It is important to understand why and how slums grow and population groups inhabiting these expand in numbers. Mitra (1994) has delineated three possible situations:

- Economic opportunities and infrastructure facilities lead to concentration of population in urban centres. This pushes up land value and rents. A large proportion of the population therefore cannot afford to live in dwelling units of reasonable standards. Economies of agglomeration and the absence of planning lead to creation of megapolises with low quality of life (Datta-Choudhury, 1980). The older dwelling units get overcrowded and basic amenities become inadequate to cater to increased demands, giving rise to 'pucca slums'; these dwelling units were not so at their time of construction. In such situations it is not just the poor informal sector workers but also formal sector workers with incomes much above poverty line who also reside there.

- Individuals may also avail of poor quality housing to use limited savings for consumption of other consumer durables.

- Residual absorption of labour in low productivity informal activities generate low incomes in relation to the high cost of living in cities. This does not really allow them to lead an above poverty line of level living. Earnings insufficient to meet urgent consumption requirements like food and clothing leave little scope for investment in better quality housing. The existing dwelling units and basic amenities also get overused leading to congestion and rapid expansion of slums.

While poor households may be expected to live in slum households, all slum dwellers may not necessarily be poor. Industrialisation and commercialisation increasingly lead to
inequality in the urban sector during the initial stages of industrialisation. The level of inequality declines only at a later stage when the share of wages in total income increases substantially (Kuznets, 1966). This inequality in the initial phases also leads to inequal access to land and housing in the cities.

Water and Sanitation Scenario in Indian Cities

A study by the Central Pollution Control Board in 1989 on the status of wastewater collection and treatment in 212 Class I, and 241 Class II cities revealed that the total volume of water supply to and wastewater from Class II towns was about 10% of Class I cities. 45 Class I cities generated more than 50 Million litres per day of wastewater, as 'major domestic pollution'. More than 70% of wastewater generated from Class I & II towns taken together, is accounted for by these 45 Class I cities. Bombay and Delhi individually generated more wastewater then the 241 Class II towns taken together. Gandhi Nagar (Gujarat) was the only town having 100% wastewater collection and treatment facilities.

The responsibility of providing services such as safe water, sewerage, sanitation and solid waste disposal rests primarily with state governments and is implemented through various agencies. In quite a few instances, water supply and sewerage boards have been set up to deal with these services. In some cities, specific projects are taken up to deal with slum colonies, such as those of the slum wing of the Delhi Development Authority/Municipal Corporation of Delhi. The urban poor draw water from public stand posts wherever such facilities exist. In other cases, tubewells and handpumps are installed by the municipal authorities for the slum and pavement dwellers (e.g. Kolkata Municipal Corporation, the Municipal Corporation of Delhi). However, there still remains a large chunk of the poor, who have to depend on tankers in cities like Delhi and Madras. It is important to consider the different sources of drinking water which are available to the poor, since this would have an important bearing in understanding the sources of water contamination for the domestic sector.
As far as sanitation facilities are concerned, most of the poor are dependent on free community latrines. Lack of adequate numbers of public toilets lead to defecation in open spaces. Improper disposal of human excreta leads to major public health problems such as groundwater contamination.

Keeping all these factors in mind, a number of urban development programmes were designed in the 1980's which emphasised the provision of water supply and sanitation services. These included Basic Services Programmes (e.g. Environmental Improvement of Urban Slums, Urban Community Development Programme, etc.); Integrated Development of small and medium towns for slum improvement and low cost sanitation; Low Cost Sanitation Programme, etc. However, Kundu (1993) in an analysis of these schemes observes that the success achieved in terms of the target has been extremely limited. As a result the scenario at the end of the International Water Supply and Sanitation Decade, remained virtually unchanged, especially in terms of access of the poor to such facilities. Kundu's study also revealed that there is a positive relation between the accessibility to a toilet facility and per capita monthly expenditure. He found that a heavily subsidised system of toilet and sanitation facilities are available to relatively well off sections of the population. To illustrate, it is the higher consumption fractiles who have flush latrines connected to the sewerage system, for which only a nominal user charge is levied by the authorities. On the other hand, even after availing of subsidies from local authorities, the poor often find it too expensive to incur the capital expenditure involved in constructing such flush latrines.

**CHOLERA: SOME KEY ASPECTS**

Globally, the gastrointestinal route is an important mode of transmission of infectious diseases in the less developed countries (Kelsey et al, 1986). Cholera remains the most dreaded of gastrointestinal infections. "It would be no exaggeration to say that it was through cholera, and the fear to which its pandemic sweeps gave rise, that international solidarity in matters of health was born" (Pollitzer, 1959).
Microbiological Issues

Cholera occurring in either sporadic or epidemic form is an acute bacterial enteric disease with sudden onset, profuse watery stools, occasional vomiting, rapid dehydration, acidosis and circulatory collapse, and, may in a matter of hours result in death (Benenson, 1985). This devastating diarrhoeal disease caused by *Vibrio cholerae* group O1 has been responsible for seven pandemics and enormous human suffering — and remains a global public health problem.

Under natural conditions, vibrios most commonly reside in tidal rivers and bays under conditions of moderate salinity. The vibrios live in this natural reservoir in close relation with plankton in a viable but non-cultivable form. They proliferate in the summer months when the temperature of the aqueous reservoir exceeds about 20°C. Humans are infected incidentally but once infected can act as vehicles for further spread. The most common mode of acquisition of the infection is through ingestion of water contaminated with human faeces. Consumption of contaminated food in the home, at restaurants and from street vendors also contribute to the spread (Keusch and Deresiewicz, 1998).

Cholera, in endemic areas, is predominantly a paediatric disease. However, when introduced in previously unaffected areas, adults and children demonstrate equal susceptibility. Asymptomatic infections occur more commonly with El tor biotype than the classical variant. Children under two years in endemic areas are less likely to develop severe cholera than are older children. This phenomenon has been attributed to passive immunity acquired from breast milk.

The species *V. cholerae* comprises of a host of bacteria classified on the basis of the carbohydrate determinants of their somatic O antigens. Till date 140 serogroups have been recognised. They are divided into two major groups — those that agglutinate in antisera to the O1 group antigen (*V. cholerae* O1) and those that do not (non-O1 *V. cholerae*). Though some strains of serogroup non-O1 *V. cholerae* have occasionally caused sporadic outbreaks of
epidemic diarrhoea, serogroup O1 till recently was the exclusive cause of epidemic diarrhoea. This paradigm changed in late 1992 with the identification of serogroup O139 Bengal (Ananthanarayan and Paniker, 1996).

In 1992, a major cholera outbreak occurred in Madras (the fact that it is a port, where new cholera infections often start should not be lost) and the surrounding towns of Tamil Nadu. The infection spread rapidly up and down the coast of Bay of Bengal reaching Bangladesh in December 1992 and the southern districts of West Bengal almost at the same time. The etiologic agent isolated was a "novel" strain of *V. cholerae* that belonged neither to O1 serogroup that causes epidemic cholera nor matched with any of the then identified 137 other serogroups. The organism was designated *V. cholerae* O139 Bengal. By the end of 1994 the infection had spread across India and the neighbouring countries including Pakistan, Nepal, China (western states), Thailand and Malaysia.

**Shifts in Strain**

Cholera epidemics have often been linked to antigenic shifts. Khan et al (1980) demonstrated that cholera due to El tor biotype could equal classical biotype in severity and attack rates. In Dhaka, secondary infection rate, infection to case rate, infection to hospitalisation ratio and multiple case per family rate were all higher for El tor than previous epidemics of classical cholera. Secondary infection rate was observed to be high for females above the age of 15 years and also for children aged below 15 years. Multiple cases in the family had declined from 10.6% to 17.6% in 1969 to 3.6% to 3.7%. This parameter was reported to be as high as 20% during the epidemic of 1980 when classical cholera resurfaced. Rudra et al (1997) reported changing patterns of *Vibrio cholerae* isolation over three consecutive cholera seasons from 1992 to 1994 in East Delhi. They isolated *Vibrio cholerae* 010 (non-O1) from patients admitted at the University College of Medical Sciences and also reported increased resistance to cotrimoxazole and furazolidone. This can explain a doubling of the incidence rate in 1992 over 1991.
Natural Reservoir

The natural reservoir during inter-epidemic periods has been debated for long. *Vibrio cholerae* (classical biotype) was isolated from water of two tanks in Deshpara Village, Hooghly District of West Bengal (Abou-Gareeb, 1960) repeatedly and also from healthy persons living in the vicinity of the tank though clinical cholera had not appeared in the village in the three previous years.

The importance of surface water in transmission of El tor cholera has been examined in rural Bangladesh by Hughes et al (1982). A baseline survey was done in selected cholera affected and control areas. 44% of surface water sources tested positive for *Vibrio cholerae* in affected areas and in contrast only 2% of water sources tested positive in control areas. Families using water from culture positive sources for cooking, bathing and washing were found to be at increased risk. Those individuals using the same water sources as used by the family with the index case were found to be an increased risk. For families drinking water from culture negative sources, association was observed between infection and bathing in a culture positive source. For families using different bathing source from index family, association was established between infection and drinking water from the same source as the index family. This study highlighted the role that unsafe water sources used for non-drinking purposes played in transmission of cholera.

**Behavioural Factors**

Some researchers have laid emphasis on behavioural factors as key determinants for diarrhoeal diseases including cholera. On scrutiny of methodology and issues, the complex interplay of socio-economic status, their impact on access to infrastructural facilities and practices is evident. These "secondary routes" of transmission have been considered to play a crucial and complementary role vis a vis water and sanitation.
Chakraborty and Das (1983) conducted a comparative study of incidence of diarrhoea among children belonging to low families with poor socio-economic status in two different environmental situations in Calcutta – one group living in slums and the other residing in relocation projects of the Calcutta Metropolitan Development Authority (CMDA) in multi-storey buildings, and observed that diarrhoea episode per child was 1.6 in slums and 1.4 in CMDA area; there was no significant difference. Incidence was high among infants in both the groups but declined sharply in CMDA children at 2 years. The decline in case of slum children was observed to take place at the age of 3 years. Provision of running water and sanitary latrines (as common facilities and not at the household level) in CMDA project areas did not reduce diarrhoea to any significant extent as compared to the slum children. Incidence declined in both groups with increase in mothers’ educational status. Partially breast fed children suffered the most among both groups.

Henry and Rahim (1990) examined transmission of diarrhoea in two crowded areas with different sanitary facilities in Dhaka, Bangladesh. The degree of contamination in each child's drinking water (water borne) and on the hands of each child (water washed) was correlated with diarrhoea incidence. Diarrhoea attacks increased significantly for children with more contaminated hands.

Ghosh et al (1997) have, through community based studies, explored the risk behavioural practices of mothers of families residing in slums in Calcutta and Varanasi and in rural areas in Haryana and Hyderabad. He observed that a sizeable proportion of children did not suffer from diarrhoea though they lived in the same area as that of the children with diarrhoea. In Calcutta slums, 53.4% of children remained diarrhoea-free during the one year study period with six days a week of active surveillance. Risk factors attributed to mothers showing significant association with presence of a child with diarrhoea in the family included use of pond water for cleaning child-feeding containers, indiscriminate disposal of children's stools, bottle feeding, non-use of soap for cleaning child-feeding containers and water storage in a wide mouthed container.

3 Studies from urban Bangkok and a suburb of Rangoon had failed to detect any significant association between diarrhoea and socio-economic status (Vathanophas et al, 1986)
Bacterial contamination of stored water and stored food was incriminated to be major risk factors for diarrhoeal diseases in a study in West Africa (Molbak et al, 1989). They identified that illegal connections of piped water supply, shallow handpumps, high degree of storage, stored food left up to 4 hours and consumed cold or reheated for short period and low breast feeding among mothers residing in urban slums as compared to rural mothers was associated with high incidence of diarrhoeal diseases. They also observed that water quality had no major influence on the standard of food in a community where faecal transmission is high and prolonged food storage was a common practice.

Glass et al (1983) investigated the level of protection against cholera in breast-fed children by antibodies in breast milk through a prospective study. Breast milk antibodies against cholera did not appear to protect children from colonisation with *Vibrio cholerae* O1, but did protect against the disease in those who became colonised.

The transmission routes of the etiological pathogens for diarrhoea are complex. Briscoe (1984) pointed out the importance of evaluating multiple routes of transmission and assessing the impact of an individual determinant. While recognising that generally speaking, the risk of infection increases exponentially with the dose (of pathogens), it ought to be remembered that transmission can take place through several routes and water, food and person-to-person transmission are the most critical variables for faecal-oral contamination leading to diarrhoeal disease.

Historically, improvements in the microbiological quality of drinking water have played a central role in the reduction of morbidity and mortality from diarrhoeal diseases (including cholera), particularly in Europe and North America in the nineteenth century. Microbiological data collected in a detailed clinical case study of cholera in Matlab, Bangladesh have focussed on each of the possible different transmission routes and had concluded that most of the transmission was through drinking water. However, on account of the existence of secondary transmission routes such as ingestion of contaminated water during bathing and also because the dose-response relationship was approximately log-linear,
elimination of the main route did not get reflected directly through major reductions in the incidence of diarrhoea.

Briscoe (1984) cautioned that it would be erroneous to conclude that improvements in drinking water are not an important intervention strategy for controlling cholera. He advocated that improvements in the secondary routes of transmission can have a dramatic effect on the incidence of cholera only if prior improvements in drinking water quality have been made. Considerable care has therefore been taken to explore the determinants related to water sources, adequacy, storage practices and microbiological quality.

The debate continues on the most appropriate intervention for reduction of diarrhoeal illnesses, particularly in the deprived segments of urban communities. Arguments continue on whether the decisive factors are engineering/infrastructural and socio-economic/behavioural. While it is imperative to provide households with adequate, safe and reliable water supply and sanitation services, household behaviour and resources and preferences of households also form critical determinants of diarrhoeal diseases.

In the ultimate analysis, all these factors are highly intertwined. These include water sources, interruptions in piped supplies, water storage practices and water quality of both sources and on storage. The household's access to a sanitary latrine must also be taken into account.

II
Methodology

Conceptualisation of the Problem

Drawing out from the above reviews we see cholera as an epidemiological complexity. In Delhi, this complexity is intertwined with the history and evolution of its urbanisation. It is therefore intricately linked with the organisation of the city, in terms of spaces, services,
population settlements, natural terrain and resources and its administrative and political structure.

The epidemiological patterns of cholera in Delhi are therefore determined by the above factors. Time trends in cholera are expected to correspond to expansion, reorganisation and upheavals in the city spaces, its services and its administration. Historical epidemiology therefore would help throw a light on the underlying causality.

To explore the causal linkages another option available to us is to look at the detailed contemporary epidemiological data and contextualise it within the present organisation of the city. This organisation would involve understanding constructs such as zoning, locating within them colonies of different types of populations, understanding the processes of resettlement and provision of services to the marginalised, the health service infrastructure and, cholera surveillance and monitoring institutions. Zones or colonies with consistently high prevalence of cholera or frequent focal outbreaks of cholera would be considered as vulnerable. Using the vulnerable colonies we would try to identify the socio-economic and environmental conditions which generate vulnerability.

In addition to the population level analysis of socio-economic and administrative factors, there is also a potential for exploring the role of individual factors in which risk factor epidemiology puts so much emphasis. It is our contention that individual risk factors when located within the larger socio-economic, political and administrative framework become less significant as compared to simplistic studies which look at individual behaviour alone.

Within this conceptualisation of the problem, the study adopts a historical approach to elicit possible time trends and to locate these time trends within recorded major events. Other than a broad overview of historical epidemiology of cholera and its specific patterns in Delhi the 1988 cholera epidemic would be studied in all its dimensions. In addition, the available historical material from 1965 to 2000 is analysed for epidemiological trends and patterns. From 1994 onwards available data makes it possible not only to study trends but to make zonal and colony level analysis. This therefore will be both a historical epidemiological study
as well as a time series study for the period 1994-2000. A cross-sectional dimension will be added to explore household level factors affecting disease causation.

Our hypothesis is that behavioural factors at the individual household level loose their significance as major determinants of cholera (and other diarrhoeal diseases) once they are analysed in a more comprehensive and holistic social epidemiology frame that takes into account factors such as poverty, provision of services, living conditions and settlement patterns.

The Objective
The objective of the study is to assess time trends of cholera in Delhi and its determinants and, to identify the key factors that make populations vulnerable and, the role of household level and some other factors in determining vulnerability to cholera.

The Design

The study period can be divided into two distinct phases, one historical and the other contemporary. The historical period covers the colonial and post-independence period, upto 1988. The contemporary phase focuses on the period 1988 onwards till 2000.

Historical : Colonial & Contemporary Periods

A historical approach was taken to elicit time trends. The data sources used include administrative reports, community based studies, annual reports, texts and journal articles. Most of the material was made available at National Institute of Cholera and Enteric Diseases, Calcutta, and, the National Institute of Communicable Diseases, National Medical Library, Archives of the Delhi Administration, Library of the Delhi Legislative Assembly and the Municipal Library, at Delhi.
A brief history of the cholera pandemics of the classical biotype was reviewed to elicit the routes through which Delhi and northern Indian states, particularly United Provinces (Uttar Pradesh) and Punjab were affected from time to time. Utilising the available data sources the study sought to identify regional patterns and seasonal trends. Traditional literature on cholera in India has focussed on the critical role of pilgrimages and impact of travel and troop movements. A critical analysis was made of these aspects in order to examine their relevance in contributing to the spread of cholera across India. In keeping with the debates on sanitary policy for effective cholera control in the West, official Indian policy also underwent changes in the second half of the 19th Century. These debates and their impacts have been reviewed. An attempt has been made to analyse, through historical data, the reasons for decline of classical cholera in India beginning from the Fifth Pandemic, the point from when data is available. In the context of Zurbrigg's (1992) work on famine and malaria deaths, an attempt has been made to link cholera time trends with famine in different Indian states.

This historical approach continues in the subsequent section which focuses on the all-India time trends following the introduction of El tor cholera in 1964. The various factors that were responsible for rapid spread of El tor infection in India, the states that were affected and the population groups that suffered have been studied. The study also focussed on the decline of deaths and case fatality rates. It is interesting that while the study was being conducted a new strain, O139 Bengal, emerged in the country. Its detailed documentation has also been done in this study.

Several Indian states emerged as new endemic foci for El tor cholera. Till date Delhi continues to be one of the leading endemic states and is the focus of the current study. The role of civic services is crucial in understanding this endemicity as has been mentioned earlier. The study therefore recorded and analysed the history of the municipal services following the planning process initiated by the British in the second half of the 19th century. The history of the developments of various local bodies and planning strategies adopted by them has been described.
Intensive analysis was done for gaining an understanding and evaluating the developments from Independence onwards, when Delhi emerged as one of the most populous and thriving urban centres, to the present times. Throughout these fifty odd years, various planning models were adopted from time to time in response to the challenge of providing services to a fast growing body of population. Detailed analysis was made of the population growth and migration issues along with certain key socio-economic characteristics. Special attention was paid to the settlement patterns in Delhi which are a key determinant for further analysis. Access to water supply and waste disposal services is closely linked with settlement types and infrastructure issues were therefore examined from this perspective. Safe water, the key to the prevention of cholera (and other water-borne diseases), was examined in considerable detail with regard to sources, availability, consumption and contamination issues.

Having developed an understanding of the settlements and their access to infrastructure, through this historical approach, a more statistical analytical approach based on available data was attempted subsequently, for analysing time trends and their determinants in Delhi. The overall trends were analysed for the period beginning 1965, when the first El tor case was reported in Delhi, till 2000. Particular emphasis was laid on the analysis of the seasonal trends as well. O139 Bengal was responsible for a large number of cases in Delhi during 1994-95. The impact of this new strain was also given due consideration in the analysis.

The 1988 Epidemic

In 1988 a major cholera (and gastroenteritis) epidemic was reported from several localities of Delhi. Information and data for this part of the study was gathered from administrative reports, epidemiological investigation reports and microbiological studies at the National Institute of Communicable Diseases and the Municipal Corporation of Delhi. Informal discussions were also held with informed field workers who had had experience of the control measures adopted during the epidemic.
To develop an understanding of the vulnerability factors, an analytical epidemiological study of this epidemic was conducted with particular reference to settlement factors, administrative issues, water supply and waste disposal. Microbiological factors were also explored. The containment measures adopted during this epidemic have been debated and criticised in scientific literature, social discourses and judicial proceedings. The present study has attempted to construct a comprehensive picture of the issues raised. This epidemic lead to the introduction of wide ranging preventive and control measures for diarrhoeal diseases, in a manner as never before. At the same time it lead to 'politicisation' of cholera. The study has detailed and analysed the control measures.


The contemporary phase focused on the study of 'vulnerability' issues in understanding time trends and determinants of cholera in Delhi. Data sources for this period included annual reports and reports of epidemiological investigations available at the National Institute of Communicable Diseases and the Municipal Corporation of Delhi. Informal discussions were held with the zonal level officials of the Municipal Corporation of Delhi and the Delhi Jal Board. Repeated visits to the concerned field areas and interactions with the community provided valuable information and insights for the analysis.

In this context, it is to be noted that civic services are provided by three local bodies in Delhi – Municipal Corporation of Delhi (MCD), New Delhi Municipal Committee (NDMC), and the Delhi Cantonment Board (DCB). For administrative purposes, the MCD is divided into 12 zones. NDMC and DCB are planned areas with adequate civic services and the resident population groups are socio-economically well-off and stable. The MCD areas, on the other hand, cater to large bodies of population who are either poor or infrastructure-deficient or both. Since the public health problems including cholera and other diarrhoeal diseases are almost exclusively confined to the MCD areas, this part of the study is confined to the MCD areas. The relevant issues were dealt with at three levels – zones, colonies and households.
Continuing with the analytical epidemiological approach, time trends were analysed in detail for each of the zones for the period 1994-2000 on the basis of available zone-wise data. Within these zones, endemic areas were identified, from where cholera cases are regularly reported. These colonies were thus considered to be vulnerable colonies and detailed analysis was made with regard to population, settlement and infrastructure characteristics in order to identify key vulnerability issues.

Cross-sectional Survey: Study of Household Level Determinants

An understanding of vulnerability at the household level is a key component in completing the construct of a comprehensive picture of cholera and its determinants. This is sought to be covered through analysis of two primary datasets. The first dataset is based on cholera cases reported during 1994. These were investigated in detail and epidemiological case sheets are available. These have not been analysed previously. They were taken up for the first time in this study, for conducting micro-level analysis of the determinants of cholera.

Epidemiological data was thus available for 2022 cholera cases notified during 1994 from different areas under the Municipal Corporation of Delhi. A 50% stratified random sample was taken for each of the 12 zones – that is a total of 1011 cases. The questionnaire administered to the cholera affected households included variables on socio-economic indicators (occupation, income and educational status), infrastructural facilities (settlement, water and sanitation), demographic data (age, sex and family size), and preventive practices for waterborne diseases. The socio-economic and infrastructure characteristics of this dataset were analysed to supplement the field observations for the endemic areas.

The determinants at the household level were further explored through a second dataset based on a primary survey of 300 households. The study was conducted in 300 households in three selected clusters in Shahdara (North) and Shahdara (South) zones which are known to be endemic for diarrhoeal diseases. These clusters are geographically adjacent to each other.

4 See Proforma in Appendix B
The field work was conducted during May-September, 1998. Two slums/Jhuggi-Jhonpri (JJ) clusters and one resettlement colony were chosen for this field study. Sanjay Amar Colony, JJ Cluster was chosen from Shahdara (South) Zone and Taj Colony, JJ Cluster and Welcome Colony, Resettlement Colony was chosen from Shahdara (North) Zone.

100 households were chosen in each cluster by random sampling. For each cluster the same sampling procedure was adopted. A simple random sampling technique was adopted as population in each cluster was small and homogenous. The unit for the sampling was the household. Simple random sampling with replacement was used, in which the probability of selection of any particular household at any drawing remains a constant, 1/N, where N is the size of the population. The technique was operationalised by using the lottery method. To start with, a complete enumeration of all the households in the cluster was done. Each household was assigned a number which was written on a card. All the cards were subsequently shuffled together and one card was drawn out of the pack at a time. The number on the selected card was noted, and the card was replaced in the pack. Reshuffling was done and a second card was again drawn, the number noted and the card replaced again in the pack. This process was repeated till 100 distinct numbers had been drawn. The cards that were reappearing were not considered. Households corresponding to the numbers selected constituted the sample.

A structured questionnaire was administered. The questionnaire covered the following aspects:

- Age-sex composition of the families
- Educational status of heads of families and mothers
- Schooling of children
- Occupation
- Income
- History of migration
- Access to water supply and sanitary latrines
• Water storage practices
• History of diarrhoea, in adults and children

Diarrhoea is defined as the passage of loose, liquid or watery stools. These liquid stools are passed more than three times a day. It is to be emphasised that recent changes in consistency and character of stools are more important than the number of stools. When blood is visible in watery stools, the condition is defined as dysentery. The term 'gastroenteritis' is often loosely used to describe acute diarrhoea. This is not strictly accurate as the term gives no indication of the causative agent. Only laboratory examination can confirm the microbiological aetiology which is not a routine procedure in the clinical management of diarrhoea in the majority of medical institutions of Delhi. It is also not cost effective to routinely undertake microbiological testing of stool sample of each case of diarrhoea.

The division between acute and chronic diarrhoea is arbitrary. UNICEF has defined acute diarrhoea as "an attack of sudden onset, which usually lasts 3 to 7 days but may last up to 10-14 days." WHO has labelled diarrhoeas lasting for 3 weeks or more as "chronic". Ghai (1996) reported that about 5% of diarrhoea cases in the community became chronic and lasted for more than 2 weeks.

Incidence rate is defined as "the number of new cases occurring in a defined population during a specific period of time" (Park, 2000). It is calculated by the formula:

\[
\text{Number of new cases of a specific disease during a given period \times 1000}
\]
\[
\text{Population at risk during that period}
\]

The incidence rates were calculated for a recall period of two weeks for the general population and children under five years of age. The associations between household level vulnerability factors and incidence of diarrhoea were examined through assessing distribution of incidence over different types of households.

\(^5\) See Appendix B for details
For the cross-sectional study, water samples were tested from the main sources accessed, and, storage containers in the household. Bacteriological tests for water quality surveillance include the following tests:

- Presumptive coliform test (most commonly performed)
- Tests for detection of faecal streptococci and Clostridium perfringens
- Colony count

The presumptive coliform test is the most relevant one for purposes of the present study and is described below in detail. This test is based on the most probable number (MPN) of coliform organisms in 100 ml of water. The test is carried out by inoculating measured quantities of the sample water – 0.1, 1.0, 10 and 50 ml into tubes of McConkey's Lactose Bile Salt Broth with Bromcresol Purple as indicator. The tubes are incubated for 48 hours. From the number of tubes showing acid and gas, an estimate of the MPN of coliform organisms in 100 ml of the sample can be obtained from standard tables. This result is known as the 'presumptive coliform count'; the presumption being each tube showing fermentation, contains coliform organisms. The reaction may however occasionally be due to the presence of some other organisms or combination of organisms.

Based on the guidelines for drinking water quality recommended by the WHO in 1996, the ISO (IS 10500) prescribes that the coliform count of a drinking water sample should be less than or equal to 10 per 100 ml of water. The WHO recommendation for drinking water quality lays down the primary standards as prescribed limits that must never be exceeded in water meant for drinking purposes.

The 'coliform organisms' include all aerobic and facultative anaerobic gram-negative, non-sporing, motile and non-motile rods capable of fermenting lactose at 35°-37° C in less than 48 hours. The coliform group includes both faecal and non-faecal organisms. Classical example of the faecal group is E. coli and that of the non-faecal group Klebsiella aerogens. As a working rule, it is assumed that all coliform organisms are of faecal origin unless non-faecal origin can be proved.
For purposes of sampling, a total of 60 water samples were collected i.e. 20% of the 300 households that were surveyed. This ensured that epidemiologically sensitive results were obtained for deriving conclusions about the exposure to contamination through the water that was being accessed by these 300 households.

The term water source was defined with reference to the means by which water was accessed. The means of access play the most important role in influencing as well as indicating the quality of water being consumed by a particular household. The word 'source' therefore was used to characterise water available at the point of access throughout the study. Points of access having similar characteristics and implications for water contamination, were clubbed together and labelled as a particular source. Thus, for example, shallow handpumps was one source, as distinguished from deep bore tubewells which was considered to be another distinct source.

A two stage sampling was conducted. In the first round, all the community sources were tested. Based on the results, household stored samples were lifted to test for the extent of contamination at the domestic level. If a certain source failed the test, water samples were not tested for households storing drinking water from that source. Only households storing water from sources that had passed the initial screening test were further sampled.

Analysis and Presentation

The historical data on cases and deaths for the colonial, post-independence and contemporary periods were analysed by constructing incidence rates and case fatality rates on the basis of available and estimated population figures. Moving averages and trendlines were computed. Historical associations were arrived at by correlating incidence data and records of other major events like famines and fairs. Likewise, the 1988 epidemic was also studied with a similar approach, placing it in the context of administrative, infrastructural and microbiological aspects. Incidence rates and time trends were computed for conducting the zonal and colony level analysis, for the period 1994-2000. The two cross-sectional datasets at
the household level, provided data for a detailed statistical analysis on socio-economic, infrastructural and behavioural characteristics and, incidence of diarrhoeal diseases. For purposes of statistical and graphical analysis, computer software including Microsoft Excel and STATA were used.

To sum, Chapter 2 traces the evolution of Delhi highlighting urban planning and the growth of municipal services from the nineteenth century till the present times. Chapter 3 provides a critical overview of the time trends of cholera in India, particularly northern India, with reference to the pandemics. Chapter 4 analyses time trends of cholera in Delhi for the period 1965 to 2000. Chapter 5 contains an in-depth analysis of issues in vulnerability at zonal and colony levels. Chapter 6 analyses primary data in understanding the level of household level factors in the context of the present study. Chapter 7 concludes the study by integrating the findings from the foregoing chapters.