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THE ENVIRONMENT AND HUMAN HEALTH

An Agenda for Research

Background Paper for the ZEF Environment and Health Research Theme

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Abstract

The Working Paper *Environment and Human Health* gives a comprehensive review of the related literature in order to aid understanding of the (missing) link between the environment and health. Given the exhaustive literature on the subject the paper focuses on the water-related and land-related diseases namely in the fast growing and poor countries. By assessing the terrain of research on the subject, the paper aims to look beyond the causal linkage between environment and health and instead emphasis the underlying question about how environmental factors, along with man-made changes, influence human health. Specifically, the review examines the ability of the literature to define the incidence of environmentally-related diseases as well as their distribution across social and geographical scales, understands the role of diverse factors influencing these diseases and the adaptive capacity of societies in managing these illnesses or disorders. The paper draws on a wide range of sources from a variety of disciplines to unpack the linkage between the environment and health, and identifies issues, themes and questions raised by the literature.

The review reveals limited understanding of the complex relationship between the environment and health. Although these researches provide grounds for a curative approach and in recent years have called for a preventive approach, they still retain a 'simplistic high school model' of examining the linear cause-effect relationship. This nevertheless fails to take on the growing risks posed by climate change and globalisation, as well as the dynamics of pathogens (and vectors) and of society affecting human health. These risks characterise complexity, uncertainty, conflicts and change. Given this characterisation of risks, the review calls for a modern approach to foresee and control the future consequences of human actions in order to live and adapt to the risks. This requires a comprehensive understanding of risk (from water pollutants) by identifying the pathways of risk assessment, understanding the impacts of pollutants and identifying a diverse set of strategies adopted by the individuals, organisations and agencies involved in bringing change to existing institutions and bio-physical resources.

Keywords:
Risk governance, globalization, fast growing economies, water governance, climate change.

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ADB	Asian Development Bank
AFR	Africa
AMR	Americas
ASSOD	Assessment of the Status of Human Induced Soil Degradation in South & Southeast Asia
BAMWSP	Bangladesh Arsenic Mitigation Water Supply Project
BGS	British Geological Society
BOD	Biological Oxygen Demand
BUET	Bangladesh University of Engineering and Technology
CEReS	Centre for Environmental Remote Sensing
CETP	Common Effluent Treatment Plant
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board, Government of India
CSE	Centre for Science and Environment, New Delhi, India
CSSM	Child Survival and Safe Motherhood
DALYs	Disability-Adjusted Life Years
DC	Developing Countries
DFID	Department for International Development, London, UK
DO	Dissolved Oxygen
EIR	Entomological Inoculation Rates
EMR	Eastern Mediterranean Region
ETP	Effluent Treatment Plant
EUR	Europe
FAO	Food and Agriculture Organization
FSE	Former Socialist Economies of Europe
GEF	Global Environment Facility
GDP	Gross Domestic Product
GI tumours	Gastrointestinal Tumours
GLASOD	Global Assessment of Human Induced Soil Degradation
HIA	Health Impact Assessment
IDRC	International Development Research Centre
IETP	Independent Effluent Treatment Plant
IFAD	International Fund for Agricultural Development
IGNP	Indira Gandhi Nahar Pariyojana
IIPS	International Institute for Population Sciences, Mumbai, India
ISRIC	International Soil Reference and Information Centre
IWMI	International Water Management Institute
LAC	Latin America and the Caribbean
LEA	Loss of Ecology Authority
MEA	Millennium Ecosystem Assessment
MENA	Middle East and North Africa
MLD	Mega litre per day
MoRD	Ministry of Rural Development, Government of India
NERC	National Environment Research Council

NFHS	National Family Health Survey
NGO	Non-Governmental Organization
NPAM	National Policy for Arsenic Mitigation
NRCP	National River Conservation Plan
pH	Potential of Hydrogen, Measure of Acidity
POP	Persistent Organic Pollutant
PRC	People's Republic of China
RCH	Reproductive and Child Health
SEAR	South East Asian Regions
SEHD	Society of Environment and Human Development, Bangladesh
SOVEUR	The Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe
SPCB	State Pollution Control Board
SSA	Sub-Saharan Africa
SSI	Small Scale Industry
SS & LUO	Soil Survey & Land Use Organization
STP	Sewage Treatment Plant
TCS	Tata Consultancy Services
TDS	Total Dissolved Solids
TNPCB	Tamil Nadu Pollution Control Board, Chennai, India
TSS	Total Suspended Soils
TVIE	Township Village Industrial Enterprises
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UN-HABITAT	United Nations Human Settlements Programme
UNICEF	United Nations International Children's Emergency Fund
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
WHO	World Health Organization
WSP	Water and Sanitation Programme

1 ENVIRONMENT AND HEALTH: A Global Picture

The environment and health are intricately linked. The environment is the life support system that provides fundamental needs for water, land, air, shelter and climate for humans and for all other forms of life. Changes in these conditions, however, can significantly alter humans' well-being and their health. These changes are in the physical and biogeochemical environment, either caused naturally or influenced by human activities such as deforestation, fossil fuel consumption, urbanisation, land reclamation, agricultural intensification, freshwater extraction, fisheries over-exploitation and waste production, which are driven by complex socio-economic and natural processes, giving rise to 'global environmental change' (Leemans et al., 2009:1). These are 'global' in the sense of either being globally integrated (i.e., entailing a systemic change to a global system, such as the climate system) or occurring by worldwide aggregation of widespread local changes (e.g., land degradation, species extinctions) (Confaloneri and McMichael, 2007:8). Approximately 60 per cent of the benefits the environment provides in order to support life on earth are being degraded or used unsustainably. The World Health Organisation (2005) warns of the harmful consequences of these degradation processes on human health, which could grow significantly in the next fifty years. While the environment plays a fundamental role, socio-economic, demographic, technological advancement and human body metabolism factors equally influence human health, which WHO defines as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity". These health conditions are the 'bottom-line' for human welfare and a cross-cutting issue within ecological services. Understanding the interaction between these two systems is therefore vital for adapting and preventing disease, as well as for alleviating poverty.

Scientific evidence to support the associations between environmental contaminants and human diseases remains circumstantial. The Global Burden of Diseases reveals water, sanitation and hygiene as the major risk factors for global ecological deaths (Table 1), followed by indoor air pollution. Overall, environmental pollutants account for 8 per cent of the total global disease burden. The magnitude of health implications from exposure to environmental factors was only assessed a decade ago with the standardisation measure of health outcomes (Disability-Adjusted Life Years or DALYs – refer to Box 1) across various causes of illness and death (Murray and Lopez, 1996). The estimates (Table 2) reveal that the disease burden from environmental factors is higher in developing countries than in others (27 per cent in Africa and 18 per cent in Asia), as these countries house most of the world's poor people.

Table 1: Global Burden of Disease Attributable to Selected Sources of Pollution

RISK FACTOR	DEATHS		DISABILITY-ADJUSTED LIFE YEARS	
	In thousands	Per cent	In Thousand	Per cent
Total (all risk factors)	55,861		1,456,473	
Water, Sanitation and Hygiene	1,730	3.1	54,158	3.7
Urban Outdoor Air Pollution	799	1.4	6,404	0.4
Indoor Smoke from Solid Fuels	1,619	2.9	38,539	2.5
Lead	234	0.4	12,926	0.9
Total Ecological Pollution (related)	**4,382**	**7.8**	**112,027**	**7.6**

Note: This information does not include people affected by chemical and geogenic pollution as a result of global environmental change.

Source: Ezzati et al. (2002), cited in Eyles & Consitt (2004:26).

BOX 1
DALYs as a measure of the burden of disease

Disability-adjusted life years are a standard measure of the burden of disease. The concept of DALYs combines life years lost due to premature death and fractions of years of healthy life lost as a result of illness or disability. A weighting function that incorporates discounting is used for years of life lost at each age to reflect the different social weights that are usually given to illness and premature mortality at different ages. The combination of discounting and age weights produces the pattern of DALY lost by a death at each age. For example, the death of a baby girl represents a loss of 32.5 DALYs, while a female death at age 60 represents 12 lost DALYs (values are slightly lower for males). The use of DALYs as a measure of the burden of disease has provided a consistent basis for systematic comparisons of the cost-effectiveness of alternative interventions designed to improve health. When combined with the results of large-scale epidemiological studies, it enables public health specialists to identify priorities and focus attention on development programs that have the potential to generate significant improvements in the health status of poor people in the developing world.

Source: Murray and Lopez (1996), cited in Lvovsky (2001:3).

The burden of disease from major environmental risks is at its highest in Sub-Saharan Africa, Asian & Pacific islands and Middle Eastern and North African countries (Table 2). Of the mentioned factors, inadequate water supply and sanitation pose the largest threats, while air pollution causes the most damage in China and in European transition economies. Indoor air pollution is the greatest threat in Asia and Sub-Saharan Africa, and malaria has taken a heavy toll, but only in Sub-Saharan Africa. These international estimates do not include people affected by industrial and domestic water pollution or health impacts from the degradation of land.

Table 2: Burden of Disease from Major Environmental Risks
(% of all DALY's in each country group)

Environmental Health Groups	SSA	India	Asia & Pacific	China	MENA	LAC	FSE	ICs	All DCs
Water Supply & Sanitation	10.0	9.0	8.0	3.5	8.0	5.5	1.5	1.0	7.0
Vector Disease (Malaria)	9.0	0.5	1.5	0.0	0.3	0.0	0.0	0.0	3.0
Indoor Air Pollution	5.5	6.0	5.0	3.5	1.7	0.5	0.0	0.0	4.0
Urban Air Pollution	1.0	2.0	2.0	4.5	3.0	3.0	3.0	1.0	2.0
Agro-Industrial Waste	1.0	1.0	1.0	1.5	1.0	2.0	2.0	2.5	1.0
All Causes	**26.5**	**18.5**	**17.5**	**13.0**	**14.0**	**11.0**	**6.5**	**4.5**	**18.0**

Notes: SSA: Sub-Saharan Africa; Asia & Pacific includes countries from East and South Asia, except India, China, Pakistan and Afghanistan; MENA: Middle East and North Africa; LAC: Latin America and Caribbean; FSE: Former Socialist Economies of Europe and does not include Central Asia; IC: industrialised nations; and DC: developing countries.

Source: Lvovsky, 2001

The linkage between the environment and health is evident: the (mis)management of natural resources, natural disasters and global environmental change has increased the risk to human health (Table 3). Diseases such as diarrhoea and malaria are largely related to inadequate drainage of surface water, which encourages the breeding of bacterial pathogens and malarial vectors. Other diseases are the result of excessive use of existing water sources and the discharge of polluted water, which has not only resulted in impacts on human health, but also on land, water and other ecological systems. Land degradation plays a crucial role in influencing human health due to changes in land-use patterns, offering a favourable breeding ground for disease vectors such as malaria and diarrhoea and resulting in air-borne pollution. Air pollution[1] resulting from land degradation, excessive use of forest products and forest fires has impacts on respiratory disorders and cancerous diseases. These natural resource-related impacts caused by natural disasters such as flooding, tsunamis, landslides and earthquakes and from global environmental change have become a major threat. The literature on the environment and health is vast, so given the limitation of scope the current paper focuses on water-related and land-related diseases.

[1] This also results from burning of petro-chemical products.

Table 3: Environmental Health Disorders

ENVIRONMENTAL DETERMINANTS	HEALTH DISORDERS/ DISEASES
MANAGEMENT OF NATURAL RESOURCES (water, land & air)	
WATER-RELATED	
Infectious water-related	Diarrhoea and vector-related diseases (such as malaria, schistosomasis, dengue)
Non-infectious Water Related	Fluorosis, arsenic-related disorders
Industrial and domestic pollution	Diverse health impacts – ranging from rashes to cancer
LAND-RELATED (such as desertification, loss of wetland, flood irrigation)	Increased exposure to infectious agents Deficiencies in vitamin A, zinc and iodine.
AIR-RELATED (indoor and outdoor air pollution)	Respiratory disorders, cancer, tuberculosis
ENVIRONMENTAL DISASTER	
DISASTERS (earthquake, tsunami flooding, landslide)	Increased risk of infection leading to diarrhoea, malaria, dengue and West Nile fever. Tuberculosis, blood-borne viruses, gastrointestinal infections, damage to health infrastructures
GLOBAL NATURE OF HEALTH RISK	
Trans-boundary	SARS, AIDS and Avian influenza
Climate change	Increase in malaria, diarrhoea

The paper examines the underlying question about how environmental factors align with man-made changes to influence human health[2], by drawing on a wide range of published peer-reviewed research papers and reports from national and international agencies. Specifically, the review examines the literature to define the incidence of environmentally-related diseases, the role of factors in influencing these diseases, their distribution across social and geographical plains and the adaptive capacity of societies to manage these diseases, illnesses or disorders. The paper tends to focus on highly populated developing and fast-growing economies in mainland of Asia, Latin America and Africa. It is in these countries where half the worlds' population live, and at the same time has a large proportion of population undernourished and are living in poverty.

[2] While the (mis) management of the environment has direct and indirect impact on human health and their environment, the review focuses on the direct and indirect impact on human health only.

2 WATER AND HUMAN HEALTH

Water is a prerequisite for the day-to-day survival of humans. Its availability and accessibility in terms of quality and quantity have been major concerns in both developed and developing worlds. Globally, the availability of water per person has declined markedly. The Millennium Ecosystem Assessment (Corvalan et al., 2005:14) reveals the amount of fresh water available per capita decreased from 16,800 m^3 in 1950 to 6,800 m^3 in 2000 as a result of population growth. This fraction is expected to plummet further through the increasing use of fresh water for irrigated agriculture, livestock production, industry and the requirements of wealthier urban residents posing a threat to about one-third of the world's population now living in countries experiencing moderate to high water stress. Currently, over 1 billion people lack access to safe water supplies, and 2.6 billion people lack adequate sanitation, which has led to widespread microbial contamination of drinking water. Moreover, water-infected diseases claim up to 3.2 million lives each year, approximately 6 per cent of all deaths globally. The burden of disease from inadequate water, sanitation and hygiene totals 1.7 million deaths and the loss of more than 54 million healthy life years. Every day, each person needs 20-50 litres of clean water, free from harmful chemical and microbial contaminants, for drinking, cooking and hygiene purposes. Inadequate availability of safe drinking water and sanitation has given rise to various water-related diseases, where water acts as a conduit or a medium for the diseases. However, the problem is acute in developing countries, due to increasing population, growing poverty, globalisation, climate change, inadequate access to a water supply, poor sanitation and inadequate institutional arrangements.

The United Nations Development Programme World Human Development Report 2006 recognises that "water and sanitation are the most powerful preventive medicines available to governments to reduce the rate of infectious diseases. Investment in this area is like 'immunization to measles' – a life saver" (UNDP, 2006:6). Worldwide development agencies have increased their investment in this powerful preventive medicine in order to address the Millennium Development Goals (we refer here to goals 4, 6 and 7). The World Bank, for instance, invested 5.5 billion USD in rural water and sanitation programmes between 1978 and 2003 (Iyer et al., 2006). While water supply and sanitation are important in combating water-transmitted diseases and for overall development, the review reveals the relationship is not as simple; various factors such as socio-cultural, economic, ecological, demographic, climate change, globalisation, inadequate institutional structures and human body metabolism factors influence human health. Understanding the diverse and compounding effects of factors is important in order to identify the specific role of water supply and sanitation on human health. Water acts as a medium to transport viruses, microbes and chemicals, when this significantly affects human health it leads to various water-related health complications. Broadly speaking, the literature identifies three categories: (i) Diseases directly transmitted through water, (ii) diseases due to prolific contamination of geogenic minerals in water and (iii) diseases due to contamination by man-made water pollutants generated from industrial and domestic wastewaters.

2.1 Complex Reality of Water-Transmitted Diseases

The UN World Development Report 2006 (UNDP, 2006) emphasises the need to address water-transmitted diseases for human well-being and progress. Although these diseases affect people of all ages, it is children who are most vulnerable. Of the 60 million deaths reported worldwide in 2004, 10.6 million (nearly 20%) were children under the age of five (WHO, 2006). New estimates show that, worldwide, 73 per cent of deaths in children younger than the age of five years are mainly attributable to six causes (Bryce et al., 2005): pneumonia (19%), diarrhoea (18%) (which includes 17% of children between 1 and 59 months and 3% neonatal deaths), malaria (8%), neonatal sepsis (10%), preterm delivery (10%) and asphyxia at birth (8%). Under-nutrition is an underlying cause of 53 per cent of all deaths in children aged less than five years. The estimated proportions of deaths in which under-nutrition is an underlying cause are roughly similar for diarrhoea (61%), malaria (57%), pneumonia (52%) and measles (45%). Worldwide distribution (Figure 2.1) reveals 42 per cent of these fatalities occur in WHO African regions, followed by 29 per cent in Southeast Asia. Water-transmitted diseases are classified in four categories: waterborne, water-related, water-based and water-washed (Ashbolt, 2004:232).

1. *Waterborne diseases*: Diseases spread through water, which acts as a passive carrier for infecting pathogens. Diarrhoea is the most common waterborne disease, and if unchecked leads to cholera, typhoid, bacillary ailments and gastroenteritis.
2. *Water-related diseases*: Diseases spread by vectors and insects that live in or close to water. Stagnant pools of water provide the breeding place for disease-spreading vectors such as mosquitoes, flies and other insects. The most common water-related diseases are malaria, dengue fever, yellow fever, filariasis and sleeping sickness.
3. *Water-based diseases*: Diseases caused by infecting agents spread by contact with or the ingestion of water. Examples include dracunculiasis, philariasis, threadworm and other helminths. Water supports an essential part of the lifecycle of infecting agents such as aquatic snails.
4. *Water-washed diseases*: Diseases caused by the lack of adequate quantity of water for proper maintenance of personal hygiene; some also depend on poor sanitation. Scabies, trachworms, conjunctivitis, hookworm and amoebic dysentery are some of the more common water-washed diseases.

While it is important to review each and every disease, for the purpose of identifying the common research gaps the following section focuses on two major water-related diseases – diarrhoea and malaria.

2.1.1 Waterborne Diseases: Diarrhoea and its Effects

There are many manifestations due to waterborne pathogens, the most important of which is diarrhoea. Inadequate water supply and sanitation have been identified as the major causes of this disease. An assessment of Asian water supply and sanitation coverage indicates a large gap between those with access and those without (WHO & UNICEF, 2000). Data compiled by WHO and UNICEF (2000) indicate that rural Asia has the lowest sanitation coverage (31 per cent) and the third highest water supply coverage (75 per cent) compared to other regions of the world. WHO estimated (WHO, 2004) that 1.8 million people die every year from diarrhoeal diseases (including cholera), 90 per cent of whom are children under five years and mostly from developing countries; for example, 25 per cent (about half a million) come from India alone (Figure 1). The National Family Health Survey-2 (NFHS) study on the health status of the Indian population revealed that 19 per cent of children aged less than three years suffered from diarrhoea in the two-week period before a survey in 1998-99 (IIPS & ORC Marco, 2000).

Diarrhoea is defined as frequent passing of watery stools containing blood, usually at least three times in a 24-hour period (see Box 2 for more details). More than one million diarrhoeal deaths are caused by shigella or dysentery. Unlike other forms of diarrhoea, shigella cannot be treated effectively through simple curative oral rehydration therapies – it requires more costly antibiotics. Even for households that can afford treatment, shigella is a growing threat because it has rapidly developed resistance to these antibiotics. The UN Human Development Report 2007 (UNDP, 2006:43) claims to have identified the re-emergence of drug-resistant shigella in northern and eastern India after a hiatus of 14 years. Similarly, in rural western Kenya, half of all diarrhoea cases have proved resistant to treatment. Diarrhoea causes the rapid depletion of water and sodium in the body, both of which are essential for life. If water and salts are not replaced fast, the body starts to 'dry up', or become dehydrated, and as soon as more than 10 per cent of the body's fluid is lost, death occurs. Children are more likely than adults to die or become malnourished from diarrhoea, as they dehydrate quicker and their resistance to disease is also low. International documents and research literature claim the prevalence of diarrhoea is associated primarily with unclean water and poor sanitation, and therefore call for a preventive approach along the lines of experiences in Europe and the United States in the 19th and 20th centuries (Cutler & Miller, 2005). The UN Human Development Report 2006 states that access to clean water and sanitation is the 'most powerful preventive medicine' for reducing child mortality, namely diarrhoea, on a parallel with the importance of immunisation for measles and polio (UNDP, 2006:43).

Diarrhoea is a symptom of infection caused by a host of bacterial, viral and parasitic organisms, most of which are spread by contaminated water. Water contaminated by human faeces, for example from municipal sewage, septic tanks and latrines, is of special concern. Animal faeces also contain microorganisms that can cause diarrhoea, which is then spread from person to person, very often aggravated by poor personal hygiene. Food is another major cause of diarrhoea when it is prepared or stored in unhygienic conditions. Water can contaminate food through irrigation, and fish and seafood from polluted water may also contribute to the disease. Shortage of clean water for drinking, cooking, cleaning and basic hygiene is another cause of diarrhoea. This is further exasperated by natural disasters such as floods and tsunamis that often trigger diarrhoea due to the mixing of faecal contamination in water sources.

Box 2

DIARRHOEA AND ITS TYPES

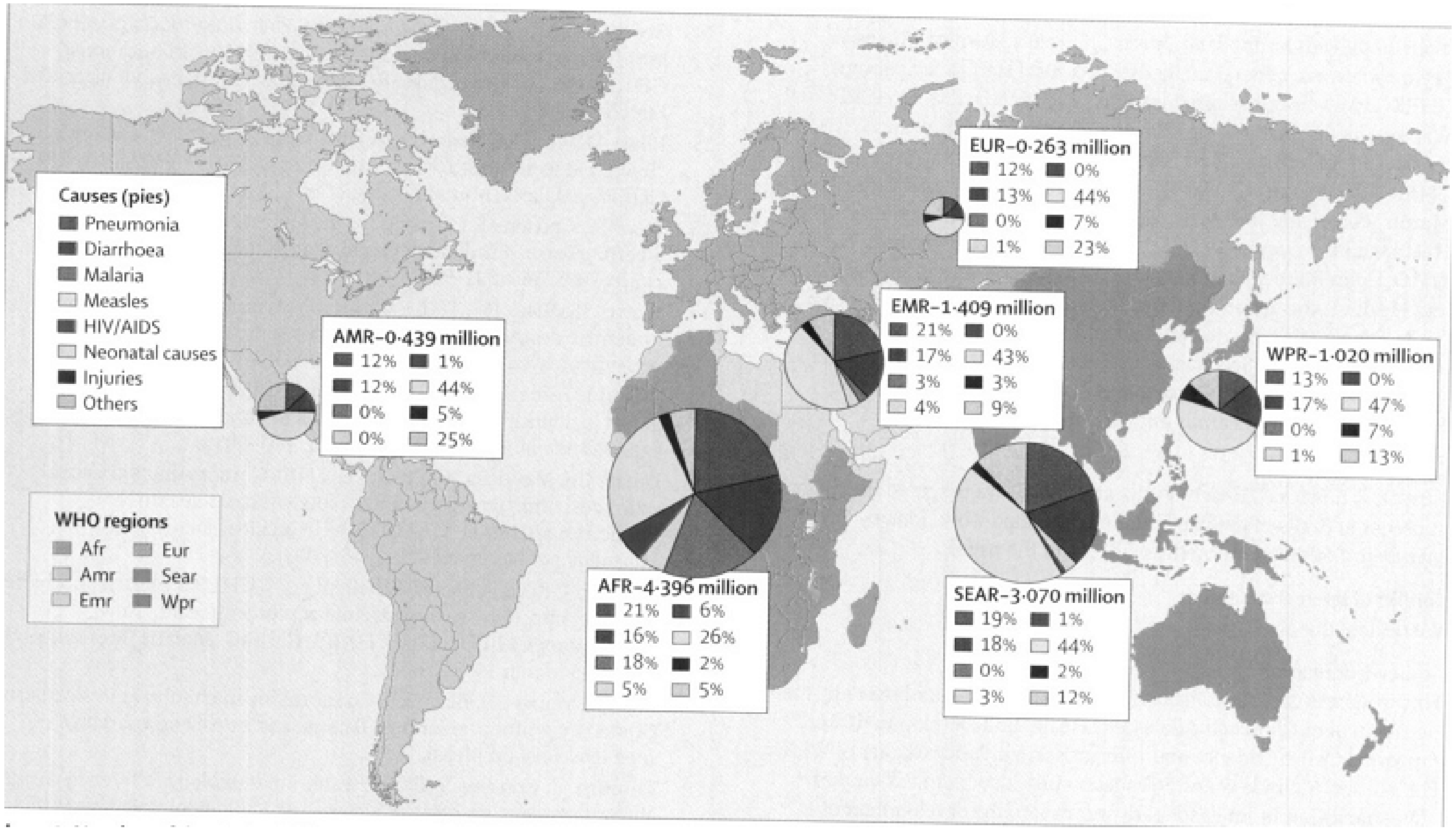
Diarrhoea is an intestinal disorder characterised by abnormal fluidity and frequency of faecal evacuations, generally the result of increased motility in the colon; it may be an important symptom of underlying disorders such as dysenteric diseases, lactose intolerance, GI tumours and inflammatory bowel disease. There are four major types of diarrhoeal diseases based on the clinical type of illness:

- **Acute watery diarrhoea** (including cholera):
  lasts several hours or days: the main danger is dehydration; weight loss also occurs if feeding is not continued.
- **Acute bloody diarrhoea** (also called dysentery):
  the main dangers are intestinal damage, sepsis and malnutrition; other complications, including dehydration, may also occur.
- **Persistent diarrhoea** (which lasts 14 days or longer):
  the main danger is malnutrition and serious non-intestinal infection; dehydration may also occur.
- **Diarrhoea with severe malnutrition** (marasmus or kwashiorkor):
  the main dangers are severe systemic infection, dehydration, heart failure and vitamin and mineral deficiency.

Source: Rehydration Project, a private, non-profit, non-sectarian, international development group. http://rehydrate.org/diarrhoea/index.html accessed September 2007.

Figure 1

Number of Deaths Among Children Younger than 5 Years and their Distribution by Cause for the Six WHO regions (yearly average for 2000-03)



Note: Size of circle represents the number of deaths in each region. AFR – Africa; AMR: Americas; EMR: Eastern Mediterranean; EUR: Europe; SEAR: South East Asia; WPR: West Pacific Region.

Source: Byrce et al. (2005: 1151).

It is clear that human and animal excreta affect human health, but a comprehensive understanding of this linkage is still fuzzy; due to precise definition of diarrhoea. Reviewing a number of studies, Baqui et al. (1991) provide a standard definition of diarrhoea as three or more stools or any number of loose stools containing blood in a 24-hour period. However, the literature reveals considerable variations in defining episodes of diarrhoea at the time of research. Some rely on the reports of events by mothers, others use loose stools (with or without blood) and the number of times these stools are discharged, while Moy et al. (1991) use the Shona word 'manyoka' for diarrhoeal episodes, as used by people in Zimbabwe to describe loose or watery stools that are passed more frequently than normal. Given the variations in identifying the episodes, Parashar et al. (2003) reveal different estimates of diarrhoea incidence. In 1976, Rhode and Northrup estimated that diarrhoea killed up to 5 million children in developing countries annually. In 1982, Snyder & Merson estimated the numbers of deaths to be at 4.6 million, while Bern et al. (1992) revised these estimates to 3.3 million per year. Murray et al. (2001) revealed a decline in mortality, but relatively stable morbidity. Some countries have adequate vital registration coverage, while in other countries the registration system is inadequate. These different estimates therefore make it difficult to define episodes and, more importantly, assess the burden of disease on a comparable basis.

The different estimates are complicated by temporal dimensions in the occurrence of diarrhoea. Lama et al. (2004) demonstrated an increased number of visits to public hospitals in Lima due to acute diarrhoea during warmer months between 1991 and 1996, mainly by children (Salazar et al., 1997; Checkley et al., 2000). Herbst (2008:169) revealed that environmental disasters increased the incidence of diarrhoea in the Aral Sea basin, with children below two years being most affected – registering 8.4 episodes per person per year. A similar study in Dhaka reported that diarrhoeal cases increase and decrease during high and low rainfall extremes. This is further complicated by climate change, which is emerging as a major threat (Singh et al., 2001) and expected to increase diarrhoeal diseases in India and Bangladesh (Mondal et al., 2001). Diarrhoeal diseases are also expected to increase due to higher temperatures, particularly in populations with lower socio-economic status.

The inadequate risk mapping of diarrhoea zones in countries most affected further aggravates the risk to human health, particularly as very few highly localised studies have examined the patterns and distribution of the illness. Attempts to assess the geographic variation of acute watery diarrhoea in rural Bangladesh among children under five years old reveal clustering patterns that enable the identification of several risk areas (Myaux et al., 1997). Similarly, Kandala et al. (2004) examine the spatial clustering of observed diarrhoea in remote, favourable climatic and geographical conditions in Malawi. Such computerised mapping exercises, supported with remote sensing and geographical information systems, can play a prominent role in defining and monitoring risk areas for the disease, particularly in view of the increasing risks caused by climate change.

An overwhelming research studies confirm the effectiveness of water quality interventions (specific to water supply or the provision of sanitation or hygiene education) in reducing diarrhoea (Clasen et al., 2007; Fewtrell et al., 2005; Pruss et al., 2002). In regions that have brackish groundwater and very low rainfall, this is of primary concern. For instance, in large areas of Pakistan, where groundwater is brackish, people depend on irrigation canal water. These areas are also affected by irrigation-induced waterlogging, making the provision of low-cost onsite sanitation very difficult. A study by van der Hoek et al. (2002) to assess the occurrences of diarrhoea in the Hakra 6R canal command area in southern Punjab, Pakistan, reveals that increasing the quantity of good quality water for domestic use and the provision of toilet facilities was the most important intervention in reducing diarrhoea and malnutrition in the region. The study also found that children from households with a large storage capacity for water had much lower prevalences of diarrhoea and stunting than children from families without this facility. Furthermore, having a toilet was highly beneficial for the prevention of these conditions. Root's (2001) study in two communities in Zimbabwe – one with sanitation facilities, the other not – confirms that there was a decrease of 68 per cent in diarrhoeal morbidity in the community that had sanitation facilities, compared to the community without. In addition, Plate et al. (2004) validate wells as an improved water source, on the assumption that they are less prone to faecal contamination, and as a result the provisioning of water has substantially improved the health of Native Americans (Galiani et al., 2005). However, it is expensive to provide piped water and sanitation to dispersed rural populations in many developing countries. Although the provision of communal rural water infrastructures and sanitation might be a less expensive alternative, there is little evidence that such alternatives reduce diarrhoea (Zwane & Kremer, 2007).

Many of these seemingly safe water provisions are often not accessible to all. Examining the effects of access to water facilities on child survival in Bangladesh, where diarrhoea is one of the two main causes of child deaths, Hoque et al. (1999) reveal that diarrhoea cases correlated positively with households further away from the water source (such as tubewell). Surveying about 700 children, the authors argued that longer distances from a tubewell forced households to store water in unclean containers. Mehta (2000) indicates that Indian water crises usually emerge because access to and control over water are disseminated unequally and differentiated in micro, meso and macro settings; sanitation facilities are no different, while socio-cultural and economic factors play further dominant roles. Kurup et al. (1996) and van Wijk-Sijbesma (1998) indicate that there is a high correlation between latrine ownership and higher socio-economic status. Mukherjee (1990) argues that younger, literate and economically well-off people, who are more exposed to urban influences and media, are more inclined towards adopting latrines. The Planning Commission of India (GoI, 2002) indicates that the sanitation problem for the majority of households is a lack of awareness and education rather than a lack of resources. These socio-economic differences are further complicated by differences among sex and age groups. Evaluating water, sanitation and hygiene education programmes in northern Pakistan, Nanan et al. (2003) concluded that boys were more resistant to diarrhoea compared to girls, while diarrhoea prevalence was negatively correlated with annual increases in either the mother's age or the child's age. Bhan et al. (1989) found a higher incidence among infants (31/ 100 child) compared to 6.3 per 100 for children between 0 and 71 months. Examining about 700 children contracting diarrhoea in India (either through hospitalisation or as out-patients), Zodpey et al. (1998) identified the significance of infancy, religious affiliation, severe under-nutrition and inadequate hygiene practices as major risk factors. These findings were confirmed by the National Family Health Survey (NFHS-2) (IIPS & ORC Marco 2000), which revealed children aged 6-11 months are most susceptible to diarrhoea.

Seemingly 'safe' water may not actually be safe. Cairncross (2003) argued that there is a general misconception that diarrhoeal diseases are waterborne and that improved water quality alone will alleviate the incidence of the disease. Jensen et al. (2003) attempted to chlorinate the public water supply in a village in Pakistan in order to understand its impact on diarrhoea. The examination of diarrhoeal incidence in the following six months revealed no significant change compared to villages consuming non-chlorinated water. The study showed that the reduction of faecal bacteria in the public water system did not seem to have reduced childhood diarrhoea. In another study, the same authors (Jensen et al., 2004) revealed the presence of faecal contamination in household storage devices as responsible for diarrhoeal incidence. These studies revealed the importance of individual-based behavioural change such as hand-washing and improved storage, along with water quality improvement. Frequent contact of hands with stored water further increases the presence of faecal coliform bacteria in water, which is aggravated by dirty latrines, as in this case less water is available. This argument is further justified by van der Hoek et al. (2002), who examined children consuming irrigation water meant for domestic purposes in southern Punjab of Pakistan. The authors found that children from households with larger storage containers and better sanitation had a lower prevalence of diarrhoea than children from households without these facilities. In addition, hand-washing practices played a major role in the occurrence of diarrhoea. Oo et al. (2000) highlighted within their study in Myanmar the importance of hand-washing with soap and water after cleansing children's defecation, and before and after feeding children. These studies highlight the importance of hygiene practices in countering infections, in addition to adequate water supply.

Under-nutrition remains a major underlying cause of 53 per cent of all deaths in children younger than five years worldwide (Bryce et al., 2005; Thapar & Sanderson, 2004). In a hospital-based study (Sodeinde et al., 1997) in Nigeria, poor nutritional status was identified as a major factor for the persistence of diarrhoea, and the number of occurrences of under-nutrition, marasmus and kwashiorkor were higher among children suffering from persistent diarrhoea. The nutritional status of children, especially infants, largely depends on child care practices, especially those of their mothers (Pattnaik et al., 2003). Although the relationship between nutritional deficiency and diarrhoea is highly recognised, it has not played a major role in many programmes addressing diarrhoea. It should therefore be a major consideration in public health interventions to prevent infection and correct malnutrition (Scrimshaw, 2003). Under-nutrition increases the incidence and severity of diarrhoea, and diarrhoea is detrimental to nutritional status (Black et al., 2003; Baqui and Ahmed, 2006), leading to a vicious cycle of repeated infections, reduced immunity and deteriorating nutritional status. Furthermore, diarrhoea has serious impacts on the nutritional status by accounting for 10-80 per cent of growth retardation in the first few years of life worldwide, with the magnitude of effects possibly modified by other factors such as aetiology and clinical types of diarrhoea (Baqui & Ahmed, 2006). Understanding the mechanism of diarrhoea-induced under-nutrition and appropriate treatment are two important processes for managing immediate illness and maximising children's well-being in the long term (Ahmad et al., 1999). In economic terms for India, estimates reveal a loss of 180 million working days and 12 billion Indian Rupees annually due to diarrhoea (Singh, 2007).

However, improving hygiene practices and adequate nutrition requires better education and awareness creation among general and child care practitioners, especially mothers. The children of mothers with high school or other types of education, as well as children living in relatively affluent households, are somewhat less likely to suffer from diarrhoea than other children in India (IIPS & ORC Marco, 2000). Evidence in other parts of India has shown an association between postnatal depression among mothers and impaired child growth (Awasthi et al., 2006; Harpham et al., 2005). In Goa, for example, malnourished children have a risk 2.3 times higher than the non-malnourished children of depressed mothers. In Tamil Nadu, the odds are 7.4 times higher. In Pakistan, Rahman et al. (2004) demonstrated that addressing this depression could reduce child impairment by 30 per cent. Moreover, diarrhoea among infants could be eradicated if these children were completely breastfed, as an exclusive breast-feeding practice in the early infancy stage was found to reduce acute respiratory infections and diarrhoea among infants in Dhaka slums (Arifeen et al., 2001).

Although legislation and health education promote breastfeeding children for at least six months from birth, such a practice is hampered due to socio-cultural practices; often, mothers start breastfeeding their children the third day after their birth. Since the 1990s there has been an increasing focus on strengthening the management of diarrhoea for children under five years of age and improving maternal knowledge related to the use of fluids in the home, oral rehydration solutions (ORSs) and continued feeding. The adoption of exclusive breastfeeding and the increased use of ORSs and advanced purification methods have resulted in a reduction of 62 per cent of diarrhoeal cases in Madhya Pradesh (Tiwari & Kakkar, 2003). It is interesting to note that in India a diarrhoeal control programme became an integral part of the child survival and safe motherhood (CSSM) programme, and was implemented through other reproductive and child health (RCH) programmes. However, it ran into problems due to a lack of manpower and motivation, corruption and poor community mobilisation.

The lack of awareness and education is further combined with inadequate institutional arrangements. While numerical information provides a colourful picture of the coverage of water supply and sanitation, on the ground we see a different picture. Technical failure, unreliable water supply, inadequate drainage facilities and the poor quality of available water pose several problems. In fact, the government of India aims to provide total sanitation by 2012 and has been 'painting' glorious picture of its coverage – particularly so on walls and hoardings. However, in reality, there are a number of factors that hinder its implementation such as the quick-fix technological approach (single-pit, pour flush latrine) adopted by international donor agencies, poor funding (about 1,900 Indian Rupees) allocated for toilets and inadequate drainage for disposing effluent into sewers. In many places, such as Himachal Pradesh, these toilets have been converted into storage rooms (Saravanan, 2006) due to inadequate drainage facilities. Examining the sanitation coverage in Tamil Nadu state in India, Sportel (2002) identifies several issues that have constrained its implementation.

- Very low priority given by governments and their people to sanitation
- Low emphasis on information, education and communication
- Promotion of just one latrine model
- Heavy reliance on subsidy and lack of motivation
- Poor disposal of wastewater from water points, creating unhygienic conditions
- People's habits
- Unwillingness to pay for the cost of sewerage, scarcity of water
- Lack of community participation and NGO/private sector involvement.

These studies have revealed the effectiveness of water supply and sanitation programmes as a short-term strategy. However, long-term efforts to ensure human well-being requires exploring unexplained and multiple interrelated factors such as hygiene practices and individual behaviour, as well as the socio-economic, demographic, under-nutrition, climatic and institutional arrangements that influence diarrhoeal diseases. While curative strategies are of little use, preventive strategies seem to hold the greatest potential for reducing the burden of diarrhoeal disease (Thapar & Sanderson, 2004).

2.1.2 Water-Related Diseases – Malaria

Malaria is the second major disease associated with the environment, exacting a heavy toll on the health and economic welfare of the world's poorest communities, especially among children below five years of age. Over the years, substantial progress has been made in initiating and scaling up programmes to prevent infection or treat those affected. However, an increased resistance to anti-malarial drugs, the deterioration of primary health care and emerging resistance of mosquitoes to vector control measures has resulted in increase in malaria cases. At the end of 2005, about 3.6 billion people lived in areas at risk of malaria (Guerra et al., 2006) compared to 3 billion in 2004 (WHO, 2005). At the end of 2005, a total of 99,568 deaths were reported due to malaria worldwide, 90 per cent of which were in African countries (Table 4). The remaining 10 per cent of fatalities were reported in Asia, mainly in Southeast Asia. Although Asia contributes only 10 per cent of worldwide malaria deaths, the disease causes high morbidity and mortality in endemic countries such as India, Indonesia, Thailand and Myanmar. During the past decade, cases of Southeast Asian malaria have increased in intensity after the interruption of eradication efforts and also re-emerged in Central Asian and Transcaucasian countries. In these countries, diseases are deeply rooted among poor communities, affecting national development and taking up a major share of health budgets.

Table 4: REPORTED MALARIA CASES AND DEATHS FOR THE MOST RECENT YEARS

REGIONS	**STANDARDISED REPORTED MALARIA**			
	Cases	Percentage	Deaths	Percentage
AFRICA				
Central	5,705,990	8.00	17,499	18.00
East	29,598,674	42.00	25,654	25.00
North	56	0	0	
South	15,244,394	22.00	30,300	30.00
West	14,401,925	20.50	19,951	20.00
ASIA				
Central Asia & Transcaucasia	6723	0.05	0	
Eastern Mediterranean	1,006,179	2.00	58	
Southeast Asia	2,881,531	4.00	4,590	5.00
Western Pacific	379,388		1,400	2.00
THE AMERICAS				
Central America & Caribbean	73,744	0.45	35	
South America	775,494	1.00	81	
TOTAL	70,074,098	100.00	99,568	100.00

Note: (i) Not all of the malaria cases and deaths reported here are clinically diagnosed.

Source: WHO, 2005

Malaria parasites (plasmodium vivax, falciparum, malaria and ovale viruses) are transmitted through special agents – the female anopheles mosquito. Ideal breeding grounds are provided by man-made and ecological factors – rainfall, temperature (between 20 and 30 degrees Centigrade) and over 60 per cent humidity. Given these conditions, the mosquito's distribution is confined to tropical and sub-tropical zones (Gallup & Sachs, 2001). Of the 150 countries with more than 1 million people in 1995, 44 (29%) currently experience intensive bouts of malarial outbreaks, 35 of which are on the African continent. The average purchasing power parity gross domestic product (GDP) per capita in 1995 for countries prone to malaria was 1526 USD, compared with an average income of 8,268 USD in countries without malaria. Not only are the countries affected by malaria poor, but also their populations are growing. The growth of income per capita between 1965 and 1990 for countries with severe malaria was 0.4 per cent per year, whereas average growth in other countries was 2.3 per cent. It is also in these countries that the livelihoods of people depend on agriculture and forest-based pursuits. It is this traditional relationship between the environment and humans that has increased exposure to malaria.

Although secondary data is available from various government records worldwide, growing interest in mapping the spatial distribution and variability of malarial risk can be observed in the recent years. Briet et al. (2003) made such an attempt at the national level for Sri Lanka, illustrating considerable variations on the island, with the cases of malaria showing a seasonal peak at the beginning of the year in the north, with a second peak around June in the south. Such mapping exercises played a major role in assessing the risk of malaria in Sri Lanka after the 2004 Tsunami (Briet et al., 2005). The ability to understand and map malarial variability in Malawi helped Kazembe et al. (2006) to identify several determinants of risk, the availability of health services and accessibility and the health-seeking behaviour of the population. Combining spatial information with household surveys, Brooker et al. (2004) mapped the clustering effects of malaria in western Kenya to identify risk factors associated with households in the region. Simple GIS mapping by plotting prevalence has been useful in defining and monitoring risk areas for water-transmitted diseases in Africa under the Mapping Malaria Risk in Africa (Kleinschmidt et al., 2001; Gemperli et al., 2006) and Sri Lanka (Briet et al., 2003; Briet et al., 2005; Scotch et al., 2006) initiatives. Rahman et al. (2006a) also attempted to correlate epidemiologic data with satellite-based vegetation health indices in order to analyse malarial cases in Bangladesh, while mapping coupled with Bayesian spatial analysis has helped in identifying high prevalence areas in a heterogeneous and unknown environment, and therefore direct programmes and resources accordingly (Antunes et al., 2002; Kandala et al., 2004; Clements et al., 2006). These time-series and spatial data analyses offer important insights for health policy planners, travellers and health professionals.

While malaria can be attributed to many environmental factors, two main activities increase the risk to human health: agriculture and deforestation. Agricultural systems have long been associated with ill-health tied to water-related diseases. Changes in the distribution and availability of water through storage (such as dams), irrigation, stream diversion, land use practices and the application of fertilizers, for instance, have been major anthropogenic drivers. Technology matters in the way the environment is affected, making it conducive for malarial mosquitoes (Konradsen et al., 2004). A comprehensive review of studies that assessed the impact of irrigation and dam building on malaria incidence shows a maximum of 848.3 million people living in the close vicinity of irrigation systems and 19.9 million near large dam sites worldwide (Keiser et al., 2005). Although these irrigation systems are home to malaria parasites, the authors argue that transmission of the disease depends on the epidemiological setting, socio-economic factors, vector management and the health-seeking behaviour of the population. In addition to irrigation systems, there is an increasing realisation that agricultural practices, particularly tropical rice irrigation systems, influence malarial mosquitoes and thereby pose a very real danger to human health. Tyagi (2004) demonstrates the resurgence of malaria in the Thar Desert in north-western India, primarily due to extensive canal irrigation systems, under the Indira Gandhi Nahar Pariyojana (IGNP), which have altered the desert environment. Nearly all epidemics have come about as a consequence of the progression of the canal irrigation work. Prior to this intervention, a particular form of mosquito, *Anopheles stephensi*, was prevalent exclusively in households and community-based underground reservoirs, and transmitted malaria at a low level. However, the introduction of IGNP in the 1980s changed the cropping pattern of rice cultivation, increasing the retention of high surface moisture, so excessive canalisation coupled with the rampant mismanagement of irrigation water attracted *Plasmodium-falciparum*-dominated malaria in the region. Such positive correlations between rice cultivation and malaria episodes are widely contrasted by several studies. Henry et al. (2003) reveal how the prevalence or incidence of malaria is less in irrigated-rice growing areas compared to neighbouring areas without irrigated rice cultivation. However, Ijumba and Lindsay (2001) reveal that in regions such as desert fringes and African highlands, irrigation can lead to an increase of malaria. This is not the case for sub-Saharan Africa, though, where irrigation has little impact on malaria transmission. Sissoko et al. (2004) reveal that malarial prevalence is higher (47%) in villages without irrigated rice farming compared to a lower proportion (34%) in villages with irrigated rice farming. This compares with a study by Ijumba et al. (2001) in northern Tanzania, where a higher incidence was reported in non-irrigated villages. These authors attribute the lower incidence in rice-irrigated farming to a number of factors. First, irrigation communities have greater wealth created by these schemes, which enables them to have better access to improved health care. Also, they make greater use of bed nets and the perennial transmission of the malarial virus may have improved the immune statuses of people in the irrigated zone. In contrast, Afrane et al. (2004) attempt to verify that the role of irrigation in agriculture triggers the higher presence of adult malarial mosquitoes (Anopheles) in urban and peri-urban locations, compared to non-agricultural urban locations. Mutero et al. (2004a, 2004b) attribute the role of livestock and application of ammonium sulphate fertiliser to an increased larval population of malarial mosquitoes in Kenya. De Plaen et al. (2004) argue that although vector densities, host-vector contacts and biological resistance to the parasite can influence malaria, pathology can also be influenced by protective behaviours and the rapidity of reaction to initial symptoms. Their study in northern Cote d'Ivoire reveals that socio-economic transformation and gender repositioning, induced or facilitated by the intensification of low land rice cultivation (double cropping), make women and children more vulnerable to malarial diseases. This 'paddies paradox' calls for examining the socio-economic determinants of agriculture and its linkages with malaria.

Tropical and sub-tropical zones have high population densities and are also the home for the world's poorest people. Increasing population and inadequate space often lead to high rates of forest clearing and degradation to meet the growing demand for food. The mean annual rate of deforestation is particularly high in south-eastern Asia compared to Africa and Latin America (Guerra at al., 2006). A study by Vittor et al. (2006) claimed that deforestation has increased the biting rate of *Anopheles Darlingi* 278 times more than the rate determined for areas that are predominantly forested. Malarial rates in the Peruvian Amazon have soared dramatically in recent years, jumping from a few hundred cases in 1992 to more than 120,000 cases, or over a third of the population, by 1997. In India, 8 per cent of the tribal population contribute to about 30 per cent of malarial cases, of which more than 60 per cent are caused by *Plasmodium-falciparum*. This group of people also contributes about 75 per cent of all malarial deaths. There is growing evidence of this juxtaposition of poverty, deforestation and malaria. Singh et al. (2003) show in their study in the forest fringe area of Madhya Pradesh an increase in the incidence of malaria from 0.31 per 1000 in 1990 to 6.75 per 1000 in 2000. Many of these people lead a primitive lifestyle in a remote location close to thick forest, with poorly ventilated housing, scant clothing, the sheltering of animals in the house and poor working conditions. Pattanayak et al. (2003) identify six different pathways through which deforestation can affect malaria infection and disease: (i) Offering a conducive environment for the vector; (ii) Increasing the rate of mosquito growth, its frequency of blood feeding and incubation of the parasite; (iii) Beginning for a variety of land use changes; (iv) Exposure of migrants with lower immunity; (v) Its impact on the climate and (vi) Helping the mosquitoes to become resistant to pesticides. While deforestation does provide the right climate and ecology for malarial mosquitoes, several socio-economic factors are also involved.

Recent decades have seen the unprecedented increase of urban population. It is estimated that, by 2015, 80 per cent of the world's population will live in the cities of developing countries. While many developed nations have rapidly urbanised and are growing at only less than one per cent annually, urbanisation in the developing world is taking place at a rapid pace. Sub-Saharan Africa has the highest growth at 4.58 per cent, followed by South-Eastern Asia (3.82%), Eastern Asia (3.39%), Western Asia (2.96%), Southern Asia (2.89%) and Northern Africa (2.48%). Asia and Africa will continue to dominate global urban growth until 2030, with Asia alone accounting for more than half of the world's urban population. This rapid urbanisation is unable to match the health infrastructure and civic amenities, therefore leading to the rise of communicable diseases such as malaria. Once confined to rural areas, urban malaria (the vector *Anopheles Stephensi*) has gained prominence through the migration of once rural people into squatter settlements. Wells, overhead tanks, cisterns, water logging and stored water are conducive for breeding the malarial vector in urban centres. Urban malaria in India accounts for about 12-15 per cent of the cases (Sharma, 1999). In Sub-Saharan Africa, it is a major health problem and is likely to increase in importance, unless addressed (Warren et al., 1999; Donnelly et al., 2005). Based on a meta-analysis of entomological inoculation rates (EIR), Robert et al. (2003) revealed that the magnitude of urban malaria was lower than in rural areas in Sub-Saharan Africa; however, no major variations were reported between peri-urban and rural environments. Urban environments influence the transmission of malaria through changes in land use and demography, variations in the quality of water and socio-economic differences amongst the urban population (Robert et al., 2003). The incidence of malaria is also likely to increase with climate change; because of the dependence of vectors and pathogens on climatic factors, they are expected to change in distribution and intensity. Examining the influence of climate change on malarial incidence in the State of Karnataka, India, Reid (2000) reveals a significant correlation between malaria rates and climatic variables. In essence, malaria is said to infect poor populations in rural, peri-urban and urban environments.

Looking at global figures from different countries, Gallup and Sachs (2001) argue that malaria creates an economic burden on society. Many of the countries confirm the relationship between malaria and economic growth. Taking into account initial poverty, economic policy, tropical location and life expectancy, among other factors, the authors demonstrate that countries with intensive malarial incidence grew by only 1.3 per cent, but with a 10 per cent reduction in incidence, there was a 0.3 per cent increase in economic growth. Therefore, addressing malaria can result in higher economic growth in countries. Following on from this study, Laxminarayan (2004) demonstrated a reduction in malaria through government-financed control programmes, which could contribute to higher household income for all households in Vietnam. Empirically, a reduction in malaria cases of 60 per cent during the 1990s led to an increase of 1.8 per cent in annual household consumption. Efforts to reduce malaria require an increase in the household income of women, as well as poverty reducing measures. While malarial incidence, the climate and its economic burden at global level seem to be closely linked, strong spatial heterogeneity has been reported at regional level. Mapping malarial distribution in West Africa, Kleinschmidt et al. (2001) reported strong variation due to socio-economic development. A similar result was revealed by Gemperli et al. (2006) for West and Central Africa. Malaney et al. (2004) contrasted such macro estimates through microeconomic studies that found a considerably smaller impact (less than 1%) of annual per capita gross domestic product. This large gap emphasises the need to examine the magnitude of the linkage between malaria and poverty.

Reviewing the literature, Worrall et al. (2005) found mixed evidence on the links between malarial incidence and its relationships with socio-economic status. Many of these studies used different measures of poverty and ways of defining malarial incidence. Similar findings were reported by Malaney et al. (2004), who argued that although correlations between malaria and poverty were apparent, the nature of the linkages in terms of directions and mechanisms of causation was less so, and different methodological approaches provided widely divergent perspectives concerning the impact of the disease. These approaches to assessing linkage have been contrasted with the need to understand the socio-cultural context, as it is socio-cultural factors that affect the biomedical burden of malaria (Jones & Williams, 2004). The authors argue that burden is a social construct, as those households with the least amount of social influence and power, the socially vulnerable within a society, share a larger burden of disease, no matter how disease burden is measured. They identify socio-economic differentials in accessing malaria interventions, thereby increasing the vulnerability of the poorest.

Epidemiological studies in areas of high malaria transmission in Africa and Southeast Asia indicate an age-dependent development of protective immunity against the malarial virus. In endemic African countries, malaria accounts for 25-35 per cent of outpatient visits, 20-45 per cent of hospital admissions and 15-35 per cent of hospital deaths, imposing a great burden on already fragile health care systems. The ability of the female anopheles mosquito to transmit the parasite to humans depends on the recipients' immune systems. Examining spleen rates, and supported by data on malaria parasite prevalence and malaria incidence, Sharma et al. (2004) revealed a decrease in prevalence and incidence with an increase in age. Beyond five years of age, active immunity develops with increasing age. Furthermore, transmission is influenced by intensity and seasonality. The relative immunity of infants to malaria has been attributed to maternal immunity, a milk diet, low attack rate (due to low attractiveness or low exposure) and the persistence of foetal haemoglobin, which is unfavourable for the development of *p.falciparum*. However, children between the ages of one and five, and pregnant women are more susceptible to malarial infection (Sharma et al., 2004), which has been a major cause of anaemia among children and pregnant women, low birth weight, premature birth and infant mortality. These groups are also more vulnerable to morbidity and mortality due to malaria. In areas where the intensity of the virus is highly endemic, such as Tanzania, the prevalence of *p.falciparum* parasite has decreased gradually over the years, with an abrupt drop in the risk of malarial fever. In the meantime, in areas of low to medium transmission, parasitic prevalence is very low during the summer months. Nutritional status plays a major role in addressing malaria, too. Caulfield et al. (2004) argued that nutritional deficiencies (such as a lack of vitamin A, zinc, iron, folate and other micronutrients) double the risk of malaria deaths in children. This relationship is further corroborated by Friedman et al. (2005), who argued that protein-energy malnutrition places children at higher risk of malaria-related morbidity.

The review demonstrates the growing awareness among national and international agencies that regularly collect primary and secondary information on water-related diseases at regional and national scales. This has helped to understand the spatial and temporal distribution of these diseases. However, application for the process of decision-making has been limited, in spite of advancements in spatial analytical technology (such as geographic information systems, remote sensing and statistical tools) that could be used to understand the magnitude of the problem and to develop risk management strategies (as experimented on in Sri Lanka and Africa for malaria).

Opposed to a curative approach in the past, new research studies now focus on preventive approaches (through development interventions and changing individual behaviours). In the process, they have discovered that socio-economic, cultural, man-made intervention (agriculture, urbanisation), human metabolism and institutional factors playing a dominant role in constraining access to safe water supply and adequate sanitation. This is complicated by the rapid evolution of pathogens as they interact with socio-ecology. The evolutionary 'trial and error' approach of pathogens not only defeats the most carefully thought-out human defence strategies, but also gives rise to new human pathogens, typically known as *zoonosis*, evolving when non-human viruses cross the species barrier (Woolhouse, 2002). The emergence and re-emergence of infectious diseases illustrate the intimate intertwining of disease dynamics with socio-political, economic, ecological and demographic change (Bloom et al., 2007), which confronts contemporary stable institutions and standard health interventions. This situation is further aggravated by differences in perceptions on the magnitude of these diseases.

National and international agencies portray malaria and diarrhoea as two of the deadliest diseases, and therefore call for adequate water supply and sanitation to prevent their spread and incidence (UNDP, 2006; WHO, 2010). Okeke and Okafor (2008) revealed many of the people in Africa perceive diarrhoea and malaria as a 'common' illness. Differences are also notable on the causes of these diseases; for instance, Sommerfeld et al. (2002) note that people believe etiological factors such as humidity and exposure to rain and cold are causative factors influencing malaria, in contrast to vectors and pathogens that are waterborne. More interesting is that people always administer home remedies as a first option, seeking formal health care only as a last resort. In fact, the importance of nutrition is underplayed given the socio-economic differences and its spatial distribution, especially for the poor, pregnant women and children. These differences in perception and the important role of nutrition often question the investment in the most powerful preventive medicine to overcome water-transmitted diseases.

2.2 Agriculture and Human Health – Role of Geogenic Pollution

Naturally occurring minerals can be found in rocks, soil, water and in biota. They are essential for human well-being, but can be toxic when they exceed a certain threshold level. There are about 20 or more common elements in nature that have been identified as potential risks to human health. Of these, fluoride, arsenic and nitrate are the most common. The erosion of these elements from their natural environment, partly induced by agriculture (exploitation of groundwater and the application of fertilisers), has led to entry into the human food chain, threatening many lives. The use of pesticides is also of growing concern in many developing countries, as many are assumed to have entered the human lifecycle. The Centre for Science and Environment (2005a) drew alarming attention to the concentration of pesticides such as organochlorines and organophosphates, which exceed desirable WHO standards. To make the matters worse, the increasing use of fertilisers (nitrogen, phosphate and potassium) is having adverse impacts on water resources (Bhatnagar & Sharma, 2002). The most common process through which these pollutants affect human health is either through food consumption or from exposure to water. Though precise data is lacking, estimates indicate that about 200 million people have been affected by the dental disease fluorosis, while more than 100 million are affected by arseniosis. Excess fluoride, arsenic and nitrate in drinking water have caused serious public health problems worldwide. This section examines arsenic and fluoride and their influence on human health in more detail.

2.2.1 Arsenic Pollution

Groundwater is one of the major sources of water for domestic, agricultural and industrial uses in many parts of the world. However, the presence of arsenic in groundwater above the permissible limit (0.01 mg/L) has been reported across continents and is acknowledged as a 'major public health issue', and arsenic contaminations have been reported all over the world (Mukherjee et al., 2006). Exposure to arsenic takes place through drinking from natural water sources, contamination through industrial pollution and through the consumption of food and beverages. While the presence of arsenic has been reported widely across the world, there is no systematic assessment of its presence in geological form. Scattered publications on arsenic contamination in the Ganges-Brahmaputra-Meghna deltaic regions (hereafter referred to as 'the deltaic region') spread across West Bengal, India and Bangladesh, offer a good case for examining arsenic and water management in the region. The deltaic region is of concern due to arsenic contamination, local pollution and a highly dense population[3]. A detailed survey (Chowdhury et al., 2000) of alluvial aquifers in West Bengal (India) and Bangladesh has revealed that 80 and 43 million people are affected by arsenic pollution, respectively. Here, arsenic levels in groundwater stand at more than 0.50 mg/litre[4]. Datta and Kaul (1976) reported the presence of arsenic in groundwater of the

[3] Studies reveal the presence of arsenic in groundwater as far apart as Nepal and he states of Chandigarh and Chhattisgarh in India.

[4] An additional 13 million have been reported in the western states of United States America, although an arsenic exposure of 0.01 mg/L is less severe than in the Indo-Gangetic Plains.

Union Territory of Chandigarh and its surrounding Ganges Plain. Shrestha et al. (2003), examining 15,000 tube wells in the Terai region, found about 30 per cent of them contaminated, with the presence of arsenic placing half a million people at risk. Chakraborthi et al. (2003) identified arsenic toxicity in the middle of the Ganga Plain of Bihar. However, distribution of arsenic cannot be generalised across the basin. Acharya and Shah (2006) argued that arsenic contamination in the middle-lower Ganga Plain was restricted to aquifers in the newer (Holocene) alluvium occurring in narrow entrenched channels in the floodplain. Its distribution is isolated but spread out across the Indo-Gangetic Plains. The presence of arsenic has also been reported in other basins. Acharya et al. (2000) and Saha et al. (1997) identified the poison's source as the Chotanagpur Rajmahal Highlands, from where it was deposited in sluggish, meandering streams under reducing conditions. Furthermore, Acharya and Shah (2007) identified the presence of arsenic in groundwater in the Damodar delta and east of the Bhagirathi River. Concentrations of arsenic have even been reported as far as the state of Chhattisgarh, further away from the Ganges basin.

In the past decade, arsenic has emerged as a major health risk in the deltaic region, leading to mass poisoning (Smith et al., 2000). A number of questions remain unanswered regarding this disaster. How has arsenic emerged as a major health risk now, and more prominently than ever before? How does this impact on human health? What sections of society can be classed as the most deprived? What mitigation measures are adopted by public and private agencies? What challenges exist for policy researchers?

Safe Drinking Water Option - Emergence of Mass Poisoning

Prior to the 1970s, people in this low-lying deltaic region depended to a large extent on ponds and rivers as their main source of water supply. This water became increasingly polluted, largely because of poor sewerage systems and industrial plants frequently dumping waste into the surface water. Pollution and contamination led to various health problems such as cholera, a high incidence of diarrhoea and other water-related diseases. To combat this problem, the British Geological Society (BGS) was invited to examine alternative water sources (namely tube wells) in the region. The BGS recommended groundwater as the safest and cheapest option. Tube wells used to be a perfect development tool – a cheap and effective technology, status symbol and privately owned resource (Black 1990). The expansion of tube wells was accompanied by financial aid from UNICEF after the independence of Bangladesh in 1971, helping the country to make rapid progress in water supply, sanitation and irrigation. It is estimated that about 97 per cent of the population now has access to safe water through the installation of an estimated 3 million hand pumps and tube wells (Rahman et al., 2003). About a third of this provision has been provided by the government, in cooperation with UNICEF, while the rest is privately owned. The result of this intervention is a rapid rise in total area under irrigation coverage from 1.52 million hectares in 1982-83 to 3.79 million in 1996-97. This increase is largely attributed to the installation of different types of shallow tube wells. According to the National Minor Irrigation Census 1996-97, a total of 629,834 shallow tube wells, 25,210 deep tube wells and 210 force mode tube wells were being used for irrigation in Bangladesh. The proportion of irrigation water drawn from groundwater has changed significantly, too. The contribution of groundwater in relation to the total irrigated area increased from 41 per cent in 1982/83 to 71 per cent in 1996/97 and to over 75 per cent in 2001. The situation in India is similar. Sarkar (2007) shows a 575 per cent increase in groundwater irrigation between 1970 and 1990, with the density of groundwater irrigation increasing from 298 to 952 wells per square kilometre. In districts affected by arsenic, 75 per cent of the irrigation is provided by groundwater.

This change towards groundwater as the main source of drinking water and irrigation has neither reduced waterborne diseases nor provided safe drinking water options for the people. WSP-SA reports (2005) show that mortality due to waterborne diseases was greater (120,000 to 200,000 people per year) than mortality resulting from arsenic contamination (20,000 to 40,000 per person per year). Biswas and Adank (2004) argued that although in their study the coverage of safe drinking water seemed to be impressive, the actual coverage was lower in reality due to arsenic poisoning in groundwater. In turn, this led to the exposure of millions of people to arsenic, resulting in mass poisoning.

Political Economy of Arsenic-Groundwater Dynamics

While arsenic is a naturally occurring mineral, its presence in groundwater aquifers has been politically contested among hydro-geologists. One group of hydrogeologists (Nickson et al., 1998; 2000; McArthur et al., 2004) argues that the mechanism of arsenic release into groundwater is a natural process, thereby justifying the stand taken by the British Geological Society (BGS) in the Sutradar versus NERC case, whereby arsenic is a naturally occurring mineral in the region and not influenced by the excessive extraction of groundwater. The authors show that arsenic is released when arsenic-rich iron oxyhydroxides are reduced in anoxic groundwater, a process that solubilises iron and its absorbed load and increases bicarbonate concentration (Chowdhury et al., 2000). The process is assumed to be driven by natural organic matter buried in sediments (McArthur et al., 2004), and not by excessive pumping of groundwater, as claimed by Binod Sutradar in his case against BGS. This was expected, as these studies were financially support by NERC and DfID (UK government funding agencies) (Nickson et al., 2000 part funding; McArthur et al., 2004 part funding).

In contrast, the second group of hydrogeologists (Harvey et al., 2002; 2006; Bridge & Husain, 2007; Klump et al., 2006) argues that arsenic release is not a natural process, but is instead accelerated by the excessive pumping of groundwater. The authors in this group reveal that the elevated presence of arsenic in aquifers is caused by the desorption of arsenic solids accompanying the influx of fresh, labile, carbon-laden recharge water that is associated with rapid aquifer recharge resulting from extensive irrigation pumping over the last 25 years. Bridge and Hussain (2007) argue that dams and barrages constructed in India have reduced groundwater flow in the Ganges valley, which has subsequently exposed deltaic sediments (consisting of arsenopyrite) to oxidation, leading to arsenic presence in groundwater in Bangladesh. Studies in India have shown that arsenic contamination from industrial pollutions affects groundwater quality (Guha Mazumdar et al., 1988; Chowdhury et al., 1999), but there are no studies along the Ganges, which has one of the largest concentrations of highly polluted industries (tanneries, iron- and steelworks, to name a few) in the world. This trans-boundary angle to arsenic contamination adds complexity to cause-effect relations present in understanding arsenic and groundwater dynamics.

Unfortunately, these research studies, influenced by aid organisations, are limited in scope. Firstly, the above studies demonstrate the cause-effect relationship between arsenic in sediments and groundwater, but in the process ignore natural and man-made processes (industrial pollution from upstream, agricultural pollution, large-scale irrigation projects and other activities) involved in releasing arsenic. Secondly, the studies do not inform about the interactions of arsenic with other elements before entering water sources. Finally, the diverse views expressed by these studies show the extent of complexity in the release of arsenic as a naturally occurring mineral into water sources as a toxic element, therefore questioning the legitimacy of researchers as objective, consensual, scientific and neutral players in development policies.

While the understanding of arsenic release from sediment into water is inadequate, the understanding of its impact on human health is even fuzzier. Human exposure to arsenic takes place through ingestion, inhalation or skin absorption (Box 3). High doses of arsenic in the human body can cause acute toxic effects including gastrointestinal problems (poor appetite, vomiting, diarrhoea, etc.), disturbance of cardiovascular and nervous system functions (e.g. muscle cramps, heart complaints) or death. The first visible symptoms caused by arsenic concentrations in drinking water are abnormal black-brown skin pigmentation, known as *melanosis*, and hardening of the palms and sores, known as *keratosis*. If arsenic intake continues, skin pigmentation develops further, resulting in white spots that look like raindrops (medically described as *leukomelanosis*). These can subsequently lead to cancer. Arsenic may also attack internal organs without causing any visible external symptoms, making it difficult to recognise their presence. Elevated concentrations in hair, nails, urine and blood can also be indicators of human exposure to arsenic before visible symptoms occur. The symptoms of the disease are called *arsenicosis* and develop when arsenic-contaminated water has been drunk for several years. Long-term exposure to arsenic may lead to problems in kidney and liver functions, and damage to internal organs such as lungs, kidneys, liver and bladder. This can disrupt the peripheral vascular system and lead to gangrene in the legs, known in some places as 'black foot' disease. There is increasing evidence of mortality from cancers of the lung, bladder and kidney in populations exposed to elevated arsenic concentrations in water consumed in various ways. What is more worrying is that many of the health impacts are revealed only after a long period of time, leading to uncertainty in identifying or even predicting possible outcomes.

Box 3
Arsenic in Water and its Effects

Arsenic is a naturally occurring mineral which is present in rocks, soil, water, air and biota. However, excess levels of arsenic are being introduced into water from both natural and man-made sources. As a natural process, it enters water through the dissolving of minerals and ores, and concentration in groundwater is elevated as a result of erosion from local rocks. As a man-made process, it enters water because of groundwater exploitation from industrial effluents and atmospheric pollutants mixing with water sources. Although arsenic exists in both organic (such as seafood, but are eliminated by the human body) and inorganic forms, the inorganic forms are more prevalent in water and are considered far more toxic. Exposure to high levels of toxic arsenic leads to health hazards.

The first visible symptoms caused by arsenic concentrations in drinking water are abnormal black-brown skin pigmentation, known as *melanosis*, and hardening of the palms and sores, known as *keratosis*. If arsenic intake continues, skin pigmentation develops further, resulting in white spots that look like raindrops (medically described as *leukomelanosis*), which can subsequently lead to cancer. Arsenic may also attack internal organs without causing any visible external symptoms, making problems difficult to recognise. Elevated concentrations in hair, nails, urine and blood can also be indicators of human exposure to arsenic before any visible symptoms. Disease symptoms caused by chronic arsenic ingestion are called *arsenicosis* and develop when arsenic-contaminated water has been drunk for several years. Long-term ingestion may lead to problems for kidney and liver function, and then damage internal organs including lungs, kidneys, liver and bladder. This can disrupt the peripheral vascular system, leading to gangrene in the legs, known in some places as 'black foot' disease. There is increasing evidence of mortality from cancers of the lung, bladder and kidney in populations exposed to elevated arsenic concentrations in drinking water.

The health effects following on from arsenic consumption have wide ranging ramifications, but there is still no generally accepted consensus on the constitution of arsenicosis (WSP-SA, 2005). This term is used for skin changes that occur after the chronic ingestion of arsenic. These are the first symptoms to appear in the presence of high concentrations (about 100 μg/l) of arsenic in water, but epidemiological studies have identified cancerous effects even with lower concentrations (below 50 μg/l), including skin cancers and internal cancers (lung, bladder and kidney). Internal cancers account for the most deaths, while skin cancer is less fatal, but only if detected at an early stage. These epidemiological studies[5] primarily examine arsenic entering the human body through ingestion, but arsenic also enters the human body through other channels, such as inhalation and skin absorption. Temporal variation is also reported in the presence of arsenic. There is no adequate information on the relative importance of arsenic intake from sources other than drinking water.

In recent years, extensive use of arsenic-contaminated irrigation water has significantly 'fed' arsenic into food crops. Continued cropping of long-term irrigated soils subjected to arsenic-contaminated groundwater poses significant risks to animal and human health through soil-crop transfer. A study by Meharg & Rahman (2003) demonstrated a significant build up of arsenic levels in paddy fields that had used arsenic-contaminated groundwater for a long

[5] Further, most of these studies examine drinking water on the assumption that daily water intake per person is 2 litres. However, actual consumption of water varies from 3 to 5 litres (WSP-SA, 2005).

period of time. The rice grain grown in these fields had high arsenic concentrations, with three samples exhibiting levels above 1.7 µg/g. A preliminary study (Das et al., 2003) of about 100 samples of food crops, vegetables and freshwater fish indicated the high presence of arsenic in paddy, vegetables and fish depending on arsenic-contaminated water. However, a few studies (Alam et al., 2003) have found no evidence of arsenic in rice grain. There is no current precise assessment of the consequences that concentrations of arsenic in irrigation water would have on agricultural yield and on human health (WSP-SA, 2005).

Arsenic contamination is expected to increase further when cooking and boiling foods in arsenic-contaminated waters (Bae et al., 2002). For example, a study by Roychowdhury et al. (2002) showed that the concentration of arsenic in cooked rice was higher than in raw rice. It is estimated that one person in Bangladesh consumes about 100 µg/ day of arsenic (Naidu, 2001). However, these are rough estimates which may increase with larger samples. Studies explaining the chemical properties and interactions that occur during the cooking process are emerging. These epidemiological studies are still based on simplified assumptions that introduce a number of uncertainties when quantifying the relationship between the concentration of arsenic and knock-on health effects (WSP-SA, 2005).

The vagueness of arsenic impact is widening, with studies examining the demographic dimensions of its impact. Demographic dimensions reveal that adult males are more susceptible than females. The comparison of male and female members from the same households in two villages in Bangladesh illustrate that skin manifestations due to arsenic toxicity are more severe in males (Watanabe et al., 2001a; Rahman et al., 2006b). Similar findings have also been reported in West Bengal (Sarkar, 2007). Exposure across ages reveals that children are more vulnerable to arsenic toxicity than adults. Rahman et al. (2001) observed that more than 90 per cent of the children in their study below 11 years and living in arsenic-affected areas showed elevated levels of the poison in hair and nails. Examining children between newly born and 4 years, Watanabe et al. (2001b) observed that arsenic presence significantly increased with age. Multiple comparisons across different ages (newborn, one, two and three years old) revealed that the youngest group had less arsenic compared to the other three groups. Mothers' exposures to arsenic were prime determinants for infants. For children above four years, arsenic toxicity overlapped with adults, suggesting that exposure of the former was similar to the latter. However, skin manifestations were milder for children than for adults, which may be due to enhanced tolerance levels among children, or reflect their short (cumulative) length of exposure. Unlike adults there was no significant difference among boys and girls. It is notable that individuals exposed since birth or before did not show a higher risk of skin lesions than individuals who were exposed later in life (Rahman, 2006b).

So far, research on the impact of arsenic intake on human health has focused on its effects on socio-demographic spread, but there is limited research examining the role of nutrition in providing immunity to affected people. Mazumder et al. (1998) found in their case study in West Bengal that individuals with 80 per cent standard body weight were more susceptible to chronic arsenic toxicity. Chen et al. (2007) and Mazumdar et al. (1998) identified associations between indicators of general malnourishment and arsenic toxicity. Specifically, Mitra et al. (2004) identified that low intakes of dietary protein could affect arsenic methylation and may have increased arsenic-associated toxicity in 238 individuals from West Bengal. In effect, they called for a higher intake of calcium, animal protein, folate and fibre to reduce toxicity. Similar findings have also been reported among the US population (Steinmaus et al., 2005) and in Bangladesh (Gamble et al., 2005), each calling for an increase in the dietary intake of nutrients.

In view of the threat of arseniosis, various strategies have evolved. The governments of Bangladesh and its neighbouring region, the West Bengal state of India, have come out actively with policy options. The government of Bangladesh started the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) in 1998. This was followed by the National Policy for Arsenic Mitigation-2004 and an implementation plan for arsenic mitigation. The NPAM-2004 recognises public education, technical interventions, medical services and research as necessary for solving arsenic-related problems, and states that these must work in a complementary fashion. In India, the Ministry of Rural Development has proposed to establish an arsenic mitigation centre at Kolkata. The centre is expected to be a referral and documentation facility for all problems related to arsenic contamination. In addition, as part of this initiative, a well-equipped central chemical laboratory at Kolkata and eight district level water testing laboratories in the affected area are proposed to be established. In recent years, many national and international agencies have been involved in arsenic mitigation programmes in both Bangladesh and in the Indian region, but there is no comprehensive or coordinated mitigation programme. Alaerts and Khouri (2003), examining arsenic mitigation strategies and policies in Mexico and Bangladesh, revealed a lack of coordinated and comprehensive programmes for water supply in arsenic-affected regions. While arsenic mitigation programmes are important, they have had to compete with other priorities, namely waterborne diseases and poverty. Based on the estimates of mortality due to diarrhoea accounting for 120,000-200,000 deaths per year, in contrast 20,000-40,000 people per year die due to arsenic poisoning in Bangladesh (WSP-SA, 2005).

Efforts to mitigate arsenic contamination follow the general pattern of adopting a technical quick-fix approach. In Bangladesh and West Bengal, most arsenic mitigation projects follow a similar strategy (Hanchett, 2006), which includes screening of contaminated water sources, awareness creation, identifying alternative water sources and the identification and treatment of arsenicosis. The screening of contaminated water sources depends on measuring the presence of arsenic in water. Two methods are adopted, one using a field testing kit and the other through laboratory chemical analysis. The former method is more qualitative, as it highlights the presence of arsenic and identifies any higher or lower concentration of arsenic than the national standard average. The latter method is quantitative. Bangladesh has recognised large-scale screening of tube wells under its National Arsenic Mitigation Policy, but there is no specification on what measurement constitutes a national average. On the other hand, in West Bengal in India, screening is conducted within a particular laboratory and the consistency measured is assessed between laboratories. The institutional arrangements for screening are based on either a public good approach, where the government in collaboration with NGOs carries out the screening (as in Bangladesh), or on a demand-based screening approach, where the screening of public tube wells is carried out by governments and UNICEF and is the responsibility of the well owner (as in India).

Once the contaminated wells are identified, they are marked with different colours and signs in order to differentiate between safe and unsafe ones. This not only helps to safeguard the people, but also to create awareness of safe water sources. In addition, it proposes to promote the sharing of safe water sources among communities, through a user group approach. There are two technical approaches towards an alternative option to arsenic mitigation. One is to provide an arsenic-free water supply as an alternative to arsenic contaminated water; the second is to provide arsenic removal technologies that can treat contaminated groundwater. The options for the first alternative include hand-dug wells, deep tube wells, pond sand filters or rainwater harvesting. However, these options are limited, expensive and take a long time to install. In contrast, the second option promises a cheap and rapid form of arsenic mitigation and allows rural households to contribute by using their own private hand pumps (see WSP-SA, 2000 for a list of technologies). Unfortunately, these technical quick-fix approaches have been found to be irrelevant in regard to the local social and geological contexts (SOS-Arsenic.net). Pond sand filters have been rejected by the rural population, as they do not work on occasion and most of the ponds are contaminated with biological and chemical contaminants. Deep bore wells have been found to contain saline- and arsenic-contaminated waters due to being excavated in the wrong locations. Dug wells have limited applications, as they are inappropriate in Holocene geology. Furthermore, these instant technical approaches lack integration with complex socio-cultural settings within the community, leading to frequent breakdowns and water contamination above permissible limits (Sarkar, 2007). Most of these mitigation measures lack a public consultation process related to their introduction, adequate technical know-how and adequate referral practices (Hanchett, 2006; Sarkar, 2007).

The identification and treatment of arsenicosis patients are approached in two ways in the region: passive or active. Passive patient identification simply allows individuals to present themselves for treatment, while active patient identification involves going out into the field to examine individuals for signs of arsenic impact. Although arsenic can cause a variety of health-related outcomes, patient identification is based on skin lesion-related symptoms. However, there could be many who have been affected by arsenic-contaminated water, but where only intensive and expensive laboratory testing can identify arsenic influence on their hair, nail and urine samples. Identification and treatment ignore the social isolation of patients, which leads to discrimination within society. Hanchett (2006), Sultana (2006) and Hassan et al. (2005) present widespread social problems associated with arsenic-affected patients and their families, especially women and girls. It is presumed by most people that arsenic-affected people have a contagious disease, so as a consequence many women are unable to get married or, if they are already married, they are divorced by their husbands. Furthermore, children infected with arsenic are not accepted into schools. These reactions, however unfounded they may be, have potential implications for social behaviour (Hanchett, 2006; Dunn, 2007).

In addition to these issues, legal litigations have been attempted. In 2001, Binod Sutradhar, a carpenter from Ramrail in the Brahmanbaria district, along with other victims of arsenic-contaminated water, took on the National Environment Research Council (NERC), a parent body of the British Geological Society (BGS), alleging that the BGS was negligent in its conduct of a pilot research study (to overcome waterborne diseases in the region through use of groundwater as a safe drinking water option) into groundwater movement in central and north-eastern Bangladesh in 1992. The BGS study ignored the presence of arsenic and called for the installation of tube wells as safe and clean drinking water sources for the people in the region. This led the international community, the government of Bangladesh and the government of India to install a large number of tube wells, consequently exposing local people to arsenic contamination. Sadly, the case was dismissed in favour of BGS researchers in July 2006. Lord Hoffman, from the House of Lords, UK, claimed the case was "hopeless" (BBC, 2006), as the BGS researchers had carried out the research 'professionally and competently' (NERC, 2004) and they were not aware of the presence of arsenic. Though considered 'hopeless' by the House of Lords, the case opened up a Pandora's Box of complexity in relation to arsenic pollution.

2.2.2 *Case of Fluoride Contamination*

Fluoride is an essential element for all living beings from a health point of view. It helps in the normal mineralisation of bones and the formation of dental enamel. Fluoride, when consumed beyond its optimal level (more than 0.5 ppm) causes health problems such as dental caries, the inadequate formation of dental enamel and mineral deficiency in bones, especially among children. Higher fluoride concentrations exert negative effects on the course of metabolic processes, and an individual may suffer from skeletal fluorosis, dental fluorosis, non-skeletal manifestations or a combination of the above. The incidence and severity of fluorosis are related to the fluoride content in various components of the environment, of which groundwater is the major danger.

Groundwater with high fluoride levels can be found in large parts of Africa, China, the middle-East and southern Asia (India and Sri Lanka). Water with high levels of fluoride content are mostly found at the feet of high mountains and in areas where the sea has made geological deposits. Known fluoride belts on land include one that stretches from Syria through Jordan, Egypt, Libya, Algeria, Sudan and Kenya, and another that stretches from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China. There are similar belts in the Americas and Japan (WHO, 2007). However, the intensity of the fluorosis problem is most acute in the two most heavily populated countries of the world, China and India. In China, over 26 million were suffering from dental fluorosis and one million people from skeletal fluorosis in 2004 (WHO, 2007). In India, it was affecting more than 66 million people, including 6 million children under 14 years of age, in 2006 (Ayoob & Gupta, 2006).

The impact of fluoride contamination on human health is visible through its effects on dental and skeletal bones. A review of a growing body of literature indicates a well established linkage between dental fluorosis and the concentration of fluoride in water (Ayoob & Gupta, 2006). Studies have observed that children and adolescents aged 8-16 years are more susceptible to dental caries. Examining the prevalence of dental fluorosis among school children across 18 districts in Gujarat, Choubisa (2001) revealed a prevalence of dental fluorosis varying between 2.6 to 33 per cent, with no one affected by skeletal fluorosis. Such high variations were also observed by Susheela (2003) in Haryana, where the prevalence rate of dental fluorosis varied from 13 to 77 per cent. Further, there is no correlation to state that increases or decreases in fluoride cause skeletal fluorosis. Studies found skeletal fluorosis present when fluoride levels in water ranged from 9-13 ppm in Madhya Pradesh (Chakma et al., 2000), while the same kind of fluorosis was reported when water fluoride levels were at 3.3 ppm in Punjab (Jolly, 1968). Similarly, skeletal fluorosis increased from 7.4 to 15.9 per cent in the villages of Rajasthan in reaction to a marginal increase in the fluoride level from 2.5 to 2.6 ppm (Choubisa, 2001). Such wide variations in the occurrences of skeletal fluorosis within the same concentration of fluoride presence call for a detailed examination of other factors that may be detrimental to human health. This has an important bearing in understanding factors such as nutritional status, climate, individual susceptibility and biological response, the duration of fluoride exposure and the amount of dissolved salt in drinking water (Ayoob & Gupta, 2006).

Pandit et al. (1940) observed that nutritional Vitamin C deficiency and poor nutrition in several villages in India had a correlation with skeletal fluorosis. Jolly et al. (1968) also highlighted the importance of calcium in influencing fluorosis in India. They observed that in Punjab skeletal abnormalities were not encountered, as in Andhra Pradesh and Rajasthan, due to more dietary intake of calcium. Further, they reported the prevalence of skeletal fluorosis varying among two villages with the same fluoride contamination. Low levels of fluorosis are associated with the higher total hardness of water (as calcium and magnesium presence has a protective influence). Skeletal fluorosis also occurs where there is no malnutrition and fluoride levels are less than 1.5 ppp. Diesendorf (2003) argued that although most cases of skeletal fluorosis have been reported from tropical countries, there is no basis for assuming that the patients were necessarily malnourished. Observations from China indicate that food contributes significantly to total fluoride intake (Liang et al., 1997). Rao and Mahajan (1991) reported that average fluoride content in 32 locally grown agricultural crops in Andhra Pradesh ranged between 0.2 to 11.0 mg/kg. This only suggests the importance of nutritional intake on people vulnerable to fluorosis.

2.2.3 Summary

Geogenic contamination due to intensive agriculture presents a potential threat to populations living in intensive agrarian economies. While the scattered presence of geogenic pollutants has been reported worldwide, there is no systematic mapping of its presence in geological form or in groundwater, other than in independent research studies. Moreover, no comprehensive attempt has been made to understand activities contributing to the entry of geogenic minerals into water sources and its influence on human health. In these regions, the approach of providing safe access to water supply is virtually meaningless, as the available surface and groundwater are polluted. In some cases, the pollutants are undetectable using standard water testing parameters. The 'safe haven' for access to safe water supply only exists in the form of rainwater, which certainly cannot meet all of a community's needs. Although there is vague reference to dug wells as 'safe havens,' comprehensive attempts to understand their distribution remain unexplored. Technologies to treat geogenic-contaminated water are still naive and are available more in laboratories than in the field. Therefore, in order to be socially and economically relevant, and to institutionalise improvements, innovations are required beyond the current technical quick-fix approaches.

The consumption of geogenic pollutants is recognised to have both short- and long-term impacts on human health, but it is only the short-term impacts that are detected. Research focusing on the risk assessment and management of long-term impact could offer measures to address geogenic pollution. Second, while geogenic pollution affects whole populations living in a region, its worst impacts have often been on deprived sections of society such as the poor, (pregnant) women and children, which is still unexplained by the literature (there is only a vague reference to illustrate that villages affected by these contaminations live in very poor conditions (Chowdhury et al., 2000)). The economic consequences of illness deserve attention, as many who are affected lose employment due to weakness or because of discrimination. Though geogenic contamination impacts on human health, the role of the human metabolism (or interaction with nutritional status and other health-related diseases and disorders) is not adequately understood. In addition, the social consequences of these diseases or disorders are of concern. Women and girls particularly, but also entire families, suffering from the impact are often socially discriminated against – adults lose their jobs, girls are hindered from marrying, married women are betrayed by their husbands and children are deprived of an education. There is no comprehensive study to understand the experience, burdens and social factors influencing the population affected by geogenic minerals, or of any existing institutional arrangements in India and Bangladesh's arsenic-affected regions for developing adequate mitigation measures. Such cross-border studies help in understanding the political economy of arsenic contamination, failures of existing institutional arrangements and means to build their capacity to address arsenic contamination. As the problem transcends international boundaries (India and Bangladesh), there should be a policy of cross-learning between these neighbours in order to promote closer ties to exploring these environmentally-related problems.

2.3 Industrialisation and Human Health: Man-made Disasters in Waiting

While the concern for the adequate provision of water supply and sanitation in many urban and rural areas is growing, there is equal concern towards addressing wastewater generated by both industrial and domestic effluents that affects urban areas and their hinterlands. Nearly half the world's population now lives in urban settlements. It is estimated that by 2015, 80 per cent of the world's population will be living in the cities of developing countries. Sub-Saharan Africa has the highest growth of 4.58 per cent, followed by South-Eastern Asia (3.82%), Eastern Asia (3.39%), Western Asia (2.96%), Southern Asia (2.89%) and Northern Africa (2.48%). Asia and Africa will continue to dominate global urban growth until 2030, with Asia alone accounting for more than half the world's urban population. These burgeoning patterns of growth have not only created a major challenge for meeting the growing demand for water supply, sanitation and food, but also have increased the call for disposing of proportional wastewater that affects urban and peri-urban regions and contributes to the wide spread of ecological problems in and around cities.

In many developing countries domestic wastewater remains untreated. The UNDP (2006:39-40) revealed that less than 14 per cent of domestic wastewater gets treated in Latin America. China, though, has a strong record of expanding access to water, but it generates domestic and industrial wastewater at the same time. In China, 16 cities that have more than half a million of population have no wastewater treatment facilities. Nationally, less than 20 per cent of municipal waste receives any treatment, forcing households to boil their water before drinking. Improved sanitation without proper disposal in Manila, Philippines, poses serious public health hazards, as less than 4 per cent of Metropolitan Manila's population is connected to the sewer network, resulting in the River Pasig being one of the world's most polluted rivers. In Pakistan, waterborne diseases are common, as more than 40 per cent of water supplied is unfiltered and 60 per cent of effluents remain untreated. In the first half of 2006, major outbreaks of waterborne disease epidemics swept Faisalabad, Lahore, Karachi and Peshawar as a result of sewage leakage and industrial waste seeping into drinking water through damaged pipes. This led the government to finance more than 6,000 water filtration plants. In India, with more than 50 per cent of the urban population living in squats, only about 35 per cent of the wastewater from class I cities (populations more than 100,000) and class II towns (populations between 50,000 and 100,000) is treated, posing potential hazards to the human population (Bhardwaj, 2005). As the cities grow, so do their slum populations. According to the UN-Habitat report (2006), 31 per cent of the total urban population in the world and 41 per cent in the developing world live in slums. Variations do exist; for instance, the slum population in sub-Saharan Africa accounts for over 70 per cent, while in southern Asia it is 57.4 per cent of the total population. Slums are increasing at a rapid rate in these regions, too. While more than 70 per cent of the urban population is provided with access to sanitation, improper housing and inadequate sanitation coverage leads many slum dwellers having no choice but to defecate in the open. This causes contamination of water and land resources within cities and their periphery, leading to diffuse sources of pollution.

Urbanisation, coupled with globalisation, has led to fairly consistent high growth rates since the 1990s and to an increase in the overall levels of national income. There has been an increase in industrial investment, with the expanded growth of new economic sectors, particularly in emerging Asia (ADB, 1999). Estimates in this region reveal 16 times suspended solids, 17 times TDS and 18 times biological pollution loading over the coming decades. What is more worrying is that these cities also contribute disproportionately to the national economies. Bangkok contributes 40 per cent to Thailand's gross national product, but has just 12 per cent of the nation's population. As a whole, cities in the developing world account for 50-80 per cent of their nation's respective gross national product. Sectoral pictures in China and India reveal decreasing contributions of agriculture to the GDP from 1980 to 2000, while recording notable increases in the industrial and service sectors (Table 5).

Table 5: Sectoral Break-up of Gross Domestic Product in China and India (%)

	1980	**1990**	**2000**
Agriculture			
China	30.1	27.1	15.9
India	42.8	31	28
Industry			
China	48.5	41.6	50.9
India	21.9	28	26
Services			
China	21.4	31.3	33.2
India	35.3	41	46

Source: Compiled from Guruswamy et al., 2006

These unprecedented levels of urbanisation and industrialisation are associated with ever-growing pressure on the quality of water resources, which if not improved places human health at risk. Official estimates (PRC, 2004) of water quality across seven major rivers in China indicate that about 60 per cent of the water falls under grade iv, grade v and markers inferior to these (Annexure 2). These water quality grades are inadequate for human consumption (i.e. the water can be mainly only be used for industrial and agricultural activities). The most polluted rivers in China are the Liaoche, Huaihe, Yellow Songhuajiang and Haihe, in which have been found ammonia nitrogen, biological oxygen demand (BOD), permanganate index and petroleum compounds beyond permissible limits. Of the total lakes and reservoirs examine in China more than 70 per cent were at grade iv and above, with nitrogen and phosphorous being the main polluters. Information on groundwater is not available for comparison. In India, out of 17 major rivers, ten are considered grossly polluted on specific stretches, with organic and bacterial pollution dominating in these stretches and making all water unfit for human consumption (Bhardwaj, 2005).

However, the assessment of risk is constrained by a lack of reliable and comparable official water quality information, especially in developing countries. For instance, water quality is assessed differently in both India and China (Annexure 2 & 3). Although there is commonality among the variables used to measure water quality (biological oxygen demand (BOD), dissolved oxygen (DO), acidity (pH), total phosphorous, nitrates and faecal coliform), there are variations in the parameters and acceptable limits, depending on contextual factors. In both of these countries, measuring toxic metals, pesticides and other micro pollutants is still limited. Even if measured, they vary, as the detection limits of instruments vary from laboratory to laboratory. Groundwater quality is generally poor, due mainly to natural reasons and the excessive withdrawal of water, insanitary conditions in rural and urban areas and an increased application of fertilisers. However, these official estimates do not reveal a complete picture on water quality, as many parameters such as those pertaining to pesticides and heavy metals remain unexamined, or are only examined occasionally in selected stretches of the rivers and wells.

Agriculture, though, remains the major consumer of water. In recent years, industries have emerged as a major source of demand for water in fast growing economies such as China and India. In China, between 1980 and 2002, water use in industry increased from 46 to 114 billion cubic metres, which is an increase of 250 per cent in two decades (Shalizi, 2006). The increasing demand for water also proportionately increases wastewater discharge. Of the total industrial discharge, six sectors (pulp/paper, food, chemicals, textiles, tanning and mining) account for 87 per cent of total industrial chemical oxygen demand (COD) load, but only 27 per cent of gross industrial output value. Although toxic content data for wastewater discharge is not available, estimates reveal the figure to be about 1.7 per cent of total COD loads, representing a significant threat to public health and aquatic systems. In India, based on the Central Pollution Control Board's (CPCB) notified industries, iron and steel were the highest water polluters, contributing 87 per cent of the total water pollution load. They were also the highest in terms of toxicity (Table 6). In terms of pollution load, leather industries (that officially report) are in second place, leaving large informal players who remain unaccounted for in official records. The leather industry is also one of the major contributors to total exports in India. The Dyes intermediaries though contribute just 1 per cent of the total pollutants, being small-in-scale and home based there are number of them who unaccounted in official statistics. Many of these are silent polluters, in many places clustering around urban centres such as Kanpur, Tiruppur, and Surat. The situation in neighbouring countries is no different. Although data is scarce, a UNIDO report claims industrial pollution in Pakistan to be increasing at a rapid pace and thus having a significant impact on health and productivity (Aftab et al., 2000). Most Pakistani industries are located around major cities and are increasingly polluting streams, rivers and the Arabian Sea through untreated toxic waste. Major industrial contributors are the pulp and paper, chemical, petrochemical, tannery, refining, metalworking, food processing and textile industries. Of these, the textile and leather industries are the worst polluting industries in Pakistan (Khan et al., 2001:384).

Table 6: Relative Share of Total Pollution Among Cpcb-Notified Industries in India

Industry	% of Total Water Pollution Load	% of Toxic Pollution Load
Iron & Steel	87.4	39
Pulp & Paper	4.6	6.2
Aluminium	2.5	7.6
Sugar	1.6	1.2
Copper	0.9	2.6
Zinc	0.4	1.2
Oil Refinery	0.2	7.8
Pesticide	0.1	5.8
Leather	0.1	14.2
Dyes Intermediaries	Negligible	1.1
Fertiliser	Negligible	1.1

Source: Pandey, 2005.

2.3.1 Alarming Small-Scale Polluting Industries

Small-scale industries drive the fast growing economies of the developing world, such as Ghana, Brazil, China and India. In Ghana, these industries provided employment opportunities for 70 per cent of the total available workforce in urban centres in 1983. In China, these industries, known as Township Village Industrial Enterprises (TVIEs), a subset of township village enterprises (enterprises established outside of urban areas, with more than 50 per cent of investment from rural collective organisations or farmers), accounted for 42 per cent of the total national industrial output in 1994 (Wu et al., 1999). Although there was an increase in wastewater and COD between 1989-1995, a decrease is notable from 1994 (Table 7), partly due to economic factors (economic slowdown and industrial restructuring), but also to increasing regulatory effectiveness and the application of emergency measures in response to a major pollution incident in the Huai River in 1994. However, in other developing countries, businesses operate as usual. In India, small-scale industries contribute 40 per cent of industrial production and 35 per cent of total exports, and employ about 17 million people in 3.2 industrial units. Of these, engineering plants, paper mills and textile production units are the largest wastewater generators (Table 8). In Pakistan, the textile and leather industries form a large part of informal and small-scale sectors. Textile industries contribute 67 per cent of the export earnings and engage 35 per cent of the labour force, while the leather industry is the second largest export earning sector (ACU, 2005). As of 2003, these two industries contributed US$ 700 million a year to the economy, but has the potential to increase the volume of exports by improving quality and diversification in a different range of products (Bashar, 2003). However, these two industrial units are the most polluting industries in Pakistan. The situation is no different for Bangladesh, which has an estimated 1,176 units that heavily pollute the environment. Of these, pulp and paper, textiles and leather industries are the dominant sources of wastewater pollutants (Table 9). Of these industries, tannery and textile (dyeing industries) industries are examined to understand the linkage between water pollution and its influence on human health.

Table 7: Trend in Industrial Discharge of Wastewater – China

	1989	1995	1997	1998
Wastewater Flows (BcM)				
County and above county owned Enterprises	25	22	19	17
TVIE	3	6	4	3
All industry	28	28	23	20
COD (million tons)				
CAOEs	8	8	7	5
TVIA	2	6	4	3
All industry	10	14	11	8

Source: World Bank (2001: 54).

Table 8: Wastewater Generation by SSIs in selected Industrial Sectors in India

Industry	**Wastewater Generation in (MLD)**
Engineering	2125
Paper and board mills	1087
Textiles	450
Organic chemicals	60
Tanneries	50
Pharmaceuticals	40
Dye and dye intermediaries	32
Sops, paints, varnishes and petrochemicals	10
Edible oil and vanspati	7

Source: Kathuria & Gundimeda, 2001, cited in Maria, 2003

Table 9: Estimated wastewater loads from industries – Bangladesh

Industry	Public (num)	Private (num)	Wastewater discharge m^3/day	Pollution load BOD kg/day
Leather	1	195	15,800	17,600
Textiles	20	482	40,000	26,000
Pulp & paper	4	1	228,000	40,000
Fertilisers	7	1	Na	1748
Urea				323
TSP				16
Ammonium				
Chemicals	1	99		
Soap			1,350	1,200
Glycerin			98	195
Others			Na	na
Pharmaceuticals	2	100	3,500	700
Sugar	12	4	30,000	4,000
Food and fish	-	193		
Biscuits			799	1,670
Shrimps			4,009	4,184
Fish Products			268	81
Fruits & veg.			225	18
Beverages			79	38
Milk products			Na	na
Rubber		25	Na	1,755
Plastics		30	Na	na
Pesticides	1	3	200	na
Distilleries	-	4	-	-
Spirits			945	3,300
Syrup + compounds			693	2,420
Metal finishing/re-rolling	17	67	13,802	na
Cement	1	1	Na	na

Source: Government of the People's Republic of Bangladesh, 2002

Tannery industries

Tanneries are widely encouraged to operate as cottage industries, as they generate employment and earn export revenue for the government. Tanneries belong to the intermediate stage of leather production. These small-scale industries acquire raw hides and skins from slaughter houses, which they then clean and tan using toxic chemicals for the final leather product. The slaughtering and tanning is carried out locally and within residential settlements. Most of the workers engaged in this sector belong to the weaker section of society, and collect, flay and cure hides and skins for the industries. Environmental problems arising at this pre-tanning stage range from collecting carcasses, curing and transporting the hides and skins, and also leaving the carcasses on land. There are two main processes involved in tanning – vegetable and chrome tanning (Box 4), and most of the tanneries use either of these processes.

Box 4

Two Types of Leather Tanning Process

Leather tanning is the process of converting raw hides or the skins of cattle, sheep and pigs into leather. Hides and skins have the ability to absorb tannic acid and other chemical substances that prevent them from decaying, make them resistant to wetting and keep them supple and durable. Tanning is essentially the reaction of collagen fibres in the hide with tannins, chromium, alum or other chemical agents. The most common tanning agents used in the U.S. are trivalent chromium and vegetable tannins extracted from specific tree barks. Alum, syntans (man-made chemicals), formaldehyde, glutaraldehyde and heavy oils are other tanning agents.

There are two process of tanning, namely vegetable tanning and chrome tanning.
Vegetable Tanning: Heavy leathers and sole leathers are produced by the vegetable tanning process, the oldest of any process in use in the leather tanning industry. The hides are first trimmed and soaked to remove salt and other solids and to restore moisture lost during curing. Following the soaking, the hides are fleshed to remove the excess tissue, to impart uniform thickness and to remove muscles or fat adhering to the hide. Hides are then de-haired to ensure that the grain is clean and the hair follicles are free of hair roots. Liming is the most common method of hair removal, but thermal, oxidative and chemical methods also exist. In the vegetable tanning process, the concentration of the tanning materials starts out low and is gradually increased as the tannage proceeds. It usually takes three weeks for the tanning material to penetrate to the centre of the hide. The skins or hides are then wrung and may be cropped or split; heavy hides may be re-tanned and scrubbed. For sole leather, the hides are commonly dipped in vats or drums containing sodium bicarbonate or sulphuric acid for bleaching and removal of surface tannins. Materials such as lignosulfate, corn sugar, oils and specialty chemicals may be added to the leather. The leather is then set out to smooth and dry and may then undergo further finishing steps.

Chrome Tanning: Chrome-tanned leather tends to be softer and more pliable than vegetable-tanned leather, has higher thermal stability, is very stable in water and takes less time to produce than vegetable-tanned leather. Almost all leather made from lighter-weight cattle hides and from the skin of sheep, lambs, goats and pigs is chrome tanned. The first steps of the process (soaking, fleshing, liming/de-hairing, de-liming, bating and pickling) and the drying/finishing steps are essentially the same as in vegetable tanning. However, in chrome tanning, the additional processes of re-tanning, dyeing and fatliquoring are usually performed to produce usable leathers, and a preliminary degreasing step may be necessary when using animal skins, such as sheepskin.

Tanneries use about 30-50,000 litres of water for processing each ton of hide/skin. This is a large volume compared to the average per capita water availability for human settlements in India, estimated at around 135 litres per day. Furthermore, they consume water to process raw leather into a finished product through the application of various chemicals such as lime, sodium carbonate, sodium bicarbonate, common salt, sodium sulphate, chrome sulphate, fat liquors, vegetable oils and dyes. Due to their high demand for water, these industries are located in clusters along river basins. In India, they are clustered in the Gangetic basin in Uttar Pradesh and the West Bengal, Palar and Cauvery river basins in Tamil Nadu. In Bangladesh, more than 90 per cent of the total 270 registered tanneries are huddled around the city of Dhaka (Government of the People's Republic of Bangladesh, 2002). In China, they are distributed along the Aojiang watershed of Zhejiang province, while in Pakistan they are concentrated in Karachi near the coast of the Arabian Sea, northwest of the Indus River Delta.

Tanneries are one of the most polluting industries using toxic treatment methods. Most polluting material in the tanning industry is common salt, which is difficult to get dispose of. It is estimated that for every 10 tons of salted hide and skin processed, 2-3 tons of salt is removed, while another ton of salt is removed while pickling. The process of leather production involves considerable quantities and varieties of pollutants at several stages in the operation, with stages up to the production of wet blue, such as chrome tanning and lining, among the worst (Annexure 4**)**. Tannery waste is characterised by its strong colour (reddish to dull brown), high BOD, high pH and high dissolved solids. The other major chemical constituents of waste from tanneries are sulphide and chromium, which are mixed with water and discharged from tanneries. These waste flows pollute water courses and, if allowed, percolate into the ground, affecting the water table within a radius of 7-8 kilometres. Using toxic chemicals for tanning, it is important to know how much of these are discharged.

Studies have shown that diverse pollutants are used in the leather processing industries, the effects of which are recognised widely worldwide. The Central Pollution Control Board, which is the Indian nodal agency responsible for monitoring water quality on inter-state rivers, along with the State Pollution Control Board, measures water quality in terms of 28 parameters consisting of physiochemical and bacteriological characteristics. Besides this, nine trace metals and 15 pesticides are analysed in selected samples. However, this nodal agency monitors on a monthly or quarterly basis a limited number of organic pollution-related parameters, as well as major cat-ions, anions, other inorganic ions and micro pollutants (Toxic Metals & POPs) once in a year (Bhardwaj, 2005). However, a number of independent research studies have examined selected water quality parameters. Khwaja et al. (2001) monitored the physiochemical characteristics of tannery wastewater from the Kanpur industrial region and its influence on the River Ganga, with a primary intension of assessing the presence of chromium (directly released from tanneries) in the river. The parameters chosen were BOD, COD, sulphides, chlorides, TDS, TSS, Total solids, pH, phenols, chromium, turbidity and conductivity. The analysis revealed most of these parameters were above the desired limits. Zhang & Zhang (2006) assessed the trend in the concentration of ammonium nitrogen and germanium from the wastewater discharged from leather industries in Aojing watershed in China, which revealed 13 and 14 times higher concentration of these two pollutants between 1992 to 1998, respectively. Though these studies lack commonality amongst the parameters for comparison, they highlight the presence of highly toxic pollutants in the water.

The impact of these pollutants on the ecosystem, and subsequently on human health, has drawn attention to a number of risk factors. Mondal et al. (2005) revealed an increase in total dissolved solids (TDS) in groundwater due to the disposal of untreated wastewater from tanneries. The most dominant among them were sodium and calcium, which are attributed to cation exchange, in addition to the filtration of pollutants from effluents. Abnormal concentrations of chlorine (25 to 10,390 mg/l) have been found in shallow groundwater, due to the use of sodium chloride in the tanneries. Tannery wastewater has also had a negative impact on crop yield in Tamil Nadu (Amarnath & Krishnamoorthy, 2001). Zhang & Zhang (2006) revealed the potential harmful health effects from the presence of ammonium nitrogen and germanium pollutants in the Aojing watershed, China. The presence of nitrogen in drinking water can cause blue baby syndrome (Skipton & Hay, 1998), while high nitrogen levels can cause river nitrification (Bianchi et al., 1999; C´ebron et al., 2003) which leads to degraded water quality and reduces ecological biodiversity (Radman et al., 2003). High concentrations of nitrogen can further reduce the blood oxygen transfer and destroy the tissues of the respiratory system, which then leads to death by preventing the organism exchanging oxygen and waste gas (Cooke & Kalita, 2002; Hubei Keliang Company, 2003). As for germanium toxicity, Wang & Ding (2002) considered that Ge3+ can harm human health. High concentrations of germanium (0.015 to 0.033 mg/m3) cause nose bleeds, voice loss, nose membrane shrinkage and even lung cancer (Wang & Ding, 2002), as well as harm to fish species (Lide, 1998, cited in Zhang & Zhang, 2006; Gao & Su, 2001; Lenntech, 2004, cited in Zhang & Zhang, 2006). In addition, Li (2002) reported that Ge3+ or Ge6+ could form relatively stable compounds with ammonium, organic acids and proteins, which can absorb sediments. These sediments, along with the compounds, can then contaminate crops and vegetables grown in these soils.

These studies were able to identify risk factors, but there was no clarity on how tannery wastewater becomes mixed up with other sources of waste (domestic and other industrial wastewater). For instance, tannery pollution does not necessarily flow in the sewage line as the only effluent. In fact, it is mixed with other industrial effluent and domestic waste, thereby diluting the causal linkage. Its impact on humans depends on their contact with these pollutants. In order to understand the linkage between tannery effluents and other effluents, Khwaja et al. (2001) first analysed various parameters for the tanneries' effluents, and then compared the same parameters with river water quality further down the River Ganges (before and after the tanneries discharged their effluents). Their analysis reveals an increase in the presence of most types of harmful effluent such as BOD, COD, chlorides, sulphides, TDS, TSS, total solids, chromium and conductivity. However, not all parameters can be attributed to the tannery pollutants, as these and domestic pollution get mixed up in the drainage system. For instance, BOD, COD, chlorides, total solids, turbidity and conductivity can also be the result of domestic and other industrial pollution. The same can be attributed to phenol and sulphides, although the probability of their origin from tanneries is higher. Chromium can be confidently attributed to tannery effluent. Such pollution affects about half a million in the Bangladeshi capital, Dhaka (Maurice, 2001). Based on a report by the Bangladesh Society for Environment and Human Development (SEHD), Maurice states that chromium, one of the most harmful chemicals discharged by tanneries, is carcinogenic. In addition, acidic effluents can cause severe respiratory problems.

Bleaching and Dyeing Industries

The growth of the bleaching and dyeing industries in many developing countries constitutes a main source of industrial water pollution. The availability of cheap labour and of raw materials, simple technology and the failure of textile industries in developed worlds have contributed to the booming of this sector in developing countries. In a more globalised environment, the industry has faced high competition as well as many opportunities. In the last two decades, China has emerged as the largest clothing exporter and second largest textile exporter. Many South Asian economies, namely India, Pakistan, Bangladesh and Sri Lanka, have also emerged as significant textile and clothing exporters in the last few years.

Textile industries consume substantial volumes of water and chemicals for the wet processing of textiles. The processes followed in textile industries involve spinning fibre into yarn, sizing to improve stiffness, scouring, kiering and de-sizing to remove excess sizing materials, bleaching to remove pectin and wax from the yarn and fabric and colouring and printing to apply the desired colour and design to the cloth. Consequently, the bleaching and dyeing industries play a significant role in discharging wastewater pollutants, which range from inorganic compounds and elements to polymers and organic products. Colour dyes are the first contaminants to be recognised in wastewater and have to be prevented before discharging into water courses or on to land. The presence of very small amounts of dyes in water (less than 1 ppm for some dyes) is highly visible and affects aesthetic merit, water transparency and gas solubility in lakes, rivers and other waters. The removal of colour from wastewater is more important than the removal of soluble colourless organic substances, which usually contribute the major proportion of biochemical oxygen demand (BOD). The other pollutants consist of sodium, chloride, sulphate, hardness and carcinogenic dye ingredients. High BOD effluents are generated from the sizing and de-sizing processes and are treated by conventional anaerobic and aerobic biological methods.

The textile industry was one of the earliest trades to come into existence in developing countries such as India and China. For India, it accounts for 14 per cent of the country's total industrial production, contributes to about 30 per cent of the total exports and is the second largest employment generator after agriculture. China's textile market share has gradually increased. In 1994, it accounted for 26 per cent of clothing exports originating in developing countries and 16 per cent of the world's clothing exports (Yang & Zhong, 1998). Bangladesh has also made rapid strides in exhibiting higher growth rate in the clothing sector. Between 1990 and 1998, the country's market share increased by 2,000 per cent, moving from 35^{th} to 16^{th} position among all clothing exporters (Spinanger, 2001). Textile industries enjoy a pivotal position in Pakistan, generating more than 60 per cent of the total export earnings. A major concern of these textile processing industries is the amount of wastewater generated (Table 10). Almost 0.08-0.15 m3 of water is consumed to produce one kilogram of finished fabric, translating into 1,000-3,000 m3 of wastewater generation per day against a production of 12-20 ton/day of finished fabric. Currently, wastewater generated by the industry is discharged untreated into the local environment, which has serious negative effects on the environment, with many of the parameters exceeding NEQS limits (Table 10). While these studies reveal the diverse risk associated with the bleaching and dyeing industries, a case study of Tiruppur was undertaken to reveal its impact and the ability of society to adapt in this globalised world.

Table 10: Characteristics of Wastewater Generated by Textile Processing – Pakistan

Parameters	Prevailing Ranges	National Environmental Quality Standards (NEQS) Limits
Biological Oxygen Demand (BOD)	120-440	80
Chemical Oxygen Demand (COD)	300 – 1,100	150
Total Dissolved Solids (TDS)	200 – 5,000	3,500
Total Suspended Solids (TSS)	50 -240	150
PH Value	8 – 11	6-10
Oil and Grease	10 -45	10
Chromium	0.5 -2.5	1.0

Note: All values in parts per million (ppm) except pH.

Source: Malik, 2002:7.

The Case of Tiruppur

Tiruppur, the leading textile industrial cluster in South India, is located on the bank of the Noyyal River, a tributary of a major South Indian River the Cauvery, in Tamil Nadu State. The cotton knitwear-related industries in Tiruppur have experienced tremendous growth during the last two decades on account of export potential, and at present there are more than 9,000 small-scale units in operation. The city contributes 56 per cent of the total cotton knitwear exported from India. The knitwear industry in Tiruppur provides benefits in terms of economic development in the form of income, employment and foreign exchange, and employs more than 200,000 people. The export earnings from Tiruppur during 2002 amounted to about USD 957.5 million (Nelliyat, 2003). A similar quantity of knitwear products is sold in the domestic (Indian) markets. The bleaching and dyeing segment of the textile industry causes pollution. In 1981, Tiruppur had only 68 bleaching and dyeing units, but by 1991 this figure had reached 450 and then 866 in 1997. With strict regulation, in 2003 about 702 units used 85 mld (mega litre per day) and generated 87 mld treated water. Of these 278 units treated 38 mld of effluents through 8 common effluent treatment plants (CETP) and 242 units treated 45 mld through Independent Effluent Treatment Plant (IETP). Unfortunately, the present treatment system is insufficient for reducing total dissolved solids (TDS), particularly chloride and a number of sulphates. The average TDS concentration in treated effluent is as high as 6394 mg/l in IETPs and 6537 mg/l in CETPs, which is far higher than the TNPCB standard of 2100 mg/l. The same is true of chloride, which averages 3290 mg/l in IETPs and 3127 mg/l in CETPs, whereas the standard is 1000 mg/l. Normally, partially treated effluents are discharged on to land or into the river (Noyyal), most of which flows into the soil, groundwater and surface water sources (rivers, system tanks, reservoirs, etc.) in the area of Tiruppur and downstream of the Noyyal River.

Senthilnathan and Azeez (1999) revealed that pollution was turning groundwater quality in the vicinity hazardous and unfit for any use. Measuring the physiochemical properties of the groundwater in different localities, the authors showed that all the locations had higher TDS, indicating higher salinity and rendering the land unfit for irrigation and other uses.

Alkalinity, sodium, potassium, chloride, nitrites and heavy metals were also higher than the prescribed levels across various wells. The study conducted by Soil Survey and Land Use Organisation (SS&LUO) also highlighted pollution concentrations in soil (Nelliyat, 2003). The surface and subsurface soil sample (466 each) analysis based on pH showed that 39 per cent of the surface samples and 43 per cent of the sub-surface samples were already alkaline (pH > 8.5). Besides 45 per cent of surface and 23 per cent of sub-surface samples tended to be alkaline (pH 8 – 8.5) in their nature. Pollution impacts are visible in different sectors in the Noyyal basin, including agriculture, fisheries, domestic and industrial water supply, human health, biodiversity and others. In agriculture, since groundwater and surface water sources (irrigation tanks and reservoirs) are not fit for cultivation, farmers incur heavy losses. Nelliyat (2007) estimated that this polluted water is injurious to agriculture (EC > 3 mmhos/cm), in an area of 146.3 km^2 and critical (EC 1.1 to 3 mmhos/cm) in 218.3 km^2. Hence, crop productivity has declined substantially, which ultimately affects the welfare of farmers. The estimated overall damage cost in the agricultural sector is around Rs. 210 crores. Drinking water in Tiruppur town and downstream villages is also affected. The municipality brings 32 mld of water from the neighbouring (Bhavani) basin for drinking water supply to the town. In affected villages, the waterboard has introduced special water supply schemes. Furthermore, villagers spend a lot of time and effort fetching fresh water from distant places. The total damage cost in the drinking waters is 100 billion Indian Rupees. Fishery activities in the Noyyal River, storage tanks and reservoirs have also been affected. Since 1997, fish culture activities have stopped in the reservoir at a loss of around Rs.63 lakhs, based on a study by the Madras Institute of Development Studies (2000). The Study for the Madras School of Economics (Appasamy & Nellyiat, 2006) on 'Environmental Impact of Industrial Effluents In Noyyal River Basin' revealed that overall damage in the Noyyal basin amounts to Rs.346.53 crore (Rs. 234.54 crore in agriculture, Rs. 111.49 crore in drinking water and Rs.0.5 crore in fisheries) plus the unquantified impact on biodiversity and the aquatic ecosystem in the basin.

The estimated overall damage cost to the agricultural sector is USD 50 million. Fishery activities in the Noyyal River have affected tanks and reservoirs in the basin. Recent fish mortality at Orathapalayam reservoir compelled the fisheries department to stop fish rearing. The loss of value to the fishery sector is USD 0.15 million. In addition, the risk of toxicity in the available fish is also high and its consumption may lead to serious health problems. The effect of pollution by the textile industries on the ecology has resulted in the creation of threats to human welfare. Govindarajalu (2003) examined the impacts of these effects on the health status of the villagers in the basin. Through three major health camps and sampling 31 villages, his study revealed common health problems such as skin allergies (31%), respiratory infections (23%), general allergies (13%), gastritis (9%), joint pain (10%) and ulcers (7%).

Increasing pollution from upstream industries resulted in downstream farmers filing a court case against the polluting industries. The two reservoirs affected were the Orathapalayam and Ahtupalayam dams, which irrigated about 20,501 acres of land, but unfortunately, due to increasing pollution, farmers coming under the command area of these reservoirs were against the release of polluted water from these dams. As a result, they filed a case in 1995 against the opening of the dam for irrigation. The High Court ordered in 1997 in favour of the farmers. However, the problem did not stop, and stored water in the dam affected groundwater in the region, which resulted in another petition requesting compensation. The Loss of Ecology Authority (LEA), appointed by the Madras High Court, estimated the compensation at about 104 crores and required the government to collect this fine from the polluting industries. However, through gradual pressure from farmers, the High Court ordered the industries to install reverse osmosis plants for secondary treatment of the effluents by July 14, 2005. What is interesting is that most of the industries were able to furnish the government with proof of their ability to install the plant by 15 July (Sridhar, 2005). A politicised environment characterises the dyeing and bleaching industries in Tirupur, where diverse actors have diverse interests in this globalised textile industries. Malm (2004) demonstrated that local action against pollution is not taken for the benefit of powerful interest groups. The state is interested in promoting these industries for export revenue earnings, while people depending on these industries for their livelihood have limited power to take action. As globalisation limits how pollution is handled, because of global competition (and the retreat of the state), it provides a way for civil societies to grow stronger internationally, too. The political nature of the problem poses a major challenge for addressing the pollution.

The alarming levels of pollution across developing countries have been widely recognised by national governments, industries and NGOs, who have been making various efforts to address the problem of water quality. China has made significant efforts to address the growing crisis, since the UNCED conference in 1992, through the China Water Agenda 21 (PRC, 2003; World Bank, 2001) – controlling flood, restoring forested watersheds and improving water supply and wastewater treatment. However, demand management strategies such as better water pricing, conservation policies and better institutional coordination for integrated water management are in short supply (Shalizi, 2006). India has pioneered a number of regulations since 1985 through river cleaning programmes and the treatment of sewage and industrial pollution. The river cleaning programme primarily emerged to clean the polluted holy River Ganga, but was subsequently extended in the form of the National River Conservation Plan (NRCP). The programme was earmarked with 51.66 billion Indian Rupees, of which 23.10 billion was spent in constructing 269 sewage treatment plants (STPs) across the country. Despite these investments, about 70 per cent of the country's sewage is untreated. The Centre for Science Environment (CSE, 2007) argues that the problem with this programme was its 'hardware' approach. It is believed that industrial pollution is point-specific and can be identified, controlled and treated, and therefore there was a need to control domestic pollution as it accounted for 75-80 per cent of the sewage. This involved constructing 'hardware' to collect, convey and treat the sewage generated, and then discharge the treated effluents. About 80 per cent of the expenditure went toward channelling sewage and constructing STPs, with rest spent on constructing low-cost sanitation (10%), building electric cremation grounds (1%) to reduce cremation on river banks, introducing measures for river front development (1%) and several other miscellaneous works (tree planting, beautification and creating public awareness) (4%). Second, the programme did not assess the sewage generated from cities. Third, it only estimated constructing STPs to treat about 6,247 mld of sewage, in contrast to 29,129 mld based on the 2001 population census. This was a huge gap. To add further to the complication, many of the STPs did not end up cleaning the water systems, as many of them were not operational, because of a lack of funds and sewage connections. As a result, an STP with the capacity to treat 6,247 mld was only able to treat 13.5 per cent of the sewage. Finally, even if the water was treated, it was discharged upstream, in the process flowing past the city and picking up more waste, this negating the impact of treatment.

Two main pollution control statutes address water pollution caused by industries in India. The first, the Water (Prevention and Control of Pollution) Act 1974, which came into force in 1981, is responsible for administering the new legislation. In 1992, Central Pollution Control (CPC) launched a water pollution control programme to tackle the problem of industrial pollution by enforcing industries to set up effluent treatment plants (ETPs). CPC identified

1,551 large and medium industries. The progress report revealed a drastic reduction in the number of non-compliant industries, from 252 in March 1995 to just 24 in December 2000 (Maria, 2003). However, there is limited evidence in assessing the ability of these authorities to control industrial water pollution. Pargal et al. (1997), examining inspections on water pollution emissions, revealed that inspections had no impact on pollution emissions. Parikh et al. (2001) argue that setting up an ETP is not a logistical problem; rather the operating costs strangle the project in that when a firm sets up an ETP it cannot run it if the operating and maintenance costs are substantial (or they can operate only during inspections). Running when inspections are due is encouraged by the fact that authorities rely on 'initial compliance,' i.e. verifying that pollution control devices are installed, rather than on their regular operation. What is interesting is that most of these industries are owned by the state public sector (48%), central public sector (9%) and private sector (43%), thus revealing the nexuses between pollution control authorities and public sector industries. Up to 1988, the pollution control boards (CPCB and SPCB) had limited enforcement powers – criminal prosecutions and seeking injunctions to restrain polluters. However, in 1997, the National River Conservation Authority (NRCA) decided to instruct polluting industries to install effluent treatment systems within three months, failing which closure notices would be issued under Section 18(1) of the Water (Prevention and Control of Pollution) Act 1974 to all state pollution control boards (SPCBs). This led the CPCB to set environmental standards for all plants, lay down ambient standards and coordinate the activities of the SPCB. The implementation of environmental laws and their enforcement were decentralised and made the responsibility of the SPCBs. A total of 851 industries discharging 100 kg/day or more of BOD without adequate treatment were identified. In response, and as of August 2003, the government's website claimed about 71 per cent of the industries had installed ETP, 28 per cent had closed and less than one per cent (about 5) were yet to install an ETP,.

Common effluent treatment plants (CETPs) have been suggested as a cost-effective option to treat effluents from tanneries, due to their small size and the technical, financial and managerial constraints for SSI. The CETP concept was originally promoted by India's Ministry of Environment and Forests, in 1984. The concept was a culmination of the acceptance of a 'polluters pay principle' and collective action choices to address growing water pollution. The concept received wide acceptance among various players. Kathuria (2004) revealed the convergence of interest was due to the World Bank (providing part finance and subsidies to the Indian government), the government of India (accepting these subsidies, rather closing for environmental reasons), the judiciary that had responded to complaints filed by affected parties in Tamil Nadu and its close proximity to urban centres. The first CETP in India was constructed in 1985 in Jeedimetlha, near Hyderabad, Andhra Pradesh, to treat wastewater from the pharmaceutical and chemical industries. In 1999, 82 CETPs had been set up around the country. However, scarce and dispersed research findings reveal a number of problems in the sustainability of this decentred pollution abatement system. Kathuria (2004), following Rawl's criteria of sustainability of an institution ('fairness, stability and efficiency'), identified inappropriate cost sharing, non-adherence to contracted trade effluent and the non-recovery of user charges. Nowadays, SSI adopts mainly a linear cost-sharing platform on which to operate, whereby – irrespective of the volume and quality – all units are treated equally. There are no incentives or disincentives to units that discharged highly toxic waste compared to others. Second, at a number of places the CETP is either below or above its designed capacity. Finally, many of the SSI units for a CETP have pending outgoings of nearly one-third of the total treatment expenses. Though economics do play a role, technological problems abound. The CEPT is insufficient for reducing the total dissolved solids (TDS), particularly chloride and sulphates (Nelliyat, 2003). Lanunska et al.'s (1999) tests, carried out before and after the installation of CETPs in three CETPs in Gujarat, show alarming results, with hardly any change in water quality; in fact, the treatment plants serve to transform concentrated accumulations of persistent organic pollutants (POPs) from liquid waste streams into highly contaminated sludge. Their study in Ankaleshwar revealed an extremely high quantity of heavy metals and persistent organic pollutants, while in Vapi CETP-treated effluents were found to contain several chlorine-containing organic compounds such as the highly poisonous hexachlorobenzene and polychlorinated biphenyl. In another study (TCS, 2000), conducted jointly by CPCB and Tata Consultancy Service, water quality deteriorated after treatment, with respect to pH, BOD and DO (Kathuria, 2001). This is in addition to a number of rent-seeking attitudes and administrative delays involved in setting up and monitoring the CETPs in India (Parikh et al., 2001; Shankar, 2000). Further complicating the situation is the cottage-based nature of these industries, which are ineffectively regulated. As such, many of the pollutants produced by these operations join with storm water and domestic sewage drains. In essence, even the minuscule amount of water that is presumed to be treated through STPs and CEPTs does not result in clean water systems.

Reddy & Behera (2006) made a systematic attempt to assess the impact of water pollution in the Patancheru industrial region in Andhra Pradesh, through a comparative assessment of two villages (one affected by pollution and the other not affected). Although in the village affected the water quality was well beyond the desirable limit, in the unaffected village groundwater was equally polluted compared to surface water (stored in tanks). This indicates the ability of wastewater to pollute groundwater, rather than surface water, as the latter is often renewed and diluted with rainwater. Another striking feature is the increasing involvement of family members (women and children) in collecting water from distant areas, compared to only males prior to pollution. The use of polluted groundwater has led to drastic changes – an increase in unproductive land, a decline in agricultural productivity, damage to pump sets and the loss of agricultural income – in the livelihood systems in the affected village. The entire village affected by pollution has been suffering from various water-related diseases such as skin infections, tooth corrosion, defective vision, fever, diarrhoea and respiratory diseases. The most important feature of this health problem is that women are the worst affected, as they do the entire household work, often with contaminated water. The authors estimate the total loss at about Indian Rupees 14,125 per household, per year due to the impact of pollution on their health, agriculture and livestock.

2.4 Urbanisation and Human Health

What is more worrying in most developing countries is the growing importance of urban wastewater in urban, peri-urban and rural agriculture settings. For urban and peri-urban users, this water assumes great significance due to its year-round availability, and is less expensive for the lucrative and large urban market for fresh produce. Wastewater irrigation has been practiced in many countries around the world. A rough estimate indicates that at least 20 million hectares in 50 countries are irrigated with raw or partially treated wastewater (Hussain et al., 2002). Israel is at the forefront of this trend, using about 70 per cent of its wastewater for irrigation. Angelakis et al. (1999) present the status of wastewater reuse in Mediterranean countries. France started treating wastewater through various agricultural practices in the 1940s, but over a period has learnt to reuse wastewater for agriculture. In addition, Morocco was irrigating about 7,235 hectares using wastewater in 1994. Mexico is an example where wastewater from the country's cities and towns has been used extensively to irrigate about 200,000 to 250,000 hectares (Scott et al., 2000). Buechler et al. (2006) reveal scattered studies and assessments of a few other nations such as India, Pakistan, Vietnam, China and Jordan. From a case study of the Musi River in Hyderabad, they estimate that about 16,000 hectares of land generates one million Indian Rupees from reusing wastewater for irrigation. In Vadadora, a city in Gujarat, wastewater irrigation generates annual production equivalent to about 266 million Indian rupees. The situation is not very different in other countries. In Vietnam, about 9,000 hectares of land was irrigated by wastewater for paddy cultivation. In China, wastewater irrigates about 1.3 million hectares of land. In Pakistan, it was found that farmers irrigating with wastewater earn between $US 300-600 more per year than farmers using normal water, and that the majority of farmers were landless and therefore leased plots for agricultural production. In Kumasi, Ghana, farmers earned about 2-4 times more than their counterparts using non-wastewater for irrigation. Although there is a pressing need for a comprehensive worldwide assessment, these studies only reveal a large area under irrigation and good returns compared to agriculturists using normal water for irrigation in urban and peri-urban regions. Wastewater from urban regions has become a resource for urban and peri-urban agricultural users. There are a number of reasons for wastewater being an asset to an agricultural community. Angelakis et al. (1999) and Buechler et al. (2006) reveal this as the only resource available in sufficient quantities year-round, unlike fresh water, particularly in semi-arid and arid regions. Second, it is an easy means of disposing of wastewater from urban centres. Third, the use of wastewater helps in eliminating or reducing the application of fertilisers. Fourth, it generates income for many landless and squatter settlers, who otherwise might not have had any other income-generating opportunities.

While wastewater reuse may generate potential benefits, it is not without medium- and long-term costs (Scott et al., 2000), particularly in regard to public health. Cooper (1991) identifies several risks of infectious diseases, trace organic compounds and pathogens. In Haroonabad, Pakistan, Ensink et al. (2004) reveal the high presence of faecal coliform bacteria and worm eggs, which increases the risk of hook worm infection four- to fivefold for farmers coming into contact with reused wastewater. Living in the small intestine, hookworms cause heavy blood loss, as well as anaemia and retardation in children. This can be linked to cholera and typhoid and to faecal bacterial diseases, bacterial diarrhoea and dysentery for consumers of wastewater-irrigated produce. Buechler et al. (2006) report fevers, diarrhoea and sores on parts of the hands and legs of farmers and labourers exposed to wastewater. They also reveal its impact on agricultural produce. The paddy crop that is grown traditionally in the region has witnessed decreasing yield and broken grains. Another health threat is bacterial and viral infections, both minor and serious, which can occur after the consumption of raw vegetables contaminated with faecal matter – the cause of the 1970 cholera epidemic in Jerusalem and typhoid epidemics in Santiago (Fattal et al., 2004) and Dakar in 1987 (Faruqui et al., 2004), which were all pinpointed to urban and peri-urban agriculture. As Buechler (2004) points out, health risks also vary according to gender, class and ethnicity. For instance, women often perform tasks which expose them to wastewater, such as transplanting and weeding in flooded areas like paddy fields, in both Latin America and South Asia. Furthermore, the children of farmers or farm workers, who do not have sufficient immunity, tend to be most at risk of gastrointestinal problems. In terms of environmental impact, wastewater use over a long period of time can result in heavy metal accumulation, especially with industrial wastewater sources. Irrigation with industrial wastewater has been associated with a 36 per cent increase in enlarged livers and 100 per cent increases in both cancer and congenital malformation rates in China, compared to control areas where industrial water was not used for irrigation (Yuan, 1993, cited in Carr et al., 2004). Ironically, in some of the cases, including Haroonabad, Pakistan, and Dakar, Senegal, groundwater contamination from microbial pathogens or nitrates is not a concern, because it is already too polluted or saline-rich to serve as a drinking water supply.

Finally, the long-term use of wastewater can become self-limiting due to soil damage. Although organic matter in wastewater can help to improve soil texture and water-holding capacity, it also has harmful effects, particularly in arid environments, by causing soil salinisation, blocking soil interstices with oil and grease and accumulating heavy metals. So far, in most of the cases presented, the environmental impacts have been minor or undetectable. However, in Pakistan, over-applied wastewater with insufficient drainage (also the case with freshwater irrigation) has resulted in signs of degrading soil structure, visible soil salinity and the delayed emergence of wheat and sorghum due to an excess of applied nutrients. Although such concrete impacts on soil are generally not yet measurable, these effects are likely to occur, given continued application and greater waste loads. In some places such as Dakar, where groundwater is highly saline, if it were used for irrigation instead of wastewater, the impacts on soil could arguably be worse.

3.4.1 Summary

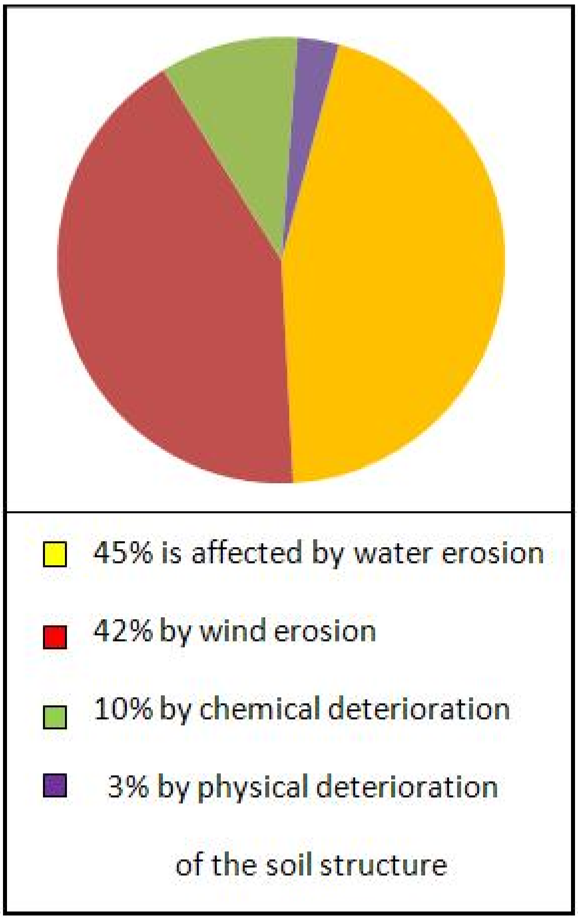
Globalisation and urbanisation have resulted in the generation of wastewater. This wastewater is an asset for urban squatter settlers and peri-urban agriculturists, due to its year-long availability. Also, it is less expensive for the large, lucrative urban market demanding fresh produce (Angelakis et al., 1999; Buechler et al., 2006). Wastewater irrigation is practiced in many countries around the world, but in recent decades it has gained momentum in the growing economies in India, Ghana and China, placing its growing population in urban and peri-urban region at risk. Ensink et al. (2004) and Buechler et al. (2006) report several risks of infectious diseases and the presence of organic compounds and pathogens. In the past, studies examined economic benefits (or loss thereof), socio-economic analysis, health effects and bio-physical studies that focus on treatment technologies (case studies in Urban Agriculture Magazine, 2002; Scott et al. 2004; Ensink et al., 2004). Rare is a study that examines the inter-linkages among these diverse sets of factors to offer insights for sound legal and regulatory frameworks, offer in-depth understanding of the factors that drive farmers to use wastewater and provide directions for effective public health protection and the maintenance of environmental quality (Faruqui et al., 2004).

3 LAND DEGRADATION AND HUMAN HEALTH

Land degradation and human health are the products of the interplay between the biological and physical environment, social structure and behaviour. Land degradation plays a crucial role in influencing the status of human health by changing land use patterns and offering a favourable environment for disease vectors such as malaria and diarrhoea. Degraded land is defined as 'land which due to natural processes or from human activity is no longer able to sustain economic function and/or the original natural ecological function' (FAO, 1998:31). However, it is not as simple as this definition may suggest. Authors within the literature overlap usage of the term 'land degradation' with 'desertification' and 'soil degradation'. The different forms of land degradation include desertification, soil degradation, water-logging, salinity and erosion. Second, land degradation is a composite term. For instance, the loss of vegetation on hill slopes may lead to landslides, which in effect changes the features of land, causing human and property losses and disrupting activities. However, in the long term an area affected by a landslide may regain its productive status for supporting better crops and engender more intensive agriculture and the availability of plain land for settlement. The case is similar for urbanised regions, where the dumping of urban waste may render the land unproductive, but with urban expansion the same land might be converted to residential or commercial centres. It is the linkage between degradation and its effect on land use that is central to its definition. In this paper, land degradation will be considered to include all forms of degradation affecting the economic and natural function of the land. This section primarily is concerned with changes in land characteristics such as the loss of soil due to water and wind, the decline in soil fertility, water-logging, the increase in salinity, lowering of the water table, the loss of vegetation cover and the exposure of rocky surfaces. In addition, we assess it from its impact on human health.

Land degradation has a significant impact on agricultural productivity, the environment and the quality of life. It adversely affects about 2 billion hectares, or 23 per cent, of the landscapes available for humans (GEF, 2003). Agricultural lands in both dry lands and forest areas have been the most affected by land degradation. They cover about one-quarter of the world's total land area and account for 95 per cent of all animal and plant protein, as well as for 99 per cent of the calories consumed by people. About two-thirds of these lands have been degraded to some extent during the last 50 years. There are many different estimates of the extent and rate of land degradation. Dregne and Chou (1994) estimate degraded lands to be about 3.6 billion ha of the total 5.2 billion ha of the total land considered, while Oldeman (1994) shows the global extent of land degradation at about 1.9 billion ha. A more recent estimate (GEF & IFAD, 2002) puts the figures at about 1.035 billion ha.

Figure 2: Causes of Land Degradation



Source: GEF & IFAD, 2002:2.

Of the different causes of land degradation, water erosion is the dominant form in semi-arid and dry sub-humid regions, while wind erosion is dominant in arid zones (Figure 2). These two processes account for more than 80 per cent of the land degradation in the world. In terms of distribution across various continents, the largest areas affected are in Asia and Africa (Table 11), where water and wind erosion are prominent.

There are five different forms of land degradation. These include desertification, soil degradation, water-logging, salinity and land erosion. Of these forms, desertification and water-logging are examined in the following section.

Table 11: Soil Degradation by Region in Susceptible Drylands, 1990s (million ha)

	Water erosion	Wind erosion	Chemical deterioration	Physical deterioration	Total
North America	38.4	37.8	2.2	1.0	78.4
South America	34.7	26.9	17.0	0.4	79.0
Europe	48.1	38.6	4.1	8.6	99.4
Africa	119.1	159.9	26.5	13.9	319.4
Asia	157.5	153.2	50.2	9.6	370.5
Australasia	69.6	16.0	0.6	1.2	87.4
Total	**467.4**	**432.4**	**100.7**	**34.7**	**1035.2**

Source: GEF-UNEP, 2002

Desertification

The United Nations Convention to Combat Desertification (UNCCD) defines desertification as 'land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic, variations and human activities' (MEA, 2005). Drylands occupy 41 per cent of the Earth's land and are home to more than 38 per cent of the world's population. Severe land degradation is present in 10 to 20 per cent of drylands, estimated to affect 250 million in developing countries. Desertification affects the livelihoods of millions of people, including large proportions of the poor in drylands. It takes place worldwide in drylands due to overgrazing, deforestation, salinisation, droughts and erosion or sand movement, and its effects are experienced locally, nationally, regionally and globally. A persistent, substantial reduction in the provision of ecosystem services as a result of water scarcity, intensive use of services and climate change is a much greater threat in drylands than in non-dryland systems. In particular, projected intensification of freshwater scarcity as a result of climate change will cause great damage in these areas.

Desertification is a result of excessive pressures on resource ecosystems. Darkoh (1998) refers to these as local forces, such as increases in populations and the escalation of their needs, poverty, land shortages and landlessness, civil strife, wars and poorly conceived national policies. These may be aggravated by external forces such as the state of the global economy, commodity prices, debt burden, terms of trade and other factors. Climate change may further aggravate this by prolonging drought and desiccation.

Box 5
Different Assessments of Desertification

1. The Global Assessment of Human Induced Soil Degradation (GLASOD), by International Soil Reference and Information Centre (ISRIC), is the first worldwide assessment of soil degradation and is currently the only uniform global source of land degradation. *Merits*: Global coverage and maps the actual status of soil degradation, percentage of degraded area, rapidity of the soil degradation process and the kinds of physical human intervention. *Demerits*: Considers only human-induced degradation processes, is small in scale and restricts data at national level.
    a. The Assessment of the Status of Human-Induced Soil Degradation in South and South-East Asia (ASSOD) -1997: A follow-up activity of GLASOD and therefore slightly refined. *Merits*: More detailed and more accurate compared to GLASOD. *Demerits*: Similar to GLASOD, as it deals with human-induced degradation.
2. The 'Soil degradation assessment in Central and Eastern Europe' (carried out in 1997-2000 as a part of the 'Mapping of Soil and Terrain Vulnerability in Central and Eastern Europe' project (SOVEUR), conducted jointly by ISRIC and FAO used a slightly modified GLASOD methodology that focused on diffuse pollution. The status of degradation is evaluated in terms of the type and intensity of the process, as well as the impact of degradation on various soil functions. The impact is examined as a combination of change in productivity and the level of management.
3. The Centre for Environmental Remote Sensing (CEReS) examined degradation of drylands in Asia and Northern Africa using satellite imagery. The significance of this mapping is that it distinguishes land degradation in different land use types. The degree of degradation is defined using three degree scales (slight, moderate and severe).
4. A study by Dregne & Chou (1992) provided desertification data for most dryland countries in the world. However, it remains silent on the methodology used, though it acknowledges the poor quality of data.
5. A study on land degradation in South Asia by FAO, UNDP & UNEP (1994). The report provides country-level data on degradation in general, water erosion, wind erosion, soil fertility decline, salinisation, water logging and the lowering of groundwater table. The data source was mainly from GLASOD, but depends entirely on existing publications and reports. The authors themselves point out the results are provisional and subject to modification.

Estimates on the geographical extent of desertification have been carried out by multilateral and national agencies (Box 5). Of these, GLASOD is basically the only global survey available. It is one of the core studies in soil degradation research, but using country-level results is difficult. The ASSOD activity is more detailed, but overlaps between the subtypes of degradation. All of these studies focus on soil degradation, but desertification is much more complicated than the simple loss of soil (Kniivila, 2004). Further, each of these studies relies on different sources, making comparisons difficult. Given these limitations and problems, the actual estimation of the geographical extent of desertification may range between 6 million and 12 million square kilometres. These studies only highlight the necessity for reliable data on the global and regional scale (MEA, 2005).

At least 90 per cent of the dryland population live in developing countries, lagging far behind the rest of the world in human well-being and development indicators. Drylands suffer from the poorest economic conditions in comparison with non-dryland regions (MEA, 2005). The average infant mortality rate (about 54 per 1,000) for all dryland developing countries exceeds non-dryland countries by 23 per cent or more. The difference is even higher when compared with developed countries. This is further exacerbated by a high population growth rate in drylands, which rose by 18.5 per cent in the 1990s, and is combined with political marginalisation and the slow growth of health and education infrastructure, facilities and services. The worst situations are observed in the drylands of Asia and Africa.

Africa is one of the continents at high risk of desertification. About 1859 million ha (66 per cent of the continent) comprises drylands, of which one-third constitute uninhabited, hyper-arid desert (672 million ha), while the rest (1287 million ha) is composed of arid, semi-arid and dry sub-humid areas with a population of about 400 million (two-thirds of all Africans) (Darkoh, 1998). There are three distinct areas in this region: Mediterranean Africa, the Sudano-Sahelian region and the Kalahari-Namib region in Southern Africa. About 42 per cent of the land is affected by one or more forms of land degradation in South Asia (Perera & Fernando, 2004). It is estimated that as much as 63 million ha of rain-fed cropland and 16 million ha of irrigated land has been lost due to desertification, especially in India and Pakistan. FAO, UNDP & UNEP (1994) estimate the financial loss to be about 10 billion USD per year, which is equivalent to seven per cent of the region's combined agricultural gross domestic product.

Waterlogging and Salinity

One of the most evident and adverse effects of irrigation development is the creation of waterlogging and salinity. There is no reliable estimate of the area affected by these factors; however, it is estimated to range between 20-30 million ha of the world's 260 million ha of irrigated land (Tanji & Kielen, 2002). The table (Table 12) below shows examples of waterlogging and salinity in Central Asia, Near-East and South Asian countries from two main sources (FAO, 2000; FAO, UNDP & UNEP, 1994). Of these, Central Asia is the most affected, with 24 per cent of its irrigated land affected by salinity, followed by countries in Near-East and South Asia. In the Central Asian countries, such as Uzbekistan and Turkmenistan, 35 to 50 per cent of the irrigated area is saline.

Table 12: Salinised areas compared with total irrigated area, Central Asia and the Near-East

COUNTRY	SALINISED AREAS	
	HECTARE	% OF IRRIGATED AREA
CENTRAL ASIA		
Kazakhstan	242 000	6.8
Kyrgyzstan	60 000	5.6
Tajikistan	115 000	16.0
Turkmenistan	652 290	37.4
Uzbekistan	2 140 550	50.0
TOTAL	**3 209 840**	**23.6**
NEAR-EAST		
Bahrain	1 065	33.6
Egypt	1 210 000	37.3
Iran	2 100 000	28.9
Jordan	2 277	3.5
Kuwait	4 080	85.5
Lebanon		
Mauritania		
Saudi Arabia		
Syria	60 000	5.9
Tunisia		
Turkey		
TOTAL	**3377422**	**17.7**
SOUTH ASIA		
Afghanistan	1 300	3.0
Bangladesh	-	-
Bhutan	-	-
India	7 000	4.0
Iran	16 000	27.0
Nepal	-	-
Pakistan	4 200	16.0
Sri Lanka	Less than 1 000	2.0
TOTAL	**28 500**	**9.0**

Source: FAO, UNDP & UNEP, 1994:60; Tanji & Kielen, 2002:4

Shallow water tables and insufficient water levels available to seep through the salts accumulated in these soils contribute to the rapid redistribution of salts in the soil profile, which results in the secondary salinisation of soils. While inadequate drainage accelerates the rise of groundwater in irrigated areas, the rate of salinisation becomes high when the water table is shallow and saline. The use of poor quality groundwater for irrigation further aggravates the dilemma of secondary salinisation. An integrated approach is therefore crucial for overcoming the problems in waterlogging and salinity because of the relationship between irrigation management and effluent disposal.

Root causes of different forms of land degradation are highly complex, as well as site-specific. Broadly, they result from activities that are directly or indirectly caused by natural calamities (FAO, UNDP & UNEP, 1994) such as increasing populations, inappropriate use of land and water, deforestation, industrial activities, the failure of government policies and administrations and persistent natural disasters (Darkoh, 1998; Perera & Fernando, 2004). However, human and natural causes of land degradation are not fully understood, although they are generally better known than they were some years ago. While the causal factors influencing desertification have been well studied, the spatial scale has been ignored. Most of the studies emphasise desertification at the macro-management level; rarely do they draw on its linkage with the micro-management level (Darkoh, 1998).

Health Implications

While the causes of different forms of land degradations are still not understood, its impact on human health is even fuzzier. Growing concern of its health impact has been recognised among international agencies and researchers. The WHO, while releasing the Millennium Ecosystem Assessment report on 'Ecosystems and Human Well-Being – Desertification Synthesis,' claimed that ecosystem degradation has serious implications on humans, especially among poorer nations. The report (MEA, 2005) identifies some of the adverse impacts of degradation as biological and societal. Biophysical impacts include dust storms, downstream flooding, the impairment of global carbon sequestration capacity and regional and global climate change, whereas societal impacts relate notably to human migration, economic refugees and urbanisation, leading to deepening poverty and political instability.

Land degradation results in a reduction of vegetation and the easy removal of top soil by wind, and water, which in turn lead to dust storms in semi-arid and arid regions. For instance, visibility in Beijing is adversely affected by dust storms from the Gobi desert in springtime. These large dust storms emerging from China also affect the Korean peninsula and Japan, and are even observed to have an impact on North America. Moreover, they are widely considered to be a cause of ill-health – fever, coughing and sore eyes. Dust emanating from the East Asian region and the Sahara has also been implicated in respiratory problems in the Caribbean, while trans-boundary impacts remain a major threat.

Case of the Aral Sea Basin

The Aral Sea basin is one of the most significant cases of land degradation affecting human health. It is located in Central Asia, includes two basins, the Amu Darya and the Syr River, which flow into the sea, the Tedzhen and Murgabi rivers, the Karakum canal and shallow rivers flowing from Koper Dag and western Tien-Shan, as well as areas around these rivers and the Aral Sea with no runoff. Administratively, the region covers all of Uzbekistan and Tadzhikistan, portions of Kazakhstan, Kirghizstan, Turkmenistan and North Afghanistan.

The collapse of the Aral Sea Basin was based on a simple logic: water is of greater value if used for irrigation rather than flowing into the sea unused. The former Soviet Union decided that the water of the Aral Sea, especially in Uzbekistan and Turkmenistan, should be used for cultivating cotton in order to meet the needs of the entire Soviet Union.

Box 6
Some indicators of land degradation

1. Increase in population: From 13.2 (1950) to 33.2 million (1988) and 34 million (1990).
2. High population growth rate: Tadzhikistan (35%), Uzbekistan (31%), Kazakhstan (18%), Turkmenistan (8.5%) and Kirghizstan (5.5%).
3. Population below 15 years old comprises 42.5 % of the total population in the basin.
4. Increase in irrigated land since the 1960s: Uzbekistan and Tadzhikistan (1.5 times), Kazakhstan (1.7 times), Turkmenistan (2.4 times).
5. Agricultural production increased 5-7 times.
6. Application of chemical fertilisers 2-6-fold increase.
7. Groundwater consumption in the basin increased by about 80 per cent between 1960 and 1990.

Some selected impacts

1. The area of the basin fell from 68,300 km3 (before 1960) to 34,800 km3/year in 1990.
2. The volume of seawater decreased from 1,066 km3/year (prior 1960) to 304 km3/year (1990).
3. Beginning in the 1960s the runoff into the Aral started to fall and decreased to approximately 4 km3/year compared to 116 km3/ year between 1911-1960.
4. Changes in runoff caused by natural effects decreased in the Amu Darya basin (from 6.7 cubic kilometres/year in 1940 to 1.6 in 1985, while in the Syr Basin the decrease went from 15 in 1940 to 2.5 in 1985.
5. 14,000 square miles of dry seabed contains 10 billion metric tons of salt.
6. The presence of DDT is about 27 times above the maximum permissible concentration (MPC), and in some regions it is 46 times higher.
7. Organochlorine pesticides have been recorded along the Syr and Amu Darya basins.
8. High, almost stable incidences of diarrhoea are reported between May and August. Children aged below two years face the highest diarrheal disease burden, with 8.4 episodes per person, per year.

Source: Boyle, 2000; Herbst, 2008

Deteriorating land and water in the basin, as a result of irrigation development and the chemicalisation of agriculture, have contributed to increased sickness in the population, with an estimated 3 million people victims of chronic illness (Boyle, 2000). The death rate from respiratory infection in Karakalpakstan (167 per 1000) is among one the highest in the world. The infant mortality rate is an important indicator of human well-being. In certain regions of the Aral Sea area, and particularly in the Bozataus region of the Karakalpak Republic, infant mortality rates exceed 110 per 1,000 newborn, a rate higher than that of Thailand (88), Mexico (82), Costa Rica (78), Jordan (75), Colombia (74), Syria (73) and many other countries. In Turkmenistan it is about 58 per 1000, Uzbekistan it is 46 (in 1986), Tadzhikistan it is 47 and in Kirghizstan it is 38.

The data on medical examinations reveal a growing number of cases of gallbladder and gallstone diseases, chronic gastritis, nephritis and oesophageal cancer. According to Selyunin (1989), para-typhoid morbidity in the Karakalpak Republic is 23 times higher than the average in other republics of the USSR. Since the middle of the 1970s in some regions, the mortality rate has increased 15 times, cardiovascular morbidity six times, tuberculosis six times, gallbladder and gallstone disease five times and oesophageal cancer by seven to ten times. Between 1984 and 1989 in the Kzyl Orda area on the lower reaches of the Syr Darya River, typhoid morbidity increased 20 times.

The inadequate development of the water supply and sewerage systems has greatly aggravated ecological criticality in the Aral Sea Basin. Thus, centralised water supply in the lower reaches of the Syr Darya in the Kzyl Orda area of Kazakhstan provides water for only 65 per cent of the population, and in Karakalpakia for only 33 per cent. Samples of water taken from sources in the Aral Sea Basin reveal that the quality of piped water does not meet state bacterial standards in 25-47 per cent of the cases. About 90 per cent of the rural population of the Aral Sea Basin obtain spring and summer water from the irrigation network. Only the largest cities of the basin have sewage systems, and these cover an insignificant part of the territory in these cities. This case illustrates the complexity of the problem.

3.1 Summary

One of the most evident and adverse effects of irrigation development is the creation of waterlogging and salinity. There is no reliable estimate of areas affected by these events, but it is said to range between 20 and 30 million ha of the world's 260 million ha of irrigated land (Tanji & Kielen, 2002). Central Asia is the most affected, with 24 per cent of its irrigated area affected by salinity, followed by countries in Near-East and South Asia. In Central Asian countries, such as Uzbekistan and Turkmenistan, 35 to 50 per cent of the irrigated areas are saline. Shallow water tables and insufficient water amounts available to seep through the salts accumulated in these soils contribute to the rapid redistribution of salts in the soil profile, which results in the secondary salinisation of soils. While inadequate drainage accelerates the rise of groundwater in irrigated areas, the rate of salinisation becomes high when the water table is shallow and saline. The use of poor quality groundwater for irrigation further aggravates this dilemma. Studies in the past three decades, on waterlogging and salinity-related issues in irrigated agriculture, have hardly been delivered due to their lack of an integrated approach to understand the causes and means for addressing the problems. An integrated approach is crucial in overcoming the problems in waterlogging and salinity, as there is a relationship between irrigation management and effluent disposal. Root causes of different forms of land degradation are highly complex as well as site-specific. Broadly, they result from a combination of directly and indirectly caused natural calamities (FAO, UNDP & UNEP, 1994). Increasing populations, inappropriate use of land and water, deforestation, industrial activities, the failure of government policies and administration and persistent natural disasters (Darkoh, 1998; Perera & Fernando, 2004), along with global climate change, have caused excessive salinisation in the region of Central Asia. However, the linkages between human and natural causes of land degradation are not fully understood, although they are generally better known nowadays than previously. While the causal factors influencing desertification have been well studied, their spatial scale has been ignored. Most of the studies emphasise desertification at macro-management level rarely do they draw on its linkage with micro-management level (Darkoh, 1998). Land degradation in various forms has a direct or indirect impact on human health. While attention among the literature has been directed to the outcomes, little research addresses the theoretical and applied insight that can be gained through situating human health at the centre of land management policymaking (Collins, 2001).

4 LIVING IN A RISK SOCIETY

This review reveals a diverse set of factors interacting temporally and spatially in influencing environmentally-related diseases, making it a complex undertaking for the simplistic prescription of single or even multiple interventions. These diseases are intricately linked with a number of sub-systems of urbanisation, agricultural activity, food security and human health responding to stimuli in various other sub-systems (McMichael, 2001; Label, 2003). Unpacking these interlinkages requires appreciating the complexity, uncertainty, contestations and change[6]. The *complexity* of diverse environmental factors affects human health in multiple ways, and interacts with demographic, socio-cultural, economic and other regional factors differentially, subsequently impacting on human health and the environment, which are not completely understood. Often, this results in considerable *uncertainty* about which decisions have to be taken. With incomplete and imperfect understanding of these uncertainties, human entities (individuals and organisations) develop strategies, often resulting in competing claims and demands over fresh water. These *contestations* or conflicts are facilitated or constrained by socially or institutionally distinct agents, who attempt to bring about *change* in the existing institutional arrangements and bio-physical environment. These changes are not always perfect or efficient, but do demonstrate the ability of self-organisation, leading back to complexity. The interaction among these properties is cyclic only for the research, but in social reality it is punctuated by contextual factors such as natural calamities, geological disturbances, demographic factors, geomorphic processes and climate change. These contextual factors, influencing cycles locally and globally, produce a complex ebb and flow, which characterises emergence and results in multi-scale interactions, unexpected behaviours and self-organisation capacity, making them a complex adaptive system (though not necessarily to the desired expectation of human beings). In this complex adaptive system, we live in a 'risk society' (Beck, 1992). Such a society does not imply that the world is more hazardous; rather, it recognises a "modern approach to foresee and control the future consequences of human actions" (Giddens, 1999:3), to adapt to and live with risks.

The literature reveals a limited understanding of this complex set of factors. Although these research studies have moved away from curative to preventive approaches to address environmental-related diseases, they still retain the focus on cause-effect relations to understand the growing threat to human health. Moving beyond 'cause-effect' will not only opens a 'Pandora's box' of complex interlinkage between a number of factors, but also a 'can of worms' due to the intensification of agriculture, rapid urbanisation, climate change and globalisation – each of which threatens human life. For instance, national and international agencies focus on water supply and sanitation as the 'most powerful preventive medicine' to address water-related diseases. While the literature does not deny the importance of improved water supply and sanitation, it reveals that its effectiveness depends on the socio-cultural, economic, institutional, human metabolism, dynamics of pathogens and the growing threat from climate change. While each of these pieces of literature draws on the strength of different disciplines in identifying and emphasising the importance of one factor over the other, as Clasen et al. (2007) reveal, rarely do these studies explain the heterogeneity of factors influencing water-related diseases such as diarrhoea. The World Malaria Report 2005 (UNICEF et al., 2005) emphasises a technical

[6] Bruce Mitchell draws on a similar approach to understand the multifarious linkage within environment and resource management, by appreciating complexity, uncertainty, conflicts and change (Mitchell, 1997).

approach (artemisinin-based combination therapy) as the most effective treatment, as well as changing individual behaviour (through insecticide-treated nets, indoor residual spraying, epidemic preparedness and strengthening surveillance systems). Rarely do these international reports recognise the role of urban architecture, deforestation and agriculture activities behind malarial episodes for developing adequate responses. What is making this complicated is the rapid evolution of pathogens, which defeat the most carefully thought out human defence strategies and give rise to new pathogens (Woolhouse, 2005). The emergence and re-emergence of infectious diseases illustrate the intimate intertwining of disease dynamics with socio-political, cultural, economic, ecological and demographic changes (Bloom et al., 2007). These not only affect existing diseases and infections, but also introduce new, unknown infections.

National and international agencies adopt a ‘safe haven’ approach, on the presumption that safe water can, sourced either physically or technically, treat existing water sources and furthermore be a ‘most powerful preventive medicine’. However, such a ‘powerful medicine’ will soon be defeated given increasing populations, rapid urbanisation, the intensification of agriculture and a rapidly globalising world. This is further worsened by climate change, which is expected to reduce the availability of fresh water on Earth, especially in highly populated regions (Woodward et al., 1998; Ericksson, 2006). Populations in the fast-growing economies of the world are already living with poor water quality, for example people living along the Indo-Gangetic plains (polluted by geogenic contaminants) and urban and peri-urban regions around industrial clusters and urbanised regions. The impact of land mismanagement on health is even worse, as there is no clear understanding of its impact. This complexity reminds us of the comprehensive mapping of environmentally-related diseases, which has been initiated to assess drinking water quality (Rickwood & Carr, 2007; Briet et al., 2005; Gemperli et al., 2006 for mapping malaria risk in Africa and Sri Lanka). It involves physical mapping (to identify temporal and spatial patterns of environmentally-related diseases and risk-prone areas) and unpacks a complex set of local and global institutions, along with socio-ecological factors influencing environmentally-related disease.

Complexity contributes to different perceptions of and exposures to risk. These differences only contribute to incomplete and imperfect understanding of environmentally-related diseases, leading to considerable uncertainty in the decision-making process. Significant differences exist in the perceptions, human exposure, causes, sources and impacts of infections, diseases and pollutants on human health (Okeke & Okafor, 2008 for malaria; and differences in the incidence of diarrhoea). More complicated is the limited understanding of these impacts on human health, especially when many of them are revealed only after many years (such as health impacts from geogenic pollution and industrial and urban wastewater). This is further challenged by the interactive nature of different vectors, pathogens and pollutants once they are released into the environment, and then aggravated by global environmental change, which will bring new infections, diseases and disorders and cause considerable unknown health impacts on a global scale. In these uncertain times, risk assessment needs to place environmentally-related health at the centre stage to identify risks that are measurable, risks that we know, but are not measurable, risks that we are ignorant about and risks that we cannot determine. Health impact assessment (HIA) literature views health as a causal influence on one or two policies, programmes or projects, but rarely reflects the complexity of the environment and health as an integrated index of social, physical, institutional and political factors. Human health is not only an individual entity influenced by the biological functioning of the human body, the presence of genes, their nutritional status and their life history. It is also the collective property of a population

(McMichael, 2001), where the circumstances, experiences and dynamics of groups and populations (humans and pathogens) play an equally important role.

Complexity and uncertainty have placed humans (as individuals and as a group) in a position where they have to respond to different environmentally-related health impacts. Individuals, societies and national and international agencies respond differentially to health impacts depending on their perception and understanding. These differences result in different strategic actions taken by actors. National and international agencies respond to water-related diseases (such as malaria and diarrhoea) as a water-related problem, so the focus on water supply and sanitation and technical approaches to address malaria is vital. Nevertheless, Sommerfeld et al. (2002) argue that people believe etiological factors such as humidity and exposure to rain and cold are causative factors that influence malaria, in contrast to vectors and pathogens that are waterborne. While national and international agencies consider water-related diseases as 'deadly', common people in Africa consider these as 'common-illnesses'. Further, while national and international agencies go for 'scientific-technological solutions', common people go for home remedies, with visiting hospitals as the last resort. More complicating are the social strategies of discrimination (for instance due to geogenic and industrial pollution) against people affected by environmentally-related diseases, who are generally from the deprived sections of society, and mainly women and children. Understanding these different forms of strategic actions, their relative significance and the process of negotiations can help to resolve and adapt to the risk from environmentally-related diseases.

The strategic actions of individuals and societies are promoted by socially or institutionally distinct agents (Strydom, 2008), in order to adapt to the inadequacy of existing resources and institutional arrangements. Agents who mutually recognise risk embody different risk perceptions and risk management strategies in accordance with distinct modes of engagement with the world. These agents make sense of and act upon risk in multi-levelled networks – in and through which incoming information about a given risk reality is processed in a socially distributed way (Strydom, 2008). Examples include individual agents such as Sutradar for arsenic pollution in Bangladesh (Atkins et al., 2006; 2007) and downstream water users along the Noyyal River in Tamil Nadu, who use judicial activism to address pollution from upstream textile industries. Occupying different positions, yet parallel to one another, each of the participating agents frames and communicates mutually recognised risks in their own ways. In doing so, each of them contributes to the way in which the risk becomes collectively classified, understood and dealt with, which is not always efficient and desirable.

Complexity, uncertainties, strategic actions and agency question the simplistic emphasis on water supply and sanitation as a powerful preventive medicine. McMichael sums up the situation by emphasising that most contemporary attempts are "attuned to simple high school models of science, with clear-cut cause-effect relationships, most of us are yet to grasps the risks to human societies and health from these escalating changes to the world's complex non-linear systems, whether climate system or ecosystems" (Shetty, 2006:21). A comprehensive approach is the need of this hour that combines curative, preventive and adaptive approaches, where access to water and adequate sanitation is just one component of a larger programme. Here, the powerful medicine to address environmentally-related diseases emerges from the optimal combination of different interventions. This requires a comprehensive attempt to understand risk from the environment and human health and their interlinkage, in order to govern risk for a sustainable future, a future that is decided by multiple actors in a given context and socio-ecological condition.

5 CONCLUSION

The paper argues against a linear and simplistic view for addressing environmentally-related diseases. With a comprehensive review of the literature cutting across disciplines, the paper examines in-depth the ability of literature to define the incidence of environmentally-related diseases, the role of factors in influencing these diseases, their distribution across social and geographical scales and the adaptive capacity of society in managing these illnesses or disorders. The review, with a focus on water- and land-related diseases, reveals a fragmented understanding of the complex relationship between environment and health. Although these research studies and policy approaches provide ground for a curative – and in recent years calls for a preventive – approach, from a variety of disciplinary perspectives, as rightly concluded by McMichael et al. (2006:580), "little research has been done on the indirect pathways that link climate change to resultant social, economic, and demographic disruptions and their knock-on health effects". Research cutting across disciplines represents "an important input to international and national policy debates" (2006:581).

The review calls for a modern approach to predict and control the future consequences of human actions, in order to adapt to the risks and live in a 'risk society'. This will help in governing risk to sustain the livelihoods of deprived sections of the population against the growing challenges offered by environment. This requires a comprehensive understanding of risk (from water pollutants) by identifying the pathways of risk assessment, understanding the impacts from water pollutants, identifying a diverse set of strategies adopted by individuals and organisations, and the involvement of agencies in bringing change to existing institutions and bio-physical resources.

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ANNEXURES

Annexure 1: Sectoral Growth Rate – India and China

	India		China	
Sectoral Growth Rate	1980s	1990s	1980s	1990s
Agriculture	3.1	3	5.9	4
Industry	6.9	6.1	11.1	13.1
Service	6.9	7.9	13.5	8.9

Annexure 2: Water Quality Criteria in India

Designated best use	**Class**	**Criteria**
Drinking water source without conventional treatment but after disinfections	A	*Total coliform organisms MPN/100ml shall be 50 or less. *pH between 6.5 and 8.5 *Dissolved oxygen 6 mg/l or more *Biochemical oxygen demand 2 mg/l or Less
Outdoor bathing (organised)	B	*Total coliform organisms MPN/100ml shall be 500 or less *pH between 6.5 and 8.5 *Dissolved oxygen 5 mg/l or more *Biochemical oxygen demand 3 mg/l or Less
Drinking water source with conventional treatment followed by disinfection	C	*Total coliform organisms MPN/ 100ml shall be 5000 or less *pH between 6 and 9 *Dissolved oxygen 4 mg/l or more *Biochemical oxygen demand 3 mg/l or less
Propagation of wild life, fisheries	D	*pH between 6.5 and 8.5 *Dissolved oxygen 4 mg/l or more *Free ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, controlled waste disposal	E	*pH between 6.0 and 8.5 *Electrical conductivity less than 2250 micro mhos/cm *Sodium absorption ratio less than 26 *Boron less than 2mg/l

Annexure 3: Ambient water quality classification in China

Table 1. Ambient surface water quality classifications in China

Classification	Grade I[a]	Grade II[b]	Grade III[c]	Grade IV[d]	Grade V[e]
BOD^5	<3	3	4	6	10
Dissolved oxygen	90%[f]	6	5	3	2
Acidity (pH)	6.5	NS	NS	<8.5	6–9
Total phosphorous	0.02	L/R 0.025	0.1, L/R 0.05	0.2	0.2
Nitrates/nitrites	<10/0.06	10/0.1	20/0.15	20/1	25/1
Fecal coliform	NS	NS	10,000 U/l	NS	NS

Abbreviations: BOD^5, biological oxygen demand; L/R, lake or reservoir; NS, not specified. Data from Wang and Wang (*4*).

[a]Mainly applicable to water sources and national nature reserve areas.

[b]Suitable for grade I drinking water supplies, endangered fish reserves, and fish and shrimp breeding areas.

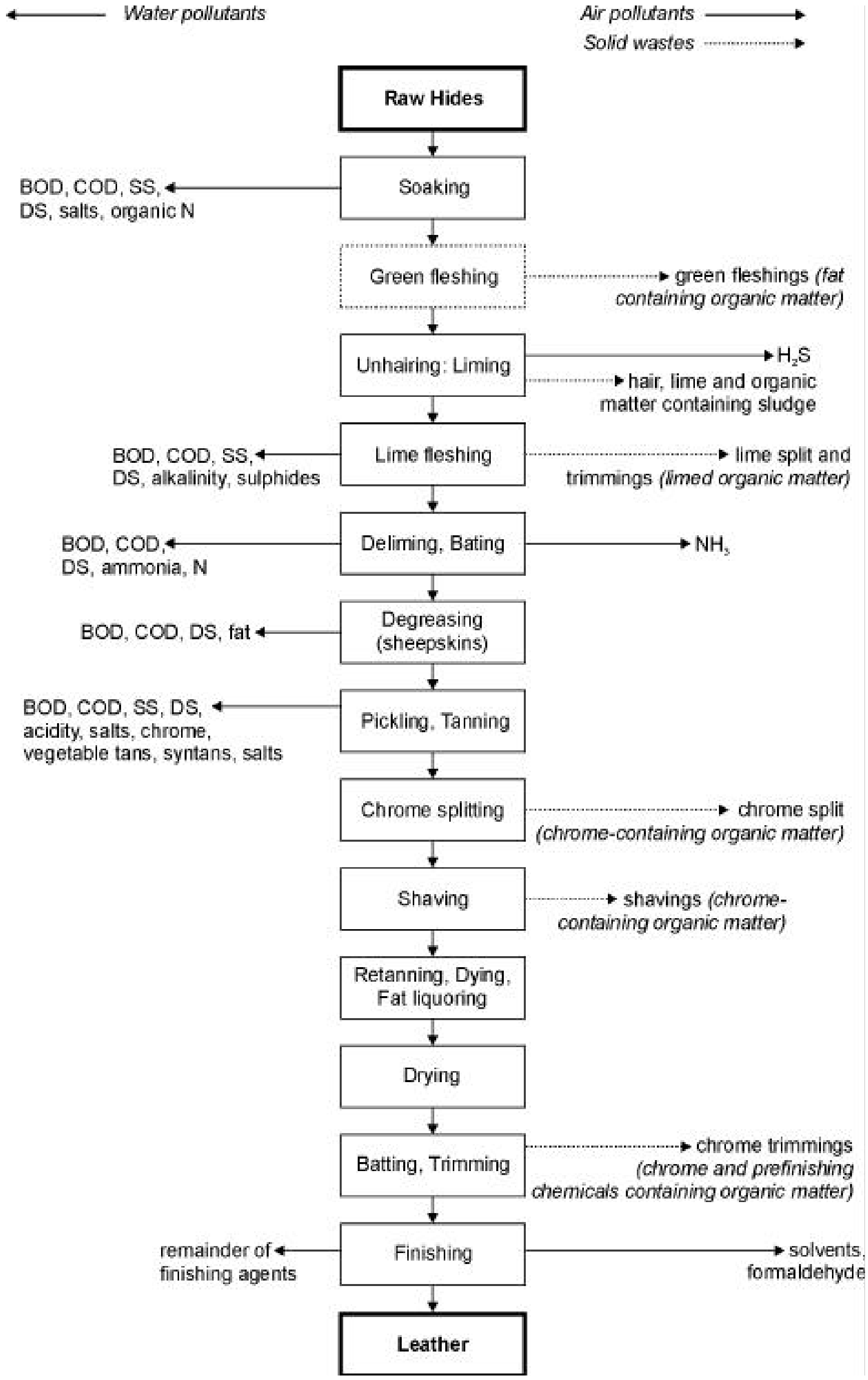
[c]Suitable for grade II drinking water supplies, general fish reserves, and swimming areas.

[d]Mainly suitable for general industrial purposes and recreational uses that do not involve direct human contact with the water.

[e]Mainly suitable for agricultural uses and general scenic purposes.

[f]Saturation rate.

Annexure 4: Process Diagram of Cow Hide Tanning and Finishing



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