Urban Wastewater: Livelihoods, Health and Environmental Impacts in India

Research Report

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Comprehensive Assessment of water management in agriculture

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Content

LIST OF TABLES

LIST OF FIGURES

LIST OF ANNEXURES

Annexure 22: Details of Sewage Farming in Class-I Cities 159

List of Acronyms

AMC	Ahmedabad Municipal Corporation
AUDA	Ahmedabad Urban Development Authority
AUWSP	Accelerated urban water Supply Programme
BCM	Billion Cubic Metres
BOD	Biological Oxygen Demand
CBD	Central Business District
Cd	Cadmium
CETP	Common Effluent Treatment Plant
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health & Environment Engineering Organisation
Cr	Chromium
CWC	Central Water Commission
DBM	diamondback moth
DDA	Delhi Development Auhority
DDT	Dichlorodiphenyltrichloroethane
DWF	Dry weather Flow
ECW	East Calcutta Wetlands
EPA	Environmental Protection Agency
FAO	Food & Agriculture Organization
GAP	Ganga Action Plan
GoI	Government of India
GT	Grand Trunk
Ha	*hectares*
HCH	Hexachlorocyclohexane
HDI	Human Development Index
HUDCO	Housing & Urban Development Corporation
ITRC	Industrial Toxicology Research Centre, Lucknow
IWMI	International Water Management Institute
KMC	Kanpur Municipal Corporation
LIC	Life Insurance Corporation
Lpcd	Litres per capita per day
MG	Million Gallons
mg/l	milligrams per litres
MGD	Million Gallons per day
mha	million hectare
MLD	Million Litres per day
MoEF	Ministry of Environment and Forest
MoWR	Ministry of Water Resources
MPN	Most Probable Number
MSL	Mean Sea Level
MTD	Million Tonnes per Day
NA	Not Available
NBRI	National Botanical Research Institute,Lucknow
NCT	National Capital Territory
NEERI	National Environmental Engineering Research Institute
NRCD	National River Conservation Directorate
NSS	National Sample Survey

NWP	National Water Policy
NWP	National Water Policy
PH	**p**otential of **h**ydrogen
SAR	Sodium Absorption Ratio
SCs	Schedule Castes
STP	sewage treatment plants
TB	Tuberculosis
TDS	Total Dissolved Solids
UASB	Upflow Anaerobic Sludge Blanket
USD	United States Dollars
WHO	World Health Organization
YUVA	Youth for Unity & Voluntary Action

Abstract

Wastewater use in agriculture leads to tradeoffs in terms of generation of livelihoods for producers on one hand, while offsetting the same by creating health and environmental risks at various levels on the other. There is a lack of systematic information on the topic, particularly on current best practices, costs/benefits of wastewater use in agriculture vis-à-vis social, economic, health and environmental parameters. In addition, there is no assessment of extent and significance of wastewater use at the national level for India. This study is a synthesis of in-depth case studies conducted in four cities—Ahmedabad, Kanpur, Delhi and Kolkata, using participatory techniques— focus group discussions, household interviews, semi-structured interviews of key informants, and laboratory testing of samples of water, soil and crop produce. Extent of wastewater use at the national level was assessed through the findings from these in-depth case studies combined with a review of literature on wastewater use in other cities in India. For this a typology was developed, categorizing wastewater into direct and indirect uses.

The results indicate that benefits from wastewater-agriculture are higher (as compared to freshwater-agriculture) for cities where industrial wastewater does not mix with urban sewage. At the same time, adverse health and environmental impacts are lower in such cities. There exist large numbers of beneficiaries in the production and marketing chains of agriculture/fishing produce from wastewater. However, it is also characterized by an inherent inequity in benefit distribution. It is estimated that wastewater contributes to irrigating 600,000 hectares in India. Though this is an insignificant proportion of the total irrigated agriculture in the country, wastewater-agriculture, nonetheless, requires adequate attention from policy makers due to the significant dependence of many marginalised producers and the scale of health risk it poses both to producers and consumers. Urban wastewater being three-fourths of total urban water supplied is potentially a considerable and more reliable water resource, which is likely to grow exponentially with the projected rapid urbanization of India. Given the urban demand and supply scenario of water in the foreseeable future, wastewater use emerges as a sustainable solution to urban wastewater management in a developing country like India.

Key Words: urban wastewater, agriculture, livelihoods, environment, health, national assessment.

1.0 Introduction

Since the late 20th century, management of urban wastewater has posed a serious challenge to planners in less developed countries on account of rapid urbanization. The large quantities of water that flow out as waste from any urban settlement, pose further challenges in the context of the onset of a global water shortage. In addition, cities in the developing world, also exhibit a novel phenomenon whereby a large population ekes out a livelihood from urban wastewater. This generates the much-needed employment and economic empowerment. As a side effect, however, such livelihood generation, in close proximity to untreated or partially treated sewage, gives rise to additional problems of health and adversely impacts the local environment.

1.1 Objectives of the study

The specific objectives of the study include:

i) To investigate through case studies: the current practices, costs and benefits of wastewater use in agriculture vis-à-vis social, economic, health and environmental parameters; identify best practices for mitigation of negative impacts; assess the replicability of potential cost-effective technologies in different agro-climatic and socio-cultural set-ups;

ii) To develop the methodology for and carry out a nationwide assessment based on secondary data and case studies on the extent and significance of wastewater use in relation to volumes of wastewater generated, volumes used, areas irrigated, families benefited, crops grown, and its impact on the national or local economy.

1.2 Case study selection, sampling and methodology

The approach included research at various levels-- macro (national), meso (city) and micro (sub-city) levels. Review of literature at the macro level helped select case study cities for meso/city level assessments. The city level assessment was carried out through review of secondary literature and semi-structured interviews of key informants. It helped select areas (sub-city) for micro level assessments through a primary survey.

1.2.1 Selection of Case studies

On the basis of data available on the quantities of wastewater generated, its treatment and mode of disposal in key urban centres and major river basins, and evidence of communities/farmers using wastewater for agriculture, four sites – Delhi, Ahmedabad, Kanpur and Kolkata- have been selected. One of the case studies (Kolkata) specifically focuses on documenting an innovative cost-effective approach to minimize the negative impacts of wastewater use through aquaculture. Specifically, by selecting these cities, an attempt has been made to capture the entire gamut of issues relating to wastewater use in agriculture in India. Further, an assessment of wastewater use has been contextualized through institutional, economic, and policy analyses of wastewater issues.

Specific advantages of selecting these four sites have been elaborated below:

Delhi and Ahmedabad: The two most polluted rivers of the country are the Yamuna and the Sabarmati with Delhi and Ahmedabad being the accountable cities. Delhi generates more than 3000 MLD (approximately) of wastewater. With sewage treatment plants' functioning erratically, wastewater enters the Yamuna partially/ untreated with a high BOD of 35 to 40 mg/l. Delhi alone generates 2,250 MLD of sewage. Some 3.5 lakh people live in the 62,000 jhuggies (in slums) on the Yamuna riverbed and its embankments. A large number of these practice farming on the riverbed. The city of Ahmedabad pours sewage and industrial effluents into the Sabarmati River, which has a BOD of 15 to 20 mg/l.

Kanpur: The city of Kanpur is on the banks of the river Ganga which is home to 47% of the total irrigated area in the country. The river is highly polluted and it passes alongside 29 Class-I cities; 23 Class-II cities and 48 towns of upto 50,000 people. It has been estimated that about $1.4 \times 106\ m^3$ of domestic wastewater and $0.26 \times 106\ m^3$ of industrial sewage flow into the river every day. The CPCB reports that three-fourths of the pollution of the river comes from the discharge of untreated municipal sewage, of which 88% is created in Class-I cities. Pollution is also caused by industrial wastewater, including effluents from tanneries, especially in Kanpur and from agricultural run-off containing residues of harmful pesticides and fertilisers.

Kolkata: Through this case, cost-effective intervention of treating wastewater through East Calcutta wetlands (natural wetlands) has been documented. Kolkata uses sewage water productively, by diverting a large part of the city sewage to the wetlands that forms the basis of extensive fish rearing. Kolkata handles approximately 3 m3/s of wastewater in 3,200 hectares of ponds to produce 2.4 T/ha/yr of fish. Three projects in the peri-urban areas of Kolkata have been taken up with the participation of local people, fishermen and the village council/ municipal government. The Kolkata Wetlands, consisting of some 30 km^2 of fishponds are the world's largest sewage-fed fish production sites. The effluence from the wastewater-fed fishponds is further used to grow non-monsoon paddy, a recent innovation compared to garbage vegetable gardens and wastewater-fed fishponds. However, there has been evidence that industrial pollutants such as chromium and cadmium find their way into the wetlands, which are causing adverse health impacts that are yet to be measured.

These four case studies contribute to the existing knowledge on urban wastewater use for agriculture in India by: (i) undertaking primary research on current practices, cost/benefits of wastewater use in agriculture vis-à-vis social, economic, health and environmental parameters, through in-depth case studies in four locations; (ii) identifying best practices for mitigation of negative impacts; and (iii) assessing replicability of potential cost-effective technologies.

1.2.2 The case studies

In-depth case studies were conducted in the above four locations in collaboration with local partners focussing on (a) quantifying and documenting the impacts and current dynamics of wastewater use; and (b) documenting cost-effective interventions for wastewater use in agriculture. For each, the current agricultural practices, poverty reduction and livelihood impacts, health risks, environmental impacts, and mitigation strategies were studied.

At the onset, review of secondary literature to understand the meso level (city level) physical (including environmental), social and institutional context of wastewater is used in agriculture/aquaculture. It helped in identifying, geographical areas (including urban/ peri-urban settlements and villages) and key informants for semi-structured interviews. In addition, it provided a general understanding of the diversity and extent of various impacts (livelihood, environmental and health) in these geographical areas. FGDs were also used to analyse the chain of economic beneficiaries along crop and fish marketing chains (in Delhi, Kanpur and Kolkata) to gain an understanding of actors and qualitative figures of the benefits at various nodes of the chain. The geographical areas in the four cities, thus covered, included areas along the riverbanks and/or along effluent channels from treatment plants. The areas covered in case study sites are as below:

Sample size and selection of respondents

In each of the case study sites, households were selected covering different castes, landholding status (leased or owned), and gender categories. The sample size in four case studies is as below:

Ahmedabad: The survey included village Gyaspur falling within city limits where 289 households were surveyed[1].

Kanpur: The Jajmau area within the city limits where wastewater is directly used for agriculture from the sewage channel. Three villages were selected in this area--Pyondi, Sheikhpur and Motipur located at 200m, 1500m and 2500m from the off take point of the sewage channel. In all 193 households were interviewed.

Delhi: Areas around Keshopur STP (Keshopur Village, Nilauthi, Ranhaula, Mundka, Bakkarwala) and Okhla STP (Madanpur Khadar and Jaitpur) using wastewater directly from sewage channels from these STPs carrying treated effluents. Here the wastewater is used for agriculture and aquaculture. Interviews of 80 farmers, 12 medical practitioners (health impacts), income-differential (comparative study of two fields dependant solely on groundwater and wastewater from the areas) were conducted.

[1] In addition, villages lying on the banks of the most severely polluted stretch of river falling in Ahmedabad and Kheda districts were surveyed to study the pattern of impact across the longitudinal section of the river. They are Asamli, Bakrol, Chitrasar, Fatehpura, Navapura, Rinza, Saorda and Vautha. Beyond Vautha, the Sabramati river gets diluted by the Watrak tributary.

Kolkata: Area in and around East Calcutta Wetlands (ECW) using wastewater directly. Villages surveyed include Bantala, Chowbaga, Panchannagram, Boinchitala, Durgapur, Krolberia, Bamonhata. In all, 432 households were interviewed from these villages practicing fishing and agriculture. These are villages along the Dry Weather Flow canal.

Methodology for case studies

Field data collection

Data was collected through various participatory techniques including PRA, FGDs (using a check list with different community groups) and household questionnaires. PRAs and FGDs helped understand the history of wastewater use and differential impacts across caste/class and gender, and also triangulate data collected through household interviews. Separate FGDs were organised for agricultural producers, vegetable growers, and fisher folk. The FGDs were also useful to select stratified households to administer the household questionnaire.

The household questionnaire included parameters such as family size, literacy level, land holding, cropping pattern, crop productivity, and irrigation practices, cattle holding, health problems and the perception on environmental degradation.

A comparative economic analysis of agriculture and fish rearing (cost of inputs and income from sale of production) was carried out for wastewater and freshwater irrigated areas in all the four sites for major crops.

In addition, tests with the help of accredited laboratories were carried out for a limited number of water samples (surface water and groundwater), soil samples from agricultural land, agriculture and vegetable produce, and fish. It provided anecdotal evidence on the levels of contamination.

Consultations with local policy makers/planning authorities

In each case study area, key informants/ institutions (government, non government, and academia) were identified in urban wastewater, to obtain information from and to share the research findings with the view to engage them in the project processes and uptake of results.

1.2.3 National assessment

The National assessment includes the current situation on the extent and significance of wastewater use for agriculture in India. Results of this assessment are based on secondary data on quantities of urban wastewater generated, nature of treatment, extent and significance of use in select urban centres in India, and primary data generated through the four case studies.

2.0 History of Wastewater Use

Wastewater (raw, diluted or treated) is a resource of global importance, particularly in an industrialized urban context. In many developing countries, especially those affected with water shortage or scarcity, access to fresh water for irrigation is limited and therefore both treated and untreated wastewater is used.

Wastewater use was a common practice much before the urbanized world emerged. Night soil has been used to fertilize crops and replenish depleted soil nutrients since the ancient times in China and in other areas of Asia. The earliest sewage farms documented were those of Bunzlau in Germany, which were in operation in 1531[2] and of Edinburgh in Scotland active around 1650[3].

With industrialization and subsequent water carriage sewerage system, interest and effort in wastewater utilization through farming and land application grew. The First Royal Commission on Sewage Disposal in England gave its official approval to the practice. In its report of 1865, the Commission stated, "The right way to dispose off town sewage is to apply it continuously to the land and it is by such application that the pollution of rivers can be avoided."[4]

However, sewage farming waned in the early twentieth century, and even completely abandoned in most areas of the highly urbanized industrial countries of the western world. All this changed after World War II when a new thrust of scientific and engineering interest in wastewater reuse developed in both industrialized and developing countries. Subsequently, sewage farming was adopted in many of the rapidly developing countries faced with water shortages and insufficient waterways to dilute and dispose off municipal wastewater. A number of governments even officially approved wastewater land application or wastewater reuse as part of their water pollution control policy and water resources management program. For example, the Five-year Plan of the Government of

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[2] Gerhard, Wm. Paul, *The disposal of household wastes: a discussion of the best methods of treatment of the sewage of farm-houses, houses in villages and of larger institutions,* D. Van Nostrand Company, New York :1890 (available at http://hearth.library.cornell.edu/cgi/t/text/text-idx?c=hearth;idno=4800136)

[3] Stanbridge, H. H., 1976. The History of Sewage Treatment in Britain. The Institute of Water Pollution Control, Maidstone, Kent, England.

[4] ibid

India also emphasized on conservation, augmentation and recycling of urban water. It advocated reuse of treated sewage in view of the fact that water is going to become scarcer. Such policy support now stands to establish, to a certain extent, the issue of wastewater use within the overall water policy in India.

With such developments, wastewater reuse is becoming widely accepted once again. India is the seventh largest country in the world with a landmass of 3.29 million square kilometers and a population of over a billion. Contrary to popular concepts of a predominantly rural India, an increasingly larger percentage of the Indian population is now residing in urban areas. Over the last 50 years, while the country's population has grown by two-and-a-half times, in the urban areas it has grown by five times. By the turn of the millennium, an estimated 305 million Indians shall be living in nearly 3,700 towns and cities spread across the length and breadth of the country.[5] With rapidly increasing urbanization, the magnitude of problems such as groundwater depletion, water logging, water pollution and increasing salinity levels will and is, multiplying, affecting the overall quality of life in urban areas.

Sewage generation from urban centres in India has grown from about 5 billion litres a day (bld) in 1947 to around 30 bld in 1997. Untreated wastewater carrying chemicals is held primarily responsible for the deterioration in water quality and contamination of lakes, rivers and groundwater aquifers. According to the Central Pollution Control Board (CPCB), 16 bld of wastewater is generated from Class-1 cities (population >100,000), and 1.6 bld from Class-2 cities (population 50,000-100,000). Of the 45,000 km length of Indian rivers, 6,000 km have a bio-oxygen demand above 3 mg/l, making the water unfit for drinking (CPCB 1998).

Options for managing urban wastewater pose a serious challenge to planners in the context of a growing urban population in the developing world. In the context of the onset of a global water shortage, the problem becomes even more serious. There is also the challenge of safe disposal of this huge quantity of urban sewage. In addition, an Indian city, beset with problems of abject poverty, has a large urban population eking out livelihoods from urban wastewater.

[5] National Assessment of Wastewater Generation and Utilization, A Case of India (July 2005) YUVA, Mumbai

Owing to severe infrastructure deficits in urban India, the quality of life for the average urban and consequently the peri-urban citizen is on the decline. It is necessary, therefore, to look at alternative and more sustainable ways of providing services within the given constraints in urban India.

Literature review and assessment of current initiatives

Wastewater use in agriculture is age old, but the legal and regulatory efforts to develop mechanisms to control its negative impacts are relatively recent. WHOs international guidelines on wastewater reuse in agriculture and aqua-culture and recommendations of wastewater treatment and crop restrictions, the World Health Organization (WHO) formulated international guidelines on wastewater reuse in agriculture and aqua-culture in 1989. The WHO's recommendations of wastewater treatment and crop restrictions are considered by many governments as the legal framework, though they are not intended for absolute and direct application in every country. While focusing on treatment and crop restrictions, the WHO guidelines pay inadequate attention to the problems of high cost involved in construction and operation of treatment plants. Authorities are therefore faced with two difficult options: either treat rapidly growing volumes of wastewater and bring it within safe limits for agricultural use, or try to stop wastewater use among the users which would deprive many households of their livelihood. The result of this situation is often that wastewater use and users are ignored and the practice of untreated wastewater use is denied.

A survey of relevant literature on India indicates that some research on wastewater use in agriculture has taken place including on development of low-cost, appropriate, and decentralized treatment technologies for treatment of wastewater in the country. Decentralized, small-scale, community operated systems and stabilization tanks have been built for successful use for fisheries (Kolkata). A similar experiment has been carried out in Pune, where after pre-treatment through anaerobic ponds, lotus and water lily are grown in a maturation pond, which renders the water colourless and odourless and the treated water re-circulated to create a waterfall. Other countries have experimented with a few techniques like up flow filter and vermin-filter. Duckweed production in excreta or sewage-fed ponds has found increasing attention recently. Other experimental options include source reduction, reduction in degree of faecal contamination of water through use of environmental sanitation technologies (Peru and Mexico) and domestic filtering of soapy water for gardens. For addressing industrial pollution of surface water bodies, possible solutions that emerge include sound regulation, proper zoning, registration and monitoring of industries and financial and technical incentives for waste minimization.

Other lessons from past or on-going work include IWMI action research with farmers (Mexico, Pakistan, Vietnam and Ghana) showing that most urban/peri-urban farmers, in spite of the risks involved, view the presence of domestic sewage in their water source as a benefit providing plant nutrients. In general, the common point of view of researchers, decision-makers, and service providers has been holds that the use of untreated wastewater in agriculture is unacceptable and that only appropriately treated water yields important benefits. Though it cannot be denied that treatment is extremely desirable, the approach seems to have has resulted in a marginalization of poor wastewater farmers unlikely to benefit from treatment of the wastewater that they use or from alternative water sources any time in the near future. This to a great extent, can be attributed to (and therefore calls for further research) lack of systematically collected information, particularly on issues such as farmer’s needs and preferences, health and environmental risks, and economics of using wastewater for irrigation.

3.0 Diverse Uses of Wastewater

3.1 Agricultural Irrigation

Farmers have used wastewater for irrigation to compensate for scarce or costly freshwater resources. Roughly 10 % of the world's wastewater is currently being used for irrigation. In developing countries, especially China and India, an estimated 80% of wastewater may be used for irrigation (Cooper, 1991). It is estimated farmers irrigate an estimated 20 million hectares using partially diluted or undiluted wastewater, a practice that sustains the livelihoods of millions of poor people in Asia, Latin America, the Middle East and parts of Africa. In fact, in many countries there are more hectares under informal irrigation with polluted urban stream/drain water than in formal irrigation schemes. Nutrient cycling and a reliable water supply to farmers have been the predominant objectives of wastewater irrigation for centuries.

Increasing volumes of domestic, hospital and industrial wastewater are being produced in cities around the world. Cities in developing countries lack resources to treat wastewater before disposal. Institutional support and legislation for pollution control is weak. Even where expensive wastewater treatment plants are installed, only a small percentage of the total wastewater volume is treated before discharge (only 4000MLD out of 17,600 MLD wastewater generated in India is treated) resulting in rivers, lakes and aquifers becoming severely contaminated. Approximately 30,000 MLD of pollutants enter India's rivers, 10,000 million litres from industrial units alone (CPCB).

According to the Central Pollution Control Board (CPCB), 16,000 MLD of wastewater is generated from class 1 cities (population > 100,000), and 1600 MLD from class 2 cities (population 50,000 - 100,000). Of the 45,000 km length of Indian rivers, 6,000 km have a bio-oxygen demand (BOD) above 3mg/l (milligrams per litres), making the water unfit for drinking.

There is growing concern about the quality of water available for irrigation due to the increased implication of wastewater use for the hydrology of many river basins. Rapidly increasing urban populations and industries lead to increased wastewater production with its contamination becoming more complex. It includes industrial wastes, such as heavy metals, acids and derivatives of plastics, and organic components characteristic of human wastes.

Worldwide, wastewater constitutes a significant portion of the irrigation water. Hussain *et al* (2001) report that at least 20 million hectare (mha) in 50 countries are irrigated with raw or partially treated wastewater. It is estimated that estimated that one-tenth or more of the world's population consumes foods produced on land irrigated with wastewater[6]. Wastewater can be used to substitute other better-quality water sources, especially in agriculture – the single largest user of freshwater.

Wastewater is being used increasingly for irrigation in urban and peri-urban agriculture, and even in distant rural areas downstream of the very large cities. It drives significant economic activity, supports countless livelihoods, particularly those of poor farmers, and very substantially changes the hydrology and water quality of natural water bodies.

In both developing and developed countries, the most prevalent practice is the application of municipal wastewater (both treated and untreated) on land. In developed countries where environmental standards are enforced, most of the wastewater is treated before it is used for irrigation of fodder, fibre and seed crops. In developing countries, lack of control and monitoring mechanisms lead to either mixing of untreated and treated water or use of industrial wastewater. Other important uses of wastewater include recharging groundwater, landscaping, industry, construction, dust control, wildlife habitat improvement and aquaculture. Wastewater use has the advantage of limiting the pollution of rivers and other surface bodies that would otherwise be used as disposal outlets.

The market for adoption of advanced technologies for the wastewater use arising from industries and municipal corporations' accounts for largest percentage of total environmental market in India. As per a survey by the US Trade department, the total market potential for water and wastewater treatment including the requirements of Municipal and Industrial sectors is estimated at US $ 900 million and is expected to grow

[6] Smit, J, Ratta A and Nassr J. (1996) 'Urban Agriculture – Food, Jobs and Sustainable Cities'. Publication Series for Habitat II Vol. I New York: United Nations Development Programme

at approximately 14% each year in the mid-term[7]. Industrial wastewater treatment is arguably; the largest segment, accounting for nearly half of the total market sizes. The water and wastewater treatment sector also accounts for the highest environmental spending within both the public and private sectors[8]. With the functioning and operating of Wastewater treatment plants, being a costly affair, the local bodies need to look at alternate ways of disposing off or recycling wastewater generated by the growing populations.

[7] Swiss Business Hub India & Heinz Habegger, Baleco AG, Thun, *Market Report: Opportunities for Environmental Technology in India. Focus on Water, Air and Hazardous Waste,* Swiss Business Hub India, 2004

[8] ibid

Table 1: Selected examples of wastewater reuse in agriculture

America		Asia	
Mexico	Cereals, vegetables, fodder, parks	Kuwait	Cereals, fruit trees, fodder
Peru	Vegetables, fodder, cotton	Jordan (indirect)	Vegetables, crops consumed processed
Chile	Vegetables, grapes	Israel	Cotton
Argentina	Vegetables, fodder	Saudi Arabia	Cereals, fodder
USA (California)	Vegetables, cereals, fodder	India	Cereals, vegetables
North Africa			
Tunisia		Citrus, fodder	
Morocco		Vegetables, fodder	

Source: Strauss, Martin. Reuse of urban wastewater and human excreta, EAWAG/SANDEC, Switzerland available at

www.ruaf.org/files/**Reuse_wastewater_in_UA_0.pdf** accessed on 25.12.2006

Some of the advantages of wastewater reuse in agriculture are given below:

- Conserves water (by recycling and groundwater recharge)
- It is a low-cost method of sanitary disposal of municipal wastewater
- Reduces pollution of rivers and other surface water
- Conserves nutrients, thereby reducing the need for artificial fertilizer, increases crop yields, crop density and provides a reliable water supply to farmers even in the lean season

Wastewater has been widely used in agriculture in various parts of the world. Generally, both treated and untreated sewage is used in irrigation but treated sewage is used more often, and primarily in vegetable cultivation. Certain countries restrict the type of crops that can be grown using wastewater. For instance, the Tunisian Water Law prohibits use of wastewater for growing crops that are consumed raw (Pescod, 1992). In Mexico, regulations state that no vegetables or fruits can be irrigated with untreated wastewater. Hence, wastewater is used to irrigate only low-value grains (maize, sorghum and wheat) and fodder (alfalfa).[9]

3.2 Aquaculture

The potential of wastewater in enhancing the yield of fish and aquaculture crops is well established (Hickling 1971; Jhingram and Ghosh 1988; Hauck 1978). Allen and Hepher (1979), in a review of wastewater aquaculture, indicated that wastewater-fed ponds produce high fish yields because of increase in the natural food organisms through fertilization by inorganic matter. A wide range of yields has been reported from waste-fed aquaculture systems, for example 2-6 tons per hectare per year in Indonesia; 2.7-9.3 tons per hectare per year in China; and 3.5-7.8 tons per hectare per year in Taiwan. Management of fishponds can have a significant effect on fish yields but the maximum attainable yield in practice is 10-12 tons per hectare per year.

The East Calcutta sewage fisheries are the largest single wastewater use system in aquaculture in the world (Pescod, 1992). Farmers here developed a technique of using domestic sewage for fish culture almost a century ago. Nutrients, mainly nitrogen and phosphorus, are absorbed by large aquatic plants such as duckweed cultivated for animal

[9] Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), Spatial Decisions, New Delhi

feed, and aquatic vegetables such as water spinach for human consumption. Thus, some degree of natural treatment is provided to wastewater. Currently, the area under the sewage-fed culture system is reportedly around 4,000 ha and generates around 50 percent of the high priced fish.[10] About 93 percent of the sewage-fed ponds are privately owned, employing nearly 4,000 families as fishermen. There are also several fishermen cooperatives. In the Kolkata case study, it was observed that an increase in sewage would increase production of fish.[11] On the other hand, when wastewater was treated and used in aquaculture, fish production declined.[12]

3.3 Floriculture/Horticulture

Wastewater quality for floriculture or horticulture varies with the type of flower/ornamental crop. For example, flowers produced for the cosmetic/ pharmaceutical industry must be irrigated with adequately treated wastewater to minimize the presence of toxics in the crop. On the other hand, flowers/plants produced for purely ornamental/decorative purposes may be grown on raw wastewater or primary treated wastewater.

Both floriculture and horticulture have tremendous potential to augment livelihoods of farmers owing to the higher selling value of the crops. Both practices pose minimal health impacts owing to low chances of direct consumption.

In some areas in Delhi, such as Mehrauli, Nilauthi and parts of the Yamuna riverbed, floriculture/horticulture is practiced, but farmers use mostly groundwater. They contend that most flower crops and decorative plants are sensitive to fluctuating levels of toxicants in wastewater. However, if properly treated wastewater is supplied to farmers in these areas, better incomes can be predicted.

In cities like Chennai and Hyderabad, though, farmers use wastewater on a large scale for floriculture. In areas near the Sabarmati River, horticulture was profuse till the quality of wastewater started deteriorating. Hence, stability in supply of treated wastewater can

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[10] National Assessment of Wastewater Generation and Utilization, A Case of India (July 2005) YUVA, Mumbai

11 Urban Wastewater: Livelihoods, Health and Environmental Impacts in India; The Case of the East Calcutta Wetlands; Dr. Gupta, G; Jadavpur University, pp 40

[12] Ibid

open up new livelihood opportunities in other urban and peri-urban areas across the country.

3.4 Industrial Use: Cooling and Process Water

Based on location and availability, treated wastewater can be used for various industrial purposes such as cooling and in boilers. Boilers generally require high quality water, but wastewater, after secondary level treatment can be safely used in cooling towers of industries. Chennai is a pioneer in such wastewater reuse in the country.[13]

(See Table 2 for trends in wastewater use in study areas)

[13] National Assessment of Wastewater Generation and Utilization, A Case of India (July 2005) YUVA, Mumbai

Table 2: Trends in wastewater use in study areas

Area of Study	Past Use	Present Use	Significance
Ahmedabad	Situated on the banks of the Sabarmati river, the water has always been used for irrigation. In some villages horticulture used to be the main income generating activity. This indicates that at some time water used for irrigation was beneficial to the community	Wastewater remains the chief source of irrigation water in the villages along the banks of the river. Presently 90% of the land area is irrigated with wastewater. At present, the onus is more on paddy and wheat than horticulture. However, over the years there has been a decline in yield.	The farmers claim that with the water getting polluted, the fruit-bearing capability of the orchards has reduced considerably over the years. The pollution has taken a toll on the agricultural crop pattern, as well as soil fertility in this village
Delhi	Till sometime ago, wastewater generated in Delhi was used mostly for agricultural irrigation and aquaculture	At present, diverse uses of wastewater are being largely experimented with and considered but the reuse pattern remains the same, which is mostly agriculture, aquaculture and industrial cooling	In a growing scarcity-demand scenario, there will be push factors that would enable newer and more innovative use of wastewater. As of now the wastewater is augmenting local livelihoods.
Kanpur	The sewage farm scheme was launched by the Central Government in 1951 to check pollution of River Ganga and increase agricultural production in the area. Villages in the downstream of the Ganga at Kanpur have been receiving city wastewater for irrigation since the early 1950s.. Respondents agreed that initially this had led to good harvests and increase in production	At present farmers, mostly marginal, are irrigating 1,253 acres of land to harvest both Ravi and Kharif crops. However, they unanimously agreed that for the past many years now the quality of the wastewater has deteriorated, adversely affecting crop production. The usage pattern has not changed since agriculture clearly remains the biggest consumptive activity related to wastewater.	Change in the quality of wastewater has led to an adverse impact on the livelihoods of the people. Both crop and milk production has decreased. Consequently, conflicts have arisen as farmers have refused to pay the money charged for sewage irrigation water since 2000 because the water contained alarming levels of heavy metals and other toxicants. Yet the use of wastewater and subsequent sale of crops and vegetables occupy 70% of the economy.

Area of Study	Past Use	Present Use	Significance
Kolkata	Farmers around Kolkata developed a technique of using domestic sewage for fish culture almost a century ago. The large-scale use of sewage for fish culture began in the 1930s. The area around the wastewater fed wetland became a viable area for growing vegetables, provided stimulus for large-scale expansion of sewage-fed fish culture system. During the 1960s, 2,400 ha of fisheries were converted to paddy cultivation by the landowners, which marked the beginning of paddy cultivation in the area as well.	Paddy cultivators have decreased in number over the last 10 years. Most of them have sold off their land for reclamation for developing the city. In the East Calcutta Wetlands (ECW), the major source of income remains aquaculture using urban wastewater. Garbage farming takes place in areas where the city waste is dumped officially. Paddy cultivation in small fields is carried out in the interior regions of the ECW. Floriculture using wastewater is a recent activity which is gaining popularity.	Wastewater has become an effective tool to enhance livelihoods in the area. Health problems are yet to be a major cause of concern. The main change in the scenario is the encroachment of common lands either by the state or by private parties

4.0 Key Issues Related to Use of Wastewater

Wastewater has high potential for reuse in agriculture; an opportunity for increasing food and environmental security, avoiding direct pollution of rivers, canals and surface water; conserving water and nutrients, thereby reducing the need for chemical fertilizer; and disposing of municipal wastewater in a low-cost, sanitary way. However, wastewater use poses a number of health and environmental risks for users and communities in prolonged contact with wastewater; for consumers of such produce and for neighbouring populations due to contamination of groundwater and creation of habitats for mosquitoes and other disease vectors. Important health risks include the transmission of intestinal infections to agricultural workers in wastewater-irrigated fields and to consumers of waste-water irrigated produce due to worms and the transmission of faecal bacterial diseases, like diarrhea, dysentery, typhoid and cholera.

The key issues pertaining to the treatment, use, application and impact of wastewater are dovetailed with livelihoods, health, environment and policy concerns. What is important is to look at mitigating the negative impacts on the beneficiaries of wastewater use and link up such use with sustainable livelihoods outcome.

The project reveals that in all four study areas, the dependence of the marginalized on wastewater as a resource is high. However, such dependence also results in prolonged contacts that may or may not affect their health and well-being. Being at the bottom of the socio-economic ladder, such communities do not have the necessary fall back mechanisms to mitigate the risks involved in the use of wastewater. Within such communities, there are further marginalised subgroups, namely women, children and the aged. In certain activities, especially growing vegetables and selling them, women acquire a lead role. Hence, their scope for economic empowerment is coupled with health risks due to exposure to contaminated water. In Kanpur, children, unaware of the dangers from such water, have got affected and ended up with acute skin and gastric disorders. In Kolkata, however, negative health impacts are yet to be seen, as the community seems to be well aware of the potential health risks and have taken precautions using indigenous knowledge. For example, even after working in wastewater for long hours throughout the year, they do not suffer from skin diseases as after work they clean themselves with soaps in freshwater. Moreover, they often apply oil made of local herbs. This prevents the pollutants to stick to their body while they are working in the sewage-fed fisheries.

The use of wastewater is linked to issues of land since the larger application remains rooted to agriculture. In Kolkata, most of the common land has been acquired by private players who manage the wetlands for commercial purposes. Most land in Ahmedabad, near the Sabarmati, is private agricultural fields, though quite a good percentage is left out as commons on which agriculture also is practised. In Kanpur, however, the municipal and urban development authorities lease out land in the drainage area of sewers to the farmers and even supply wastewater for irrigation for a certain cost. Conflicts, too, have evolved regarding payments ever since the farmers protested about the quality of wastewater supplied, which was untreated and affecting agricultural productivity while increasing health problems.

Talking about markets, while the fish and vegetables bred and grown in untreated sewage in Kolkata are valued in the markets, those from Kanpur, especially from areas affected by pollution, are not. See Table 3 for some major issues related to wastewater use.

Table 3: Key Issues Related to Use of Urban Wastewater

	PERCEIVED ADVANTAGES	DISADVANTAGES	REFERENCE
LIVELIHOODS	Wastewater and its nutrient content can be used extensively for irrigation. Its reuse can deliver positive benefits to the farming community. This has been noticed in Delhi especially with vegetable farming[14].	Some farmers reported that the soil fertility had declined over the years leading to decreased crop productivity. The farmers attributed it to bad quality of wastewater[15].	Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 5, pp 2 Spatial Decisions, New Delhi.
	Due to the presence of nutrients in wastewater, the need to apply external fertilizers is reduced. Most farmers in Delhi also reported the soil quality of their land to be enhanced in the past few years with the application of treated wastewater.	Uses of wastewater and consequent impact on livestock health have also resulted in a drop in milk production in Kanpur. This has lowered the income levels especially of those communities which earn their livelihoods by selling milk in nearby markets since their cost of producing milk per unit has gone up. (see Annexure 2). The same concern in repeated in Hyderabad[16] in a study conducted by IWMI.	Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 4, pp 2 Spatial Decisions, New Delhi. & Impact of Wastewater on Livelihoods, Health and Environment, Kanpur Case Study (April 2005), ECOFRIENDS, Kanpur, pp 83
	According to the farmers of Delhi and Ahmedabad, wastewater provides a reliable water supply to farmers even in the lean season.	Loss of soil fertility was reported in almost all researched villages in Ahmedabad where farmers complain soil becoming more compact and losing its	Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 4, pp 2 Spatial Decisions, New Delhi,

[14] See Annexure 1: Comparative Study of Income Generation Using Ground Water vis-à-vis Wastewater of Income Generation Using Ground Water vis-à-vis Wastewater

[15] Qualitative information gathered from survey of researched farmers

[16] Buechler, Stephanie & Gayathri Devi Mekala, *Innovations among Groundwater Users in Wastewater Irrigated Areas near Hyderabad, India*, prepublication paper prepared for the IWMI-Tata Annual Partners' Meet, 2004 (draft).

	PERCEIVED ADVANTAGES	DISADVANTAGES	REFERENCE
	It has been observed that wetland ecosystem of Calcutta supports 1 lakh direct stakeholders and 5.1 thousands hectares of cultivation. It provides annually direct employment for about 70,000 people, produces 1.28 lakh quintals of paddy, 69,000 quintals of fish and 7.3 quintals of vegetables. It also generates revenue of Rs.266 million and net returns of Rs.80 million[17].	moisture retention capacity. Yields are decreasing and loss of standing crops suddenly dry up due to no rational explanation. This may be attributed to excessive presence of heavy metals in the soil. (see Annexure 3) Similarly, in Kanpur study of comparative returns from agriculture in freshwater and wastewater shows negative impact on productivity due to wastewater agriculture (see Annexure 23)	chapter 4, pp 2 & Impact of Wastewater on Livelihoods, Health and Environment: Ahmedabad Case Study, 2005, ch 3, pp 16
HEALTH		Health problems occur due to the presence of mosquitoes in and around the fields irrigated with wastewater. During the field surveys conducted in Delhi, it was observed that vector related troubles were more severe in fields which were over irrigated and had problems of standing water[18]. In such areas, medical practitioners reported the frequent occurrence of Malaria, Fevers etc. which could be associated to the presence of disease causing mosquitoes[19].	Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 6, pp 4, Spatial Decisions, New Delhi.

[17] Chattopadhyay, Kunal (2004) 'Jalabhumir Kolkata' – a fact-finding observation of East Calcutta Wetlands. Kolkata, (publisher unknown).
[18] Farmers response to researchers
[19] Response by local medical practitioners to researchers

	PERCEIVED ADVANTAGES	DISADVANTAGES	REFERENCE
		Results from test village in Jajmau in Kanpur show that the Faecal coliform count far exceeded the WHO & FAO standards for raw sewage that is most often supplied as irrigation water in Jajmau villages. Hence there is a possible health risk for the irrigators and communities who are in prolonged contact with untreated wastewater (eg, in Kanpur) and the consumers of vegetables irrigated with wastewater. (see Annexure 4)	Impact of Wastewater on Livelihoods, Health and Environment, Kanpur Case Study (April 2005), ECOFRIENDS, Kanpur, pp 54
		In Ahmedabad, most people interviewed complained of gastric disorders (digestion, constipation, stomach distension and acidity) & Skin disorders (included itching, dark patches appearing on the skin, lesions and sores.)[20]	Impact of Wastewater on Livelihoods, Health and Environment: Ahmedabad Case Study, 2005
		In absence of secondary treatment plant in Ahmedabad the level of pollutants are very high in wastewater in terms of TDS and BOD levels. (see Annexure 5)	National Assessment of Wastewater Generation & Utilisation: A Case Study of India, Final Report YUVA, Mumbai, 2005

[20] This statement was based on responses by villagers to the researchers.

	PERCEIVED ADVANTAGES	DISADVANTAGES	REFERENCE
ENVIRONMENT	If utilized to the maximum possible levels, the reuse of wastewater can be treated as a measure to reduce stress on limited ground and surface water resources. With the increase in demand for potable water, this reduction in stress over ground water resources is critical. At present, approximately 57 MG per Year of wastewater is being utilized for agricultural purposes. With the available 42,000 hectares of agricultural land in Delhi, there is a potential for diverting approximately 1400 MG per Year of wastewater for agriculture saving a corresponding figure of surface & ground water.	In survey areas in Kanpur, the wastewater was found to be contaminated with high levels of the toxicants. It was laced with deadly chemicals used by leather and other factories of Kanpur. This wastewater is being used as irrigation water for the last 15 years that has led to contamination of the surface and ground water, soils, crops, other vegetations and food. (see Annexure 6 for details of tests)	Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 7, pp 1-2, Spatial Decisions, New Delhi.
	As per the views of the farmers surveyed in Delhi, soil quality in almost all areas irrigated with this water was good. The productivity of the soil was reported to increase with application of treated effluent.	In surveyed villages in Ahmedabad soil fertility loss was reported by farmers. It is becoming more compact and losing its moisture retention capacity.	Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 7, pp 1-2, Spatial Decisions, New Delhi. & Impact of Wastewater on Livelihoods, Health and Environment: Ahmedabad Case Study, 2005,ch 3 pp 13

	PERCEIVED ADVANTAGES	DISADVANTAGES	REFERENCE
	Analysis of soil, vegetable and fish samples grown on wastewater in and around the East Calcutta Wetlands do not show any threat from heavy metals as all under permissible level. Sewage effluent in ECW is very rich in nutrients and organic matter and facilitates growth of fish populations.		Gupta, Gautam Dr., Urban Wastewater: Livelihoods, Health and Environmental Impacts in India: The Case of the East Calcutta Wetlands, Department of Economics, Jadavpur University, pp 50-55
WATER QUALITY ISSUES	Wastewater use has the advantage of limiting the pollution of rivers and other surface bodies that would otherwise be used as disposal outlets. Usually treated/untreated/polluted wastewater is discharged in the end into river bodies. For example, in Kanpur, a raw sewage drain, which also contains contaminated discharge from a TB hospital, empties its polluted contents right at the water intake point.	Underground water is also a major source of clean drinking water accessed by the peri-urban rural poor. Its subsequent pollution will lead to negative health impacts on the populace.	Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 1, pp 15, Spatial Decisions, New Delhi. & Impact of Wastewater on Livelihoods, Health and Environment, Kanpur Case Study (April 2005), pp 34-37 ECOFRIENDS, Kanpur
	The possibilities of using treated wastewater to recharge groundwater reserves have also been explored (eg, South Mexico), and has led to benefits.	The pollution of underground aquifers through seepage is a major source of health and livelihood concern. In many areas across the country, irrigation is done through bore wells. Its pollution would have adverse effects on harvests and cropping patterns in such areas.	

	PERCEIVED ADVANTAGES	DISADVANTAGES	REFERENCE
AGRICULTURAL PRODUC TIVITY	Since in South Asia the major application of wastewater is in agriculture, it has been a blessing for those water-starved areas which can now grow a second crop because of a continuous supply of water.	However, the pros and cons of such use is apparent here; in many cases, untreated or polluted wastewater leads to adverse impacts such as sudden drying up of crops before harvest or lowered shelf life of vegetables as witnessed in Ahmedabad.	Impact of Wastewater on Livelihoods, Health and Environment: Ahmedabad Case Study, 2005
	Studies indicate that there is an increase in crop yield with wastewater irrigation. One such study (Minhas) provides results of nearly 36% increase in crop yield using wastewater over tubewell water irrigation[21].	Use of wastewater has also led to increased pest attacks, which have prompted extensive use of pesticides. This has led to higher input costs for the farmers[22].	
	Studies have also reported that crop density increases with wastewater irrigation. It is being observed that crop density has shown nearly 11% increase with wastewater irrigation[23].	Increase in physiological weight loss and decay loss- These losses occur in crops grown in fresh-water. However, it is observed that wastewater use increases physiological weight loss in plants by 19% over tubewell water while decay losses when kept for 10-day period, are seen to increase by 145% over freshwater irrigation[24]	

[21] Minhas P.S. Use of Sewage in Agriculture: Some Experiences. Central Soil Salinity Institute, Karnal
[22] Bradford. A, Brook. R, Hunshal. C (2000) Risk Reduction in Hubli-Dharwad, India in Sewage Irrigated Farming System, UA Magazine
[23] Minhas P.S. Use of Sewage in Agriculture: Some Experiences. Central Soil Salinity Institute, Karnal
[24] ibid

5.0 Wastewater Usage – A Comparative Regional Analysis

The various uses of wastewater across the four specific regions offer levels of data; there exists no simple correlation between urbanization and issues of wastewater use as each urban centre throws up its own contexts. See Table 4.

Table 4: A snapshot of wastewater usage in the study areas [25]

Area of Study	Total population (in million) Census 2001, GoI	Per capita Consumption of Water (lpcd)	Total Amount of Water Supplied MLD[26]	% of Population not Connected by Sewage Treatment	Volume of Wastewater Generated (MLD)	% of Wastewater Collected
Ahmedabad	5.81	135.	396.8	5	326	80
Delhi	13.78	239.6[27]	2767	55[28]	3167	47
Kanpur Nagar	4.14	250	588.5	76	408	20
Kolkata City	4.58	202.	1209.6	4	1,383	85

[25] Source: Urban Water Authorities in India, (indicated otherwise)
[26] **water supplied to the city by the municipality or the pvt utilities etc**
[27] Economic Survey 2000-2001
[28] **DUEIIP Status Report for Delhi, January 2001, MoEF**

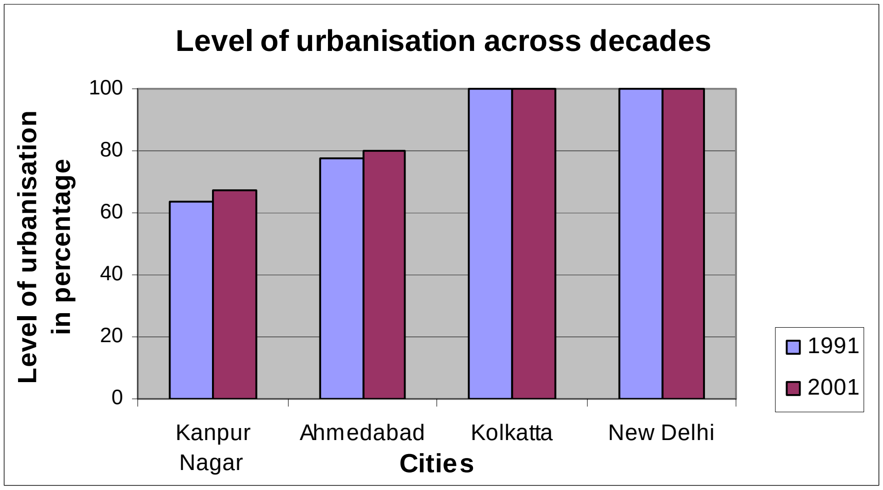
Delhi and Kolkata generate more wastewater due to population size and subsequent demand and use of water. This also depends on the levels of urbanization in the study area. Cities with higher degree of urbanisation also develop technology and infrastructure to deal with high volumes of waste[29] which includes wastewater. But this goes the other way, as city managers in an effort to cash in on real estate boom ignore parallel infrastructure development[30]. This may explain while Delhi, being the capital of India still has 55% of the population not connected with sewage treatment. Also, lower levels of urbanization, may signify inadequacy to deal with waste due to low infrastructure development. One interesting fact that comes to light is that while in most cities the demand and subsequent consumption for water is on the rise, the per capita consumption has actually decreased in Ahmedabad.

5.1 Level of Urbanization in the Study Area

The level of urbanization is an index of economic development. The two processes bear a high positive correlation. Urbanization is related to the level of economic development measured, for want of a superior indicator, by per capita income.[31] However, the relationship is not linear. When per capita income increases, urbanization also increases though not as much.[32] However, there is additional pressure on urban centers to develop infrastructure along with growing populations and often a gap emerges which may lead to environmental degradation. See Figure 1 for levels of urbanization in the study areas.

[29] Dr Léautier, Frannie (ed), Cities in a Globalizing World, *Governance, Performance and Sustainability*, World Bank Institute, 2006
[30] ibid
[31] http://planningcommission.nic.in/plans/stateplan/sdr_maha/ch-13-14-02-05.pdf
[32] ibid

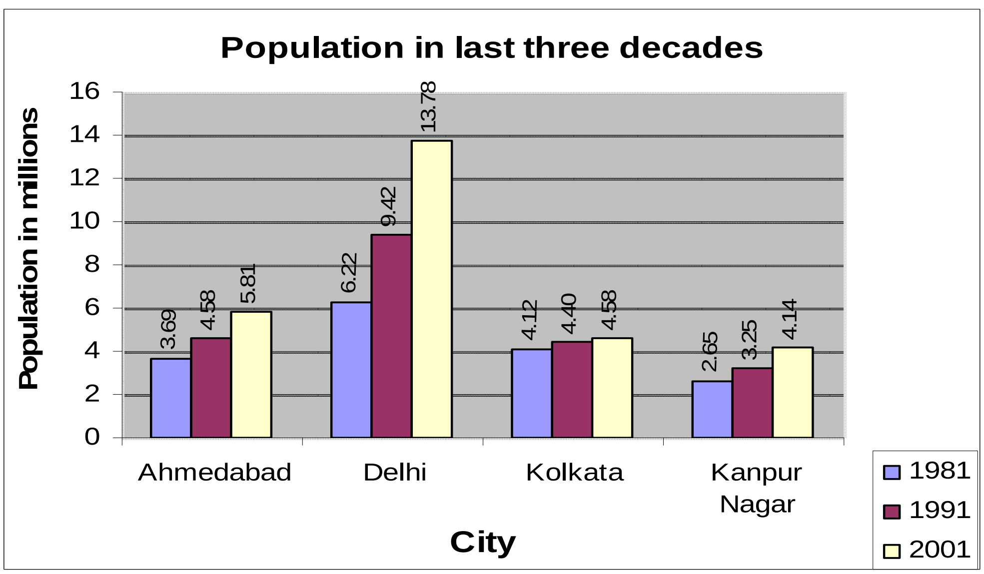
Figure 1: Levels of urbanization in the four study areas



Source: Census 2001

See Figure 2 for growth in population in the last three decades in the selected areas.

Figure 2: Growth in population in the last three decades in the selected areas



Source: Census 2001

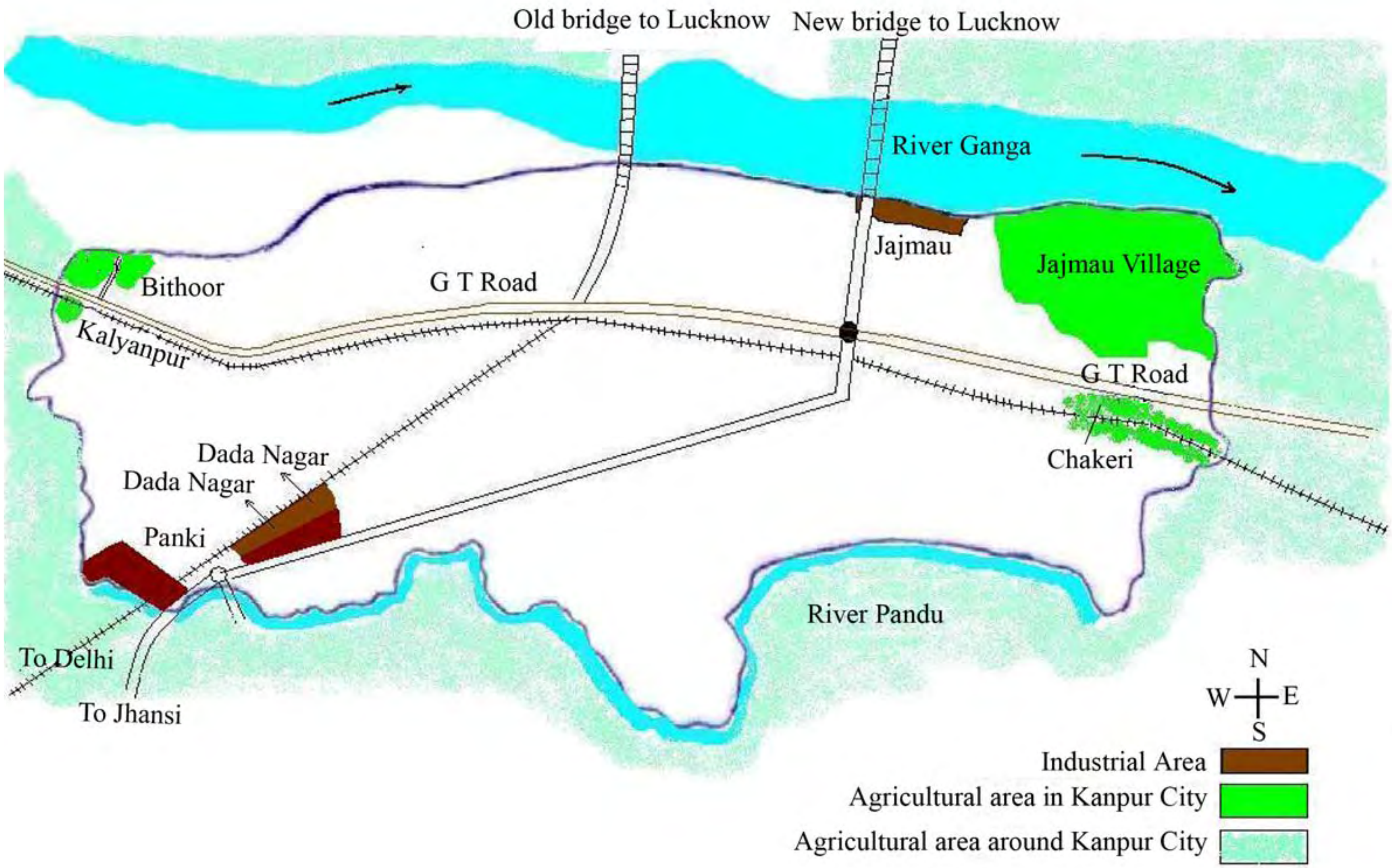
From figures 1 & 2, one can see that in smaller cities with a lesser degree of urbanization (Ahmedabad and Kanpur), population increase has been greater. Looking back at the case studies, it becomes apparent that in smaller cities, the pressure of population on existing urban infrastructure is high. Hence, the impacts, perhaps more negative than positive, will be pronounced. On the other hand, larger populations, without proper urban sanitation and water supply networks stand to be more at risk. At the same time, two different future scenarios emerge. The two big cities, namely Delhi and Kolkata, which has almost reached a level of saturation in terms of provision of urban amenities, may find it difficult to expand their services to include growing population. Hence, a gap emerges between existing facilities and excess population and their civic needs. A similar kind of "infrastructure gap" appears in smaller cities. The smaller cities are growing faster in population compared to the degree of urbanization. Further, infrastructure development cannot keep pace with the population growth, leading to a gap that leads to inadequate urban management and planning. Hence, while approaching the findings from each specific area we need to refer to this analysis not only to understand the present scenario but also the emerging trends.

5.2 Water Issues in Case Study Areas – A Profile

5.2.1 Kanpur

Kanpur is the eighth largest metropolis in India and the largest and most important industrial town of Uttar Pradesh between latitude 26^{o} 29' 35'' N and longitude 80^{o} 18'-80^{o} 25' E. Kanpur as one of India's earliest industrial towns, is an important centre of ordnance equipments, engineering and leather tanning, etc. (See Figure 3 for agricultural and industrial areas in the city). Kanpur is situated on the right bank of river Ganga at a height of about 125.6 m above MSL (Mean Sea Level) and located in the south-central of the state.

Figure 3: Map of industrial and agricultural areas in Kanpur



Map not to scale

River Ganga enters the town from the west and flows out in the east. River Pandu enters the city from the west and joins River Ganga at about 25 km downstream of Kanpur. The town is sandwiched between River Ganga in the north and River Pandu in the south.

Kanpur has a linear development along River Ganga in the east-west direction. The expansion of the city is restricted in the south by River Pandu. The land-use pattern of the city is marked with a heavily built Central Business District (CBD) area near the railway station hosting the wholesale market and cantonment area in the east. The development of public, semi-public, residential and other mixed land-uses have come up in the west and are mixed with the industrial growth in that direction.

The Grand Trunk (GT) Road has divided the town in to two parts: one slope away from GT towards river Ganga in the North; the other slopes towards River Pandu in the South. The topography is more or less flat. The peri-urban area lies in the alluvial belt of the Gangetic plains. Sediment deposits formed in successive stages form the under-bed. A bed of clay fine sand, mixed with *kankar* and stone *bajri*, in layers form the top.

Kanpur Nagar witnessed significant population growth between 1981 (2.65 million) and 1991 (3.25 m), with decadal growth rate of 22.6 percent. The population recorded in 2001 census was 4.41 million, with decadal growth rate increasing to 27.2 percent.

The main source of raw water for municipal piped water supply is River Ganga, the Lower Ganga canal and deep tube wells. Both the River Ganga and Ganga canal are heavily polluted in Kanpur. The water is treated before it is supplied, but sometimes excessive chlorination becomes necessary to bring the water to safe levels. Also, potable water gets contaminated during supply as the water supply lines run parallel to sewer lines and both the pipelines are old and broken at places.

The prevailing power situation in the city is marked with frequent power failures for prolonged periods. This aggravates the problem as vital components like raw water pumping, equipments in treatment works, clear water pumping, and tube well pumps in the water supply system are dependent exclusively on power supply for operation.

5.2.2 Delhi

With a total area of 1,484 sq km, Delhi is situated at a height of 220 m above the sea level. It is 77^{o}13'16.08'' E longitude and 28^{o} 37'58.55'' N latitude. The state of

Haryana borders Delhi from three sides – north, south and west – while the state of Uttar Pradesh surrounds it in the east. Figure 4 shows the administrative divisions of the city. River Yamuna flows through Delhi from the north towards the south. A hard rocky ridge runs from the southern border of the National Capital Territory (NCT) in the southwest in a north-easterly direction unto the western banks of River Yamuna near Wazirabad barrage. The natural drainage of the areas located east of the ridge is towards Yamuna and for the area west of the ridge is towards the Najafgarh drain.

The major surface water body in Delhi is River Yamuna that serves the source of most of Delhi's water supply and the sink for all of the wastewater. In Delhi, water is extracted upstream of Wazirabad barrage near Palla where it is treated and supplied for drinking purpose.

Delhi is divided into five main sewerage zones viz Rithala, Coronation Pillar, Keshopur, Trans Yamuna, and Okhla. The total wastewater generation from these zones is estimated as 3,167 MLD (CPCB 2003). Municipal sewage constitutes roughly 93-94 percent of the total discharge while 6-7 percent is industrial discharge (MoEF 2001) from 28 industrial areas.

All the wastewater in the city, treated or untreated, finds its way into River Yamuna between Wazirabad barrage and Okhla barrage through the 22 major drains originating in Delhi. Additionally, three drains originating in Ghaziabad and Noida discharge into the Yamuna within this stretch[33]. Results of the water quality from River Yamuna, when compared with drinking water standards (*IS: 10500:1991)* listed in *Annexure 7*, indicates that river water cannot be used for drinking purpose directly.

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[33] Trivedi, R.C. , Makhijani, S.D. , Bhardwaj, R.M., *Status of Water Quality in River Yamuna - NCT of Delhi*, Central Pollution Control Board

Figure 4: Map showing administrative divisions of Delhi

Source: Government of Delhi

Wastewater in Delhi undergoes centralized treatment at various locations. There are 30 sewage treatment plants (STPs) at 17 locations in the city, most based on activated sludge process. The monitoring results with limited parameters show that the STPs are functioning effectively to treat the sewage load reaching them, with little adverse effect on the water quality of the Yamuna. The untreated wastewater makes its way into the different drains across the city and mixes with the treated effluent, negating the advantage achieved by the operative STPs. Consequently, the treated effluent only dilutes, lowering the pollutant levels marginally in the untreated wastewater. The poor water quality of the discharge from the drains flowing into the Yamuna is reflective of this problem of mixing untreated wastewater, collectively causing deterioration in the water quality of the river within the Wazirabad-Okhla stretch.

Out of 3,167 MLDof wastewater generated in Delhi, only 2,330 MLD can be treated with the existing capacity, out of which only 1,478 MLD actually reaches sewage treatment plants; which means, only 47 percent of the total wastewater generated is being treated. In other words, about 53 percent of the untreated wastewater flows into River Yamuna. Lack of a proper conveyance system for municipal sewage is cited as the prime reason behind this. Only about 45 percent of the population in Delhi have proper sewerage systems (MoEF, 2001). The rest 55 percent generate wastewater that flow untreated into the *nalas* (drains) and then to the river.

Government agencies involved in the management of water quality and standards associated for the discharge of wastewater in Delhi include Ministry of Environment and Forests (MoEF), National River Conservation Directorate (NRCD), Central Pollution Control Board (CPCB), Delhi Pollution Control Committee, Delhi Jal Board, and Department of Environment.

5.2.3 Ahmedabad

The city lies in the region of North Gujarat, which is dry and sandy. Except for the small hills of Thaltej-Jodhpur Tekra, the entire surroundings of the city is a plain. There are no woods or forests nearby. The sea is 80.65 km far, at the Gulf of Cambay. Sabarmati, one of the longest rivers of Gujarat, bifurcates the city into eastern and western parts, connected by bridges, some of which were constructed after independence. Though the river is perennial, it practically dries up in the summer, leaving very little water.

Figure 5: City Map –Ahmedabad

Source: www.mapsofindia.com

Map not to scale

Having grown by leaps and bounds, Ahmedabad is the largest city of Gujarat state and the seventh largest city in India, with a population of 5.81 million (Census, 2001).

Major expansion in the textile industry boosted its development – once known as the "Manchester of India". Although it no longer holds that privilege, Ahmedabad is a well-established centre of commerce and industry with modern technologies in textiles, chemicals, dyes, pharmaceuticals, and intermediaries.

The three industrial zones, Vatva, Odhav and Naroda, are situated to the east of the city, housing 3,365 miscellaneous industries. The city limits have expanded from 5.70 km in 1872 to 186.78 km in 1991. In 2001, it was 190.84 km.[34]

Development of infrastructure, however, could not keep pace with the increase in population and industrial growth. The major strain was on water supply. There are a number of commercial establishments and private residences/societies with their own bore wells. Public water is supplied by the Ahmedabad Municipal Corporation (AMC) and the Ahmedabad Urban Development Authority (AUDA). AUDA supplies only to those areas that fall within its town planning scheme. Although the supply of water has increased from 20.24 MGD in 1951 to 104.83 MGD in 2001,[35] the per capita consumption has decreased.

It is estimated that almost 80 percent of the water supplied for domestic use passes out as wastewater. According to the AMC, almost 66 percent of the city's population is connected to an underground sewerage system. Currently, there are four STPs with a capacity to treat 633 MLD, but the entire volume released is not treated. The reason being ineffective maintenance as cost of maintaining these plants are high.

Besides the domestic wastewater, a huge quantity of industrial wastewater is generated too. However, each zone has a CEPTs (Common Effluent Treatment Plant) (list given below), and they are all operating below capacity. Although most of the wastewater

[34] www.indiaurbaninfo.com

[35] Chokkakula Srinivas, Shah Manali, "Issues in Urban Domestic Water Supply: Situational Analysis of Ahmedabad City." Prepared for IWMI-TATA Program, Anand

generated by the industries is diverted into the Khari River, a number of industries also drain their wastewater directly into the Sabarmati River.

Sr.No.	Name of C.E.T.P. In Operation.	Nos. of Members	Capacity In M^3 / Day
1.	ODHAV GREEN ENVIRO PROJECT ASSOCIATION, PLOT. No. 394,G.I.D.C. ESTSTE, ODHAV, AHMEDABAD	03	1000
2.	G.V.M.S.A.V. LIMITED, PLOT. No. 181, G.V.M.M. INDUSTRIAL - ESTSTE, ODHAV, AHMEDABAD	357	1000
3.	THE GREEN ENVIRONMENT SERVICES CO-OPERATIVE SOCIETY LTD. PLOT NO. 244 TO 251, PHASE-II , G.I.D.C. ESTATE, VATVA, AHMEDABAD	518	16000
4.	NARODA ENVIRO PROJECTS LIMITED,PLOT. No. 512 to 515, PHASE-I, G.I.D.C. ESTSTE, NARODA, AHMEDABAD	242	3000
5.	ODHAV ENVIRO PROJECTS LIMITED,PLOT. No. 25, G.I.D.C. ESTSTE, ODHAV, AHMEDABAD	60	1200

Source: http://gpcb.gov.in

5.2.4 Kolkata

The city's history spans over three centuries. Kolkata, the capital of West Bengal, was the capital of British India from 1773 to 1911. Over the years, Kolkata has grown manifold to become one of the biggest cities in the world.

The city limits expanded after the Kolkata Municipal Corporation Act, 1983, was passed. It included the municipalities of South Suburban, Garden Reach and Jadavpur within the Kolkata Municipal Corporation's jurisdiction, which now spreads over 18,733 hectares, consisting 141 wards.[36]

[36] http://www.rainwaterharvesting.org

River Hooghly flows past the western part of Kolkata. The South 24 Parganas district forms the southern and south-eastern boundary. The North 24 Parganas forms the eastern and northern limits of the city.

The civic infrastructure of the metropolitan area is inadequate for the growing population. The demographic density during 1981 was 22,260 people per sq km; during 1991, this rose to 23,670 persons per sq km in Kolkata.[37]

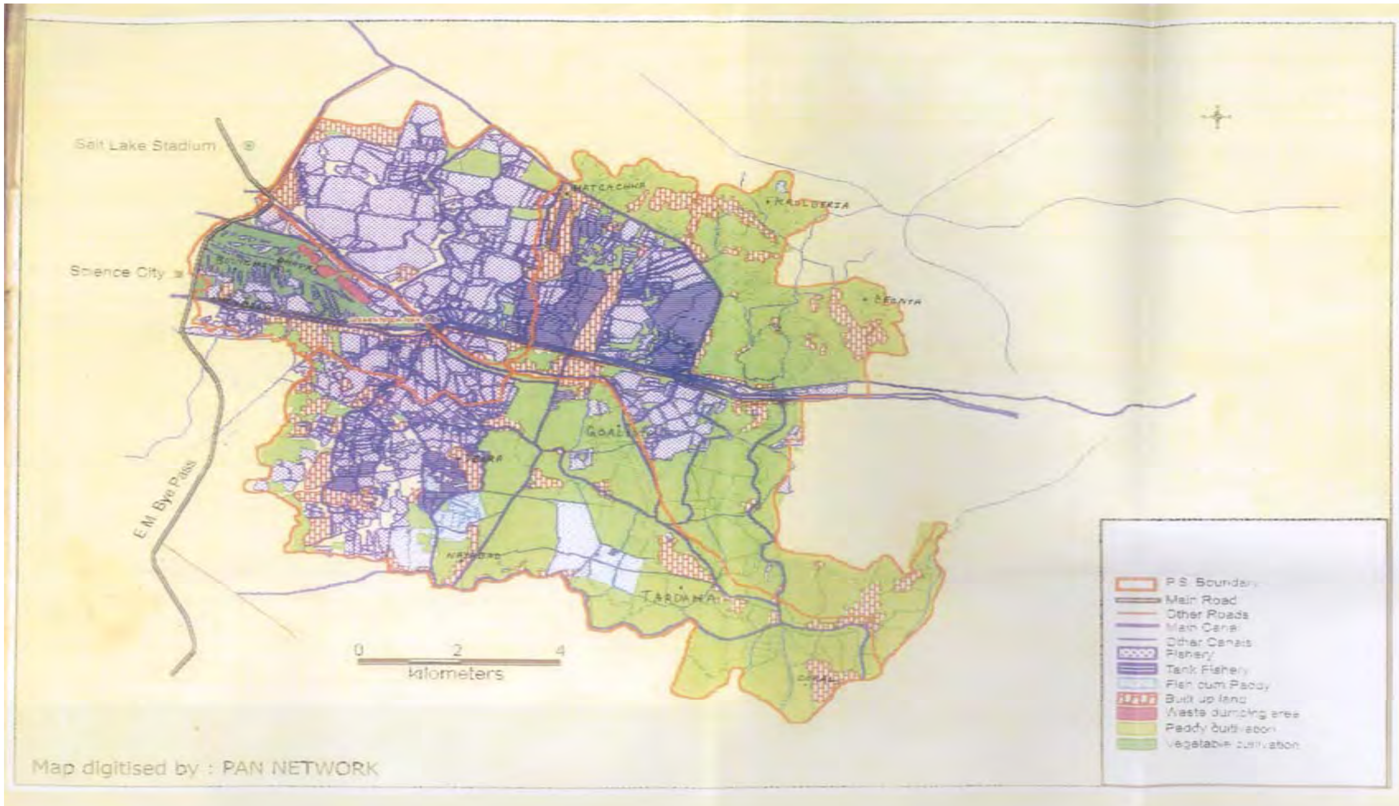
The residents get their water supply from three main sources:[38]

- The KMC, supplying treated water through an underground pipeline network
- Roadside public bore wells dug by KMC
- Innumerable private bore wells dug by residents

The municipal corporation supplies about 750-800 MLD from its surface water sources and 136 MLD from groundwater sources.[39] Additionally, it also supplies 300 MLD of unfiltered but chlorinated water.

[37] ibid
[38] ibid
[39] ibid

Figure 6: Map of the East Calcutta Wetlands showing Dry weather Flow (DWF) Network



Source: PAN Network, Kolkata

Map not to scale

Though Kolkata has a fairly abundant source of surface water close by, the community water supply system suffers from problems of poor maintenance, inequitable distribution, and poor quality management.

Chattopadhyay (2004) has estimated the economic benefits of East Calcutta Wetlands in ‘Jalabhumir Kolkata’ – a fact-finding observation of East Calcutta Wetlands. The wetland ecosystem of Kolkata supports 100,000 direct stakeholders and 5,100 hectares of cultivation. It provides annually direct employment for about 70,000 people, produces 128,000 quintals of paddy, 69,000 quintals of fish and 7.3 quintals of vegetables. It also generates revenue of Rs 266 million and net returns of Rs 80 million. The All India Institute of Hygiene and Public Health (1997) showed in a research work that Kolkata Municipal Corporation generated solid wastes of 3,100 metric tons daily – 56 percent of these wastes is biodegradable. At present, a private organization in Dhapa uses these wastes to produce fertilizers. Paddy, wheat, mustard, and corn along with pulses, vegetables are grown using wastewater. Along the DWF (Dry Weather Flow) canal, floriculture was started recently. Hence, the study of East Calcutta Wetlands (ECW) in relation to urban wastewater recycling and management is vital to this study.

6.0. Impact Assessment

The alarming statistics on water shortage for urban uses in Indian cities has compelled urban dwellers to refocus on ways to recycle wastewater – through the reuse of urban wastewater, for irrigation and other purposes. Disposal of wastewater is a problem faced by urban local bodies especially in large metropolitan cities, with limited space for land-based treatment and disposal.

Wastewater can be utilized for productive uses in agriculture. Other important uses of wastewater include recharge of groundwater and in landscaping, industry, construction, dust control, wildlife habitat improvement, and aquaculture.[40] Using wastewater or low quality water for irrigation is a good way to reduce the demand for freshwater. Wastewater use has the advantage of limiting the pollution of rivers and other surface bodies that would otherwise be used as disposal outlets.

Wastewater is a resource as well as a problem. Wastewater with its nutrient content can be used extensively for irrigation and other ecosystems. Its reuse can deliver positive benefits to the farming community, society, and municipalities. However, wastewater use also exacts negative externality effects on humans and ecological systems, which need to be identified and assessed.

6.1 Environmental Impacts

6.1.1 Impact on Soil Quality

Presence of a high nutrient content (Nitrogen and Phosphorus) in wastewater leads to conservation of such nutrients, thereby reducing the need for artificial fertilizers[41].

- Wastewater irrigation may lead to transport of heavy metals to soils and may cause crop contamination affecting soil flora and fauna. Some of these heavy metals may bio-accumulate in the soil while others, for example, Cd and Cu, may be redistributed by soil fauna such as earthworms (Kruse and Barrett 1985).

[40] Hussain Intizar et al. 2002. Wastewater Use in Agriculture: Review of Impacts and methodological issues in valuing impacts. (With an extended list of bibliographical references) Working Paper 37. Colombo, Sri Lanka: International Water Management Institute.
[41] Minhas P.S. Use of Sewage in Agriculture: Some Experiences. Central Soil Salinity Institute, Karnal

Evidences from Hubli, show that unregulated and continuous irrigation with wastewater also leads to environmental problems such as salination, phytotoxicity (plant poisoning) and soil structure deterioration (soil clogging), which in India is commonly referred to as "sewage sickness"[42]

- High salt content in wastewater leads to salt accumulation in crop root zone to a concentration that results in loss of yield. This happens because of lesser uptake of water by plant roots. Salinity needs to be removed by pumping out excess salt from the soil structure[43]
- If the used wastewater contains elevated levels of persistent-type toxicants such as metals and, to some extent, pesticides then its consistent use may lead to build-up of higher concentrations in soils from accumulation. The higher metal levels may cause negative impacts on crops, inhibiting their growth[44]

(For a detailed account of impact on soil quality in case study areas, see Table 5 below)

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[42] Bradford, Andrew, et al Wastewater Irrigation: Hubli Dharwad, India, International Symposium on Water, Poverty and Productive uses of Water at the Household Level, January 2003, Muldersdrift, South Africa

[43] Minhas P.S. Use of Sewage in Agriculture: Some Experiences. Central Soil Salinity Institute, Karnal

[44] Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 7, pp 56 EcoFriends, Kanpur

Table 5: Impact on Soil Quality in Case Study Areas

Soil Quality		
City	**Positive Impacts**	**Negative Impacts**
Delhi	- Most of the farmers reported that soil quality in wastewater irrigated areas is good. - Productivity of soil was also reported to increase with application of treated effluent. - The farmers had no complaints related to decline in the fertility of soil due to any reason.	- A small section of the farmers reported land infertility over time, which could be attributed to bad quality of wastewater with high doses of industrial loading.
Ahmedabad		- In the villages located near River Sabarmati, farmers reported decline in yields. They attributed this decline to deterioration in soil quality. - Though no scientific testing of the soil was done, the community perceived that prolonged irrigation with water from Sabarmati river has resulted in compaction and degradation of the top soil. - In Bakrol village the community believed that use of Sabarmati river for irrigation has led to change in soil texture. The topsoil has turned to hard crusts affecting fertility. In most other villages also, reduced yields have been connected to loss of soil fertility by the community, for example, in the village of Vautha, the topsoil has become compact and hard.
Kanpur		- In Jajmau area of Kanpur, the partially treated sewage irrigation water supplied to the farmland has led to widespread contamination and deterioration of soil quality and lower returns in agriculture. - Metal and pesticide levels in soil from wastewater disposal areas are very high. ITRC reports (1996) & NBRI report 2000 and questionnaire based individual farmers' survey show that crops' yield has been impacted adversely. Almost all the farmers reported that crops yield has declined by 40-50 % over

Soil Quality		
City	**Positive Impacts**	**Negative Impacts**
		the past few years due to wastewater irrigation. (See Annexure 8 for details of ITRC tests) - The problem is of high sodium toxicity in both topsoil and subsoil. Excessive sodium salts are used during leather processing, which is drained into the tannery waste stream. Sodium crystallization in the subsoil impedes efficient water permeability in the soil. This causes serious injury to the crops at the initial stage. The mean level of Cd and Cr are above their critical levels in agricultural soils of the wastewater irrigated areas. (Annexure 9) - The farmers in the selected area perceive that several hectares of land are degrading due to unscientific use of treated/untreated and heavily contaminated wastewater. Excessive deposition of heavy metals from sewage is causing irreparable damage to the soil.
Kolkata	- Both the soil and vegetable quality analysis shows non-detectable levels of mercury and arsenic in soil and food grown with wastewater. This indicates that foods grown on wastes or by using wastewater are comparatively safe for consumption. (See Annexure 1)	

6.1.2 Impact on Ground Water Quality

Common wastewater handling and reuse practices in developing nations (which are frequently unplanned and uncontrolled) generate high rates of infiltration to underlying aquifers in the more arid climates. Although the infiltration improves wastewater quality and stores it for future uses, it can also pollute aquifers for potable water supply. Wastewater infiltration to groundwater occurs directly from effluent handling facilities and indirectly from excess agricultural irrigation in downstream areas.

Positive

Conserves water (by recycling and groundwater recharge)

Negative

Wastewater has the potential to affect the quality of groundwater resources in the long run through excess nutrients and salts content leaching below the plant root zone. For example, in Kanpur, CPCB has found groundwater in four areas to be heavily contaminated. (See table 6) It was highly alkaline, hard and contaminated with very high concentrations of metals, pesticides and fluoride. (See table 6) In some areas, groundwater was found with high Sodium Absorption Ratio (SAR), rendering it undesirable even for irrigation. (See table 6) Wastewater irrigation has the potential to translocate pathogenic bacteria and viruses to groundwater (NRC report 1996)

Nitrate pollution of groundwater from application of wastewater effluent and sludge is reported but can be rectified through traditional nutrient management technique adopted in agriculture[45]

[45] US EPA Case Studies, www.epa.gov

Table 6: Type of contamination and extent of contamination of groundwater in four areas of Kanpur

	Jajmau	**Panki**	**Noraiakheda**	**Rakhimandi**
Parameter	**Avg. Max.**	**Avg. Max.**	**Avg. Max.**	**Avg. Max.**
PH	-	9.37	-	-
Alkalinity	381.9	19567.87	404.3	426.05
Sulphate	-	1917.42	-	775.31
Chloride	-	1567.95	-	382.3
Hardness	397.2	383	1534	927.9
SAR	-	38.53	-	-
Colour	10	32.5	92.5	137.5
Fluoride	-	4.04	2.19	3.82
T-Coliform	43.3	-	41	20.5
TDS	601.1	1208	858	2802.75
DDT	5.74	343.18	192.36	235.43
Lindane	617.79	19.4	83.47	37.55
Iron	3.77	25.73	121.1	2.3
Lead	7.21	3.66	-	0.12
Chromium	-	-	4.6	10.06

Note: Avg. Max: maximum of annual average values
Colour: Hazen units; T-Coliforms: MPN/100 ml; DDT, Lindane: ng/l
All other parameters in mg/l

Source: CPCB, "Groundwater quality in Kanpur-status, sources and control measures" 1997

(For a detailed account of impact on wastewater reuse on groundwater and quality in case study areas, see impact matrix table 7)

Table 7: Impact on wastewater reuse on groundwater and quality in case study areas

Impacts	Ahmedabad[46]	Delhi	Kanpur	Kolkata
Ground Water Quality	Estimates state approximately 80% of the water supplied for domestic use passes out as wastewater in Ahmedabad. This untreated water either gets discharged in the natural streams or finds its way in the groundwater. Most of the villages studied report discoloration of water drawn from bore wells (reddish hue). In Fatehpura village, newly dug bore wells at 200 ft throw out reddish colored water, confirming pollution of groundwater in the area. Complaints about contamination of groundwater are verified by looking at the color of groundwater in areas	The groundwater quality of the observed areas is mostly within the recommended limits when considered in light of its usage for consumption and irrigation. However, certain parameters such as total hardness and iron content exceed. This could be attributed to peak industrial discharges at certain periods and insufficient treatment of wastewater that lead to large concentrations of metals. *(see Annexure 10 for details)* The Groundwater Board has not reported monitoring of toxic metals such as arsenic, aluminum, nickel, and beryllium. Any serious health problems such as	In the Jajamau area, the groundwater in wastewater-irrigated areas has become highly contaminated from heavy metals, pesticides and bacteria. Groundwater is the only drinking water source for the people inhabiting these areas. People get groundwater through hand pumps from a depth of 50-120 ft. This drinking water has turned yellowish in color and smells foul. It is clearly visible that the use of heavy metal-bearing wastewater has almost doubled the concentration of chromium in the soil. Concentration of nickel is also high. CPCB found groundwater in four areas of Kanpur heavily contaminated: Jajmau area shows high concentration of alkalinity, hardness, dissolved solid, iron and excessively high concentration of Lindane; Panki shows high concentration of pH, alkalinity, sulphate and fluoride; Nauraiyakheda shows high concentration of chromium, iron, hardness, alkalinity, fluoride, coliform and dissolved	Tanneries situated in the eastern part of Kolkata are a cause for concern as industrial effluents from these units pollute the Bheris (fishponds) , wetlands and agricultural fields. Toxic trace elements like chromium and cobalt are found in the shallow aquifer in the area, which is not suitable for drinking purposes. However, an analysis of water samples from deeper aquifer (80-200 m depth) shows that concentration of chromium, cobalt and other heavy metals is below permissible limits.

[46] Most of the examples cited were obtained from farmers and other community members during surveys

Impacts	Ahmedabad[46]	Delhi	Kanpur	Kolkata
	surrounding Gyaspur. Industries are considered major culprits for groundwater contamination.	cancer, food poisoning, etc, resulting from excessive concentration of trace metals, has not been reported in the field surveys. However, some farmers reported groundwater quality to be bad in terms of colour and taste. Although the monitoring results from the Groundwater Board do not report problems with the water quality in these areas, it is important to re-evaluate it in light of the complaints by the farmers.	solids; Rakhimandi shows the same. In some areas, groundwater was found with High Sodium Absorption Ratio (SAR), rendering it undesirable even for irrigation. This indicates that the soil is getting degraded by the use of wastewater and will ultimately become useless to farmers. Worse still, there is a complete absence of government medical facilities in the area, thus hitting the villagers doubly hard *(refer to table 6 for details)*	

6.1.3 Impact on Surface Water Quality

Positive

Reduces pollution of rivers and other surface water by reducing the load entering them

Most of the heavy metals and other chemical agents attach themselves to the soil and the final quantity of water released in the rivers has lower amounts of such substances

Negative

Large quantities of treated/untreated/polluted wastewater are finally discharged into the rivers. This seriously affects the aquatic life in such areas

Build-up of harmful chemical substances in the aquatic food chain ultimately affects consumers

May lead to change in water use patterns of people downstream who look for alternate sources since the river water becomes unusable for consumption

(For details of the impact of wastewater on quality of surface water see table 8 below)

Table 8: Impact on Wastewater Use on Groundwater Quality in Case Study Areas

Impacts	Ahmedabad	Delhi	Kanpur	Kolkata
Surface Water Quality	Prior to 1968, sewage was discharged after primary treatment to sewage farms from where the yield of grass was sold to farmers as fodder for cattle and livestock. The first phase of the Vasna sewage treatment plant was commissioned in 1969, and the Pirana plant in 1974. In 1986 too, Vasna handled a sewage flow of 100 MGD that was well in excess of its capacity and, thus, a large quantity of untreated sewage was allowed to be passed into the river untreated. The 1997 statistics show that city generated 740 MLD of sewage against the treatment capacity available with the municipality for only 630 MLD. The rest of the wastewater along with	The increasing trend of wastewater generation has proved deadly to the receiving surface water body, River Yamuna. The river is recognized for being a source of drinking water supply at its upstreams and for disposal of wastewater of the city. In other words, about 53% of wastewater generated in Delhi goes untreated into the Yamuna. Use of wastewater for various purposes leaves the river with almost no flow during the lean season, which is the most serious concern in various government bodies. However, letting untreated wastewater flow into the Yamuna is no solution. Over the years, not only has the public started viewing the river as a drain but its biological diversity has also been severely affected. The quality of the water of the Yamuna has been evaluated with reference to the National River Water Quality Monitoring Standard, set by the Ministry of Environment and Forests (MoEF). According to these standards, the water being withdrawn for treatment for drinking water	The wastewater supplied for irrigation is not used all days of the year. The surplus water ultimately flows into the Ganga river through countless small drains, thus polluting it. The hazardous solid wastes of different industries are stored at the industry site for a brief period before treatment or disposal. The surface runoff during the monsoons carries the hazardous components with it and contaminates the surface water body. Households that are not connected to sewers, discharge sullage (wastewater from kitchen/bathroom and grey water from septic tanks) directly to street drains that ultimately flow into the rivers.	The fear of water-borne disease striking the people is the greatest during the monsoons. Floods increase the chances of surface water getting contaminated by sewage and garbage. The contaminated water then enters the distribution system through breaches in the distribution network. Untreated wastewater is pumped into canals specifically built to carry the water into the East Calcutta Wetlands. The rest flows out into the Bay of Bengal. During the monsoon months, this last outflow is heavy.

Impacts	Ahmedabad	Delhi	Kanpur	Kolkata
	treated wastewater found its way into the Sabarmati	should have a total coliform count of 5000 or less. However, monitoring results exceed the desired values.		

6.1.4 Other Impacts

- In Indore, Jaipur, Nagpur and Bangalore, as compared to freshwater irrigation, there is increase in yield to the tune of 30-40 % due to wastewater irrigation for principal crops. Reduction in fertilizer consumption is also one of the important features seen in these cities [47]
- Research results related to health impacts in the six major Indian cities (Indore, Ahmedabad, Nagpur, Jaipur, Chennai, and Banglore) show wastewater irrigation leads to high incidence of pest attack, high growth of weeds, and loss of fertility of soil due to high chemical content of wastewater. Presence of chemical and organic pollutants increases incidence of pest and weed attacks, thereby increasing pesticides consumption as compared to freshwater irrigation[48].
- Increase in weeds and pests: Raw sewage use for irrigation is reported to increase incidence of pests and weeds. Planting of monoculture blocks of vegetable crops increases their susceptibility to pests. In addition, with wastewater application, continuous growth of crops during dry season increases pest population when they would have normally encountered a seasonal decline. Plutella xylostella (diamondback moth, DBM) and Helicoverpa armigera are two such pests that thrive on sewage-irrigated crops. DBM affects aubergine and most Brassica species while Helicoverpa armigera infests most vegetable crops such as okra, chilli, onion, tomato, etc (Bradford et al).
- Increase in physiological weight loss and decay loss: These losses occur in crops grown in fresh-water. However, it is observed that wastewater use increases physiological weight loss in plants by 19 percent over fresh water while decay losses when kept for a 10-day period, are seen to increase by 145 percent over freshwater irrigation[49]

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[47] Londhe ,Archana , Talati, Jayesh Lokesh Kumar Singh, et al *Urban – Hinterland Water Transactions: A Scoping Study Of Six Class I Indian Cities** IWMI-Tata Water Policy ProgramAnnual Partners' Meet 2004 (draft)

[48] ibid

[49] Minhas P.S. Use of Sewage in Agriculture: Some Experiences. Central Soil Salinity Institute, Karnal

6.1.5 Health Impacts

Wastewater use can pose a threat to not only those who are in proximity and prolonged contact with it but also to those who end up as consumers of products grown by applying wastewater *(See table 9).*

In India, most of the sewage used for irrigation is untreated and there is no attempt to remove pathogenic microorganisms before use. Sewage farm workers and farmers practicing wastewater irrigation often carry a significant excess of hookworm infections compared with farmers using freshwater for irrigation.[50] A high proportion of sewage farm workers were in the country was reported to be anemic and exhibited gastrointestinal symptoms.[51]

While wastewater use for irrigation alleviates poverty for many urban and peri-urban farmers, it simultaneously places them, the consumers of their products, and the environment at risk. The farmers have repeated and close contact with untreated wastewater, which is a major source of pathogens, and the high levels of anemia found amongst them can be attributed to water-borne parasitic diseases and worm infestation. The wastewater also contains potentially injurious bio-medical waste (including disposable needles and syringes), that, after tilling operations, become half buried in the soil thus creating hazardous conditions for farmers.[52]

(For a detailed account of health impacts due to wastewater usage in case study areas, see table 10)

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[50] Final Report: National Assessment of Wastewater Generation and Utilization, A Case of India (July 2005) YUVA, Mumbai
[51] ibid
[52] ibid

Table 9: Possible sources of health risk using wastewater for irrigation purposes

Exposure Route	Receptor Population Group	Medium of Exposure	Possible Source of Risk
Dermal	**Farm workers**	**Irrigation water**	**Pathogens**
Ingestion	Farm workers and population in surrounding areas	Groundwater	Heavy metals, organic chemicals, pathogens
	End consumers including farm workers	Fruit, vegetable and cereal crops	Heavy metals, organic chemicals, pathogens
	Cattle	Water for drinking purpose	Pathogens, heavy metals, organic chemicals
	Consumers of animal and animal products	Contaminated meat and eggs	Pathogens, heavy metals, organic chemicals
	Babies	Mother's milk	Heavy metals, organic chemicals
Inhalation	Surrounding population downstream, farm workers	Inhaled air	Virus

Table 10: Health Impacts due to wastewater use and consumption of produce grown

	Ahmedabad	Delhi	Kanpur	Kolkata
Direct Contact	• The farming community remains most affected as there are complaints of intestinal problems, skin irritations and joint pains (leg joints mostly) • The affected farmers got exposed to the hazardous effluent (mixture of wastewater with industrial and tannery effluents) while irrigating their fields with wastewater	• Majority of the farmers had no health related problems with wastewater • Few farmers reported skin rashes	• Irrigation water supplied to the area is a mix of tannery effluents and sewage water from Kanpur. The tannery effluent is high in chromium and to a lesser degree, other heavy metals[53] • Men, women and children have been seen working knee deep in this irrigation water while planting paddies. Numerous types of skin diseases were shown to the study team, including advanced leprosy and large skin ulcerations and discolorations • The household survey indicated that every family in all surveyed towns has at least one person suffering from skin problems, including black fingernails, open ulcers, itching and rash	• The community did not report incidents of any skin diseases even after working in wastewater for long hours throughout the year • After work they clean themselves with soaps in freshwater, this is how they justify the absence of any skin diseases • They often apply oil made of local herbs. This prevents the pollutants to stick to their body while they are working in the sewage-fed fisheries

[53] See Annexure 9 for details of ECOFRIENDS-IIT Test, September 2002, Profile of pollutants in sewage irrigation water and sludge generated from treatment plants.

	Ahmedabad	Delhi	Kanpur	Kolkata
			• Defecation in the fields without proper hygiene might be adding to this infection rate • The reported skin ulcerations, itching and rash are said to be from chromium exposure, either through direct contact or inhalation of smoke from burning contaminated cattle dung.	
Consumption of produce	• Peri-urban farmers often complain of bad health of their siblings and frequent sickness from consuming vegetables grown from wastewater • The colour of the water in the areas around Gyaspur village is red. The food cooked with the polluted water often turns red.	• Though the village community was unaware and did not associate the prevalent diseases to the consumption of produce generated on wastewater, certain cases of dysentery, diarrhoea, presence of worms in intestinal tract, vomiting, etc, were observed in such areas • Various health centers and practicing doctors in these areas reported stomach and intestine	• Urine and blood samples were collected from the populations representing wastewater irrigated and analysed by the ITRC, Lucknow. • The results indicated a higher presence of the metals and pollutants compared to samples collected from areas not receiving the wastewater in Kanpur. Further, residue levels of metals and pesticides in human blood as well as in urine	• Though the fishermen working for long hours rarely develop any disease related to wastewater, their household members do complain of diaohrrea, dysentery and other waterborne diseases. Moreover, scientific testing of fish grown in wastewater and in fresh water shows the former to be safe for consumption[55]. Except for the fish bone which

[54] See Annexure 11 for details of test results
[55] See Annexure 12 for details of test results

	Ahmedabad	Delhi	Kanpur	Kolkata
		related problems as the most common. A few farmers consuming vegetables produced on these farms reportedly had intestine related diseases in the past 6 months.	samples of the exposed and unexposed population groups in Kanpur were higher (Singh et al, 2004). • Pesticide residue levels are present in water and vegetables, but β-HCH in guava is alarming[54].	has higher concentration of copper.
Vector Related Problems	• No direct evidence of vector related diseases was discovered in any of the study villages.	• Health problems also occur due to the presence of mosquitoes in and around the fields irrigated with wastewater. • During the field surveys, it was observed that vector related problems were more severe in fields which were over irrigated or suffered standing water. • In such areas, health centers reported frequent occurrence of malaria, fevers, etc, this could be associated to the presence of disease-causing mosquitoes.	• Though there is no conclusive evidence regarding rise in vector related diseases, the respondents to health surveys state does state that the use of wastewater has allowed breeding grounds for vectors.	• No reported cases of vector related diseases, but there was concern regarding the collection of large amounts of wastewater in the wetlands that would become ideal breeding grounds.

	Ahmedabad	Delhi	Kanpur	Kolkata
Consumption of Ground water	• In studied villages, drinking water drawn from bore wells is discoloured and complaints of gastrointestinal disorders are on the rise. • As revealed by field observations in Navagam village, a number of people suffer due to consumption of contaminated water. • Most of the farmers admitted that the groundwater was also unfit for consumption, but in absence of any other alternative source, they had to depend on it for domestic needs. • In most of the villages, gastric disorders and digestion related problems came second only to skin related diseases, which were common.	• As is apparent in the case study of Delhi, only a few parameters such as total hardness and iron content exceeded in the groundwater samples analyzed in the study areas[56]. • Most of the areas surveyed had small farms where landless labourers worked on daily wages. These communities do not necessarily reside at the same location. They usually have their residences at an average distance of 1 km from their agricultural patches. • However, the common sources of drinking water in these areas were either tap water (through surface water systems) or groundwater. Most of the farmers surveyed for the quality of groundwater did not report it to be	• Complaints of gastric, abdominal pain, gas, diarrhea, dysentery and infections from tape and roundworms were reported in every family. • Ground water is the only drinking water source for the people inhabiting these areas. The drinking water from the hand pumps has become yellowish in colour and emits a foul smell. People often complain of losing their appetite on drinking the hand pump water. Infants vomit after consuming the water with some villagers reporting 'vomiting of worms[57]. • According to ITRC, Lucknow, report of 1996, the groundwater samples show high Cr content than the recommended permissible limit in	• Most households use bore wells as their source of drinking water. • Most of the diseases in the area were reportedly water-borne. So water from tube wells was considered safer. • No direct correlation was discovered between percolation of wastewater and deteriorating quality of groundwater.

[56] See Annexure 13 for details on analysis of groundwater samples in Delhi
[57] See Annexure 14 for details of groundwater tests conducted in Jajmau in Kanpur

	Ahmedabad	Delhi	Kanpur	Kolkata
		unfit for drinking. • However, the health centers surveyed in these areas did report rare occurrence of cases of jaundice, which is usually water-borne.	drinking water.	

While comparing the results from the different case studies, we can make the following inferences:

Picture of a child with skin disorder from affected village in Kanpur

Prolonged contact with wastewater can expose farmers and their families to health risks. Skin irritation and pain in the joints are common. Symptoms of exposure to heavy metals and pesticides are only recognized when they achieve chronic and clinical levels. Since the pesticides and heavy metals are both proven neurotoxin, exposure may cause neurobehavioral disorders such as fatigue, insomnia, decreased concentration, depression, irritability, gastric symptoms, sensory symptoms and motor symptoms. For example, in a survey of wastewater irrigators around Keshopur and Okhla STP in Delhi, farmers reported skin problems due to regular contact with wastewater. The reasons could be fluctuating pH values in treated effluent or higher consumption of certain trace metals (e.g. arsenic).[58] In areas such as Kanpur, where farming communities using wastewater for irrigation live in the adjoining areas, the contact period and hence negative effects will be more while in Delhi, where most of the labour stays away from the irrigated areas and only works during the day, the potential of negative health impact will be low.

Picture showing cattle wading through sewage water in an affected village in Kanpur

There is also a risk to consumers if vegetables are irrigated with wastewater. The effects from consuming such vegetable produce arise from the presence of toxic metals or pathogens as reported in research outputs around the globe. Effects of metals on

[58] Refer Annexure 14 for details of groundwater tests conducted in Jajmau in Kanpur

human health can be classified as acute or chronic. Effects also depend on the type or route of exposure to the pollutant. Exposure to a high dose can lead to severe symptoms of poisoning – even death. Exposure to low doses over a prolonged contact also leads to mild symptoms and effects that become severe over a period of time as high levels of pollutants build up in the body. This is because other chemicals can be broken down and excreted through the detoxification processes in the body but metals cannot be since all metals are potentially toxic. Metals tend to accumulate in the body even through low but continuous exposure. In Kanpur, for example, the Pollution Control Board has put restrictions on growing vegetables that are eaten raw.

Animals are also affected when they come in contact with wastewater. The symptoms are weakness, loose motions, less milk output, and lower fertility. It is seen that animals do not reproduce as often when they drink the wastewater, get diarrhea, become weak at a younger age, and have to be slaughtered.

"For example, research in Hyderabad shows that after consuming the fodder grass irrigated with wastewater, the health of animals was affected – buffaloes that consumed the wastewater suffered fever and bloating."[59] It is mentioned in the Kanpur study that in the village of Jaana, almost all animals are suffering from some kinds of diseases. Most of them are loosing their nails and have respiratory problems. Many of them die just because of neck problems (while twisting). Half the female cattle have aborted abnormally owing to various stomach ailments.

Most cases of stomach and intestinal problems are due to the presence of Faecal Coliform in wastewater. Although pathogens are not absorbed by plants, they get attached to the leaves and other parts. Further, these pathogens get into human systems if the vegetables are not properly washed or if they are eaten uncooked. Hence, it is understood that if the treated effluent quality being provided for irrigation is within these standards, it is safe to produce crops for human consumption. If the water quality does not meet irrigation water standards, various health effects as discussed above can happen as a result of consumption of vegetables being produced using this water. In Delhi, no monitoring has been performed to detect the presence of Faecal Coliform in treated effluent. Concerned

[59] Final Report: National Assessment of Wastewater Generation and Utilization, A Case of India (July 2005) YUVA, Mumbai

authorities quote non-requirement for monitoring in drains due to the settling nature of metals. This usually makes them unavailable and non-detectable at the surface flows. However, according to documents available, the prevalent diseases in these areas are mostly associated with the presence of Faecal Coliform and high toxic metal content. The absence of monitoring results is therefore a serious data gap.

6.2 Impact on Livelihoods

Urban wastewater contains nutrients, which, if not optimally reused, may cause eutrophication in receiving water bodies, thus causing their premature ageing. An alternative use of urban wastewater is for irrigation/fodder cultivation. In India, government and individual farmers use the treated or untreated sewage for fodder cultivation around many urban centers. Owing to its potential for increasing crop yield because of the presence of nutrients, urban wastewater can increase farmers' income. In India, wastewater use for irrigation is practised in 200 places, totaling 73,000 ha.[60] The wastewater is not always used as a last resort but sometimes preferred over cleaner water, because of high nutrient content. It reduces the need for artificial fertilizers and, hence, considered as a cost-saving agricultural practice.[61] In addition, there are activities that are dependent on wastewater such as livestock rearing and aquaculture. New livelihood options such as floriculture have also grown.

Nutrient availability and a reliable water supply to farmers have been the predominant objectives of wastewater irrigation. A study conducted in India under the IWMI-TATA Water Policy Program titled "Urban–Hinterland Water Transactions: A Scoping Study of Six Class-1 Cities" has detailed the wastewater generation status and utilization in metropolitan cities of Indore, Nagpur, Jaipur, Ahmedabad, Bangalore and Chennai. It reveals that overall the farming community in these cities has benefited immensely especially by changing cropping patterns to attune with the quality of wastewater available.

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[60] Londhe Archana, Talati Jayesh, Singh Lokesh Kumar, Vilayasseril Mathew, Dhaunta Sanjay, Rawlley Bhavna, Ganapathy K.K, Mathew Robin P, IWMI-Tata Water Policy Program,Annual Partners' Meet 2004,Urban – Hinterland Water Transactions: A Scoping Study Of Six Class I Indian Cities

[61] ibid

Studies have also reported that crop density increases with wastewater irrigation. Crop density has shown nearly 11 percent increase with wastewater irrigation.[62]

Farmers follow innovated cropping patterns, to suit wastewater availability. In Indore, farmers prefer to grow vegetables with wastewater. They believe such vegetables are larger and get ready early for harvesting.

Reduction in fertilizer use is on of the major advantage attributed to wastewater irrigation. Indore, Nagpur, Jaipur and Bangalore record a 50-100 percent lower fertilizer use, as compared to freshwater irrigated areas.[63]

In Nagpur farmers have stopped growing green pepper and oranges in areas where they use wastewater. Wastewater use is assumed to have increased pest attack on pepper and reduced life span of orange trees from 20 to 14 years.[64]

In Ahmedabad, along the Sabarmati river, the cultivation of watermelon, potato, tobacco, sugarcane and chilly has been replaced by fodder, vegetables, castor and marigold flower. In the Fatehwadi canal region in Ahmedabad, farmers have changed the variety of rice in response to wastewater use. Continuous water availability has also enabled farmers to take a *Rabi (winter)* crop. Both cotton and mustard, which were the main crops of the region, are not cultivated any longer due to increased availability of water.[65]

In Hyderabad, cultivation of Jasmine through wastewater has generated employment. Jasmine plants flower for eight to nine months in a year, and a farmer can earn approximately Rs 15,000-20,000 per hectare (Buechler and Devi 2002).[66]

(See Table 11 for patterns of wastewater use in agriculture in the case study areas.)

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[62] Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004), ch 1, pp 10-12 Spatial Decisions, New Delhi,

[63] Londhe Archana, Talati Jayesh, Singh Lokesh Kumar, Vilayasseril Mathew, Dhaunta Sanjay, Rawlley Bhavna, Ganapathy K.K, Mathew Robin P, IWMI-Tata Water Policy Program,Annual Partners' Meet 2004,Urban – Hinterland Water Transactions Scoping Study Of Six Class I Indian Cities

[64] ibid

[65] ibid

[66] Buechler, Stephanie and Gayathri Devi. 2004. "Innovations among Groundwater Users in Wastewater Irrigated Areas near Hyderabad, India". Paper prepared for IWMI-TATA Annual Partners Meet 2004.

Table 11: Patterns of wastewater use in agriculture in the case study areas

Study Area	Total Land Under Formal Wastewater Irrigation (In Hectares)	Number Of Farmers Using Wastewater (Formally)	Quality Of Wastewater Used (Treated/Untreated, Diluted/Polluted River Water)	Type Of Use (Formal/Informal)	Type Of Crops Harvested
Ahmedabad	33,600	NA	Both, though treated wastewater is used on a larger scale	Both	Vegetables, rice, other cereals, fodder/grasses, cotton, fruit trees, ornamentals, pastures
Delhi	1,700 (approx)	12,000 (includes contractors as well as landless labourers)	Treated wastewater is used in areas around Keshopur STP and Okhla STP. Polluted river water is used along the river bed and downstream outside the border of the city in states of Uttar Pradesh and Haryana through the Agra Canal	Formal. Wastewater is treated in the STPs and supplied to nearby agricultural areas through irrigation channels	Cucurbits, egg plant, okra, and coriander in summers. Spinach, mustard, cauliflower, and cabbage in winters
Kanpur	2,500	2,447	Treated, untreated and polluted river water are used for irrigation in Kanpur. Wastewater is discharged in rivers and this water is used downstream. Untreated wastewater from the sewers/drains is directed to the field or pumped. Authorities sell wastewater to farmers. It may be treated or untreated	Both. In Kanpur, some areas receive the sewage mixed with tannery wastewater as irrigation water. This water may or may not be treated. This irrigation water is supplied to the farmland through a channel. Kanpur Municipal Corporation charges for this water but the farmers have stopped paying the	Wheat, rice, vegetables, mustard and flowers

Study Area	Total Land Under Formal Wastewater Irrigation (In Hectares)	Number Of Farmers Using Wastewater (Formally)	Quality Of Wastewater Used (Treated/Untreated, Diluted/Polluted River Water)	Type Of Use (Formal/Informal)	Type Of Crops Harvested
				irrigation cess since 2000. Some farmers use the polluted waters of the Ganga and Pandu rivers for riverbed farming. They do not pay any cess	
Kolkata	4,887	2,500 households	Mostly untreated wastewater. Untreated wastewater is pumped into canals specifically built to carry the water into the East Calcutta Wetlands. Some of it is diverted to the fishery feeder canals and used as fish feed in the fisheries. The rest flows along a natural canal and is drawn when necessary for vegetable farming and rice cultivation	Formal. Untreated wastewater is pumped into canals specifically built to carry the water into the East Calcutta Wetlands. Some of it is diverted to the fishery feeder canals and used as fish feed in the fisheries. The rest flows along a natural canal and is drawn as necessary for vegetable farming and rice cultivation	Mostly used for growing paddy and vegetables but most of the wastewater is used for breeding fish

6.3 A Synopsis of Livelihood Impacts in Case Study Areas

6.3.1 Ahmedabad

The livelihood profiles of the study villages *(see Annexure 15 for details of livelihoods impact surveyed villages)* show that the community is mostly agrarian and a majority belong to the backward castes. However, wastewater, which was once a vital resource for this water-starved region, has apparently done more harm than good. The quality of wastewater having deteriorated has negatively affected the local agrarian system. The following are the salient points that emerged from the case study:

It would be interesting to mention that in some of the study villages, the community perception was strongly aligned to the fact that as long as treated wastewater was being provided for irrigation, the impact on crop productivity and income generation was positive. Only when the treated water started getting mixed with industrial effluents and untreated wastewater, the negative impacts started becoming visible.

Keeping in mind the region's geo-hydrological context, the availability of year-long water has been a blessing, which perhaps explains why even with the water getting polluted, farmers in the village of Vautha reportedly has managed to increase the total land under paddy cultivation[67] as the table 12 validates:

However, on the whole, the livelihoods of the people using wastewater for cultivation have been affected adversely. Decline in yield has meant income loss in almost all villages.

Apart from one or two villages, the rest have a high composition of SCs and Baxi Panch who are socially and economically marginalized. The percentage of landless labourers is also high and, being more economically vulnerable, they run the risk of prolonged contact with polluted water without proper social and economic access to medicinal facilities.

[67] This information was obtained from the Sarpanch, Talati as well as farmers of the village

Table 12: Crop Productivity in Vautha (Ahmedabad Case Study village)

Crops Cultivated	2001		2002		2003 (good rainfall)	
	Hectares	Tonnes	Hectares	Tonnes	Hectares	Tonnes
Paddy	150	150	200	240	200	300
Cotton	200	288	125	320	175	238

The change in the cropping pattern becomes evident in certain villages as previously profitable horticultural activities have been replaced by paddy and wheat. Such a switch happened because polluted water was no longer supporting such crops. This automatically implies a lowering of income for households engaged in such activities.

A third crop, such as cumin, which is quite profitable to the tiller, has drastically decreased in the last few years. Again, this has economic ramifications for the farming community.

The case studies manage to provide in great detail the nature of wastewater impacts on local livelihood systems. The findings, therefore, can be dovetailed to future intervention strategies and policy recommendations to get a more contextualised approach towards wastewater management.

6.3.2 Delhi

Most farmers hold small pieces of land, which are either taken on lease from government agencies such as the DDA, Land and Estate Department, etc, or are owned by individuals who further give land on contract. Most of their earnings from the sale of crops produced go into paying off the lease charges and buying costly fertilizers and diesel for pumping motors to pull groundwater.

A change from use of freshwater to use of properly treated wastewater will provide environmental benefits such as saving groundwater and reduction in pollution load on the Yamuna. It will also serve as a source of higher income generation for the communities involved.

Treated wastewater irrigation in Delhi is being practised in areas around Keshopur and Okhla STPs. Both these areas are receiving treated effluent from the STPs through a separate channel provided by the STPs.

A comparative analysis of the field surveys from village where groundwater and wastewater irrigation was practised on different land pieces was done to calculate the difference in crop yield. This revealed that the income from land irrigated with treated wastewater was higher. (see Annexure 1 for details)

The results depicted that a unit piece of land generates a higher profit margin with the use of wastewater for irrigation as compared to groundwater use.

Cultivators occasionally have alternate livelihood options such as small transport business, dairy, etc, though agriculture forms the most important part of their livelihoods. However, all the labourers surveyed worked fulltime on these farms and agriculture is the only source of their livelihoods.

Of 84,000 cultivators, 3,400 work on land irrigated through wastewater. Thus, there are a big number (80,000) of cultivators for whom a higher income generation opportunity could be present if supply of treated wastewater is made available in all the agricultural patches of Delhi.

The scenario for landless labourers though is more critical. These groups are employed full-time in agriculture. Often these groups are the poorest of the poor who are not skilled in other work sectors, and they run their family with income from agriculture only. It was also found that many a times their jobs and daily wages, which ranged from Rs 50 to Rs 70, was directly proportional to the work. Since wastewater provides increased yield capacity per unit of land, a certain degree of security in terms of income is offered to these masses. Also, since the agriculture produce fulfills the food requirement of the people working on the land, they are able to save some of their earning for education of their children, for instance.

With the increase in income of the cultivator (responsible for paying daily wages to the laborers), increased wages for the laborers can be envisaged. If the whole agricultural land is subjected to wastewater irrigation, net total annual income is estimated to be about Rs 14,700 million. But if the same area gets freshwater irrigation, the net total annual income comes down to an estimated Rs 7,000 million, resulting in a loss of about Rs 7,700 million per annum.

Improperly treated wastewater results in destruction of crops. Farmers surveyed reported that at certain times (which could be peak industrial discharge periods), highly toxic wastewater was passed on by the STPs for irrigation, which destroyed the crops resulting in loss of income.

Relatively higher decay losses, which have direct or indirect effect on the income generation factor, is another issue of concern. When the vegetables grown on wastewater is moved to the market it gets mixed with vegetables brought from other sources, saving losses to sellers, there is a loss to the buyer in particular, as the same cannot be for long. Further, most farmers in the agricultural zones of Delhi have small land pieces and harvest their produce on an every-day basis and sell them in nearby markets. As the amount is small the farmer may not feel the loss due to decay. However, this factor could be of serious concern for large-scale production farms where agricultural produce might need a few days of storage before being sold off.

Table 13 provided below encapsulates the wastewater – agriculture economy that operates in the study areas in Delhi

Table 13: Wastewater economy in study areas, Delhi

Area	**Okhla Area**	**Keshopur Area**	Total
Total Area Under Wastewater Irrigation (Hectares)	205	1500	
Details of Areas	Jasaula, Madanpur Khadar, Jaitpur, Ali village	Keshopur, Nilauthi, Ranhaula, Mundka, Bakkarwala villages	
Total Volume of Wastewater Utilized Million Gallon per Year	6.8	50	56.8
Source of Wastewater	Okhla STP	Keshopur STP	
Types of Crops Produced	Egg plant, Ladyfinger	Cucurbits (Tori, Ghiya)	
Monthly Crop Yield(Tons/Hectare)	7	5	12
Annual Crop Yield(Tons)	17220	90000	107220
Monthly Income from Selling of Crops(Rs/Hectare)	70000	50000	120000
Annual Income from Selling of Crops(Rs)	172200000	900000000	1072200000
Approximate Monthly Expenditure(Rs/Hectare)	23250	23250	46500
Annual Expenditure(Rs)	57195000	418500000	475695000
Net Annual Income Generated(Rs)	115005000	481500000	596505000
Total Number of Individuals Involved(cultivators)	400	3000	3400
Total Number of Households Involved	80	600	680

6.3.3 Kanpur

To examine the issue of wastewater irrigation and its impacts on livelihoods in Kanpur, a rapid assessment was conducted in the wastewater-irrigated areas. These are downstream villages in the Jajmau area, within the city limits of Kanpur that are using the wastewater as irrigation water for the last five decades. The villages are spread over an area of approximately 2,500 ha, with a population of approximately 50,000. Scheduled Castes and backward castes of *Mallahs/Nishads* and *Yadavas* dominate the villages. Most of the population is engaged in farming on small and marginal land holdings or riverbeds, cattle rearing, and fishing in the Ganga river. Most of the villages have *kutcha* roads, poor sanitation and do not have electricity or access to safe drinking water. The area has two primary schools and is marked by a complete absence of government/private health facilities. Within this context, the following key features came up:

Flood irrigation is used in wastewater-irrigated areas. Wastewater flows by gravity and this irrigation method requires no distribution network. The villagers of the Jajmau area are poor and that is why they prefer this method. This irrigation method introduces a considerable level of personal contact with the effluent and infection by pathogens. Flood irrigation contaminates soil, vegetable crops or root crops, and exposes farmers to wastewater more than any other method of irrigation.

The inadequately treated wastewater from the STPs and CETP are utilized for irrigation by adjoining farmlands in Jajmau area; the sludge generated from the sewage treatment plants is disposed to wastewater-irrigated villages. The wastewater, however, provides benefits of irrigational support and minor values of nitrogen, phosphorous, organic carbon, etc.

Picture shows burnt crop due to excessive wastewater irrigation

Several hectares of land are degrading due to unscientific use of treated/untreated and heavily contaminated wastewater.

The critical levels of the heavy metals in soils displaying negative impacts on agricultural crops are high. However, the NBRI report 2000 and Eco Friends questionnaire based on individual farmers' survey show that crop yield has been impacted adversely. Almost all the farmers reported that crop yield has declined by 40-50 percent over the past few years due to wastewater irrigation. (see annexure 6)

A survey of household by Eco Friends in May-August 2004, could not confirm the actual number of cattle loss, but most cattle owners reported spontaneous abortion in 10-40 percent of their cattle. Lower milk production by five to six liters a day per buffalo was also reported[68].

The survey had more detailed information regarding agricultural production. Since the current irrigation practice began in the early 1990s, wheat production has decreased by 30-35 percent and rice by 40-45 percent. Many respondents said that they have stopped planting rice altogether[69].

Because of low yields of maize, pulses, barley and vegetables, all farmers who previously planted these crops, have stopped. The Similarly rose production has been replaced by marigolds or other less soil-particular flowers.

6.3.4 Kolkata

The East Calcutta Wetlands, lying to the east and south of Kolkata, receives most of the urban sewage of the city. A part of the wetland is also used as a landfill. A

Aquaculture practice in the East Calcutta Wetlands

[68] As reported by cattle owners
[69] As reported by respondents

sizeable peri-urban population is engaged in fishing, agriculture, vegetable farming and garbage recycling activities. The total area under East Calcutta Wetlands is 13,113 ha. Sewage-fed fisheries comprise 4,779 ha of the wetland; paddy is cultivated using wastewater on 4,888ha; vegetables on 467 ha in Dhapa. There seems to be an ambiguity regarding the ownership of the land *(see Annexure 16 for details of ownership pattern***)**. Initially, most of the land belonged to the *zamindars (landlords in the colonial era).* Some were vested under the Land Ceiling Act; some were abandoned by *zamindars and* forcibly occupied by settlers from Bangladesh (erstwhile East Pakistan). Later, the State Government issued a notification that the land would be taken over for development purpose, thereby preventing further sale. Around these areas people mostly work as agricultural labourers, very few own land. Many have pieces of land unviable for agriculture, and as a result they are forced to work as agricultural labourers.

Broadly, three main livelihood options using wastewater were identified: earnings from fisheries, paddy cultivation, and garbage farming.

In the East Calcutta Wetlands, the major source of income is aquaculture using urban wastewater. There are a number of large and small *bheris* (ponds for breeding fish) and ponds where fishing activities are carried out. Thus, in these areas, the majority of the households earn their primary income from fisheries. About 53 percent is engaged in fisheries, including catching fish to carrying them to the market, to working as night guards and maintenance workers, auctioneers, fish sellers, boat makers, net makers, and such others. The average monthly productivity of fish is 104.10 kg per acre.

Eggs of the fish are bought from freshwater fisheries in Burdwan, Bankura, Bandel and other districts outside Kolkata. Payments for these eggs are made according to containers called *bati*. Initially, it was thought that all fish in this region are sewage-fed. During the survey it was learnt that small fishes are reared in freshwater before fishermen working in the fisheries as daily wage labor release them into the sewage water. Hence, the livelihood options generated do not remain confined to the local area but trickle outside even to the suburbs and remote districts.

There is a positive correlation between wastewater use and fish productivity, indicating that an increase in sewage leads to increased fish production *(see table 14).* On the other hand, when wastewater is purified and used for aquaculture, there is a decline in fish production.

Paddy cultivators have decreased in number over the last 10 years. Most of them have sold off their land for reclamation for developing the city. Paddy cultivation is done twice a year. Both Aman (monsoon paddy) and Boro (winter paddy) crops are grown (Sanyal 2004). Rest of the year is utilized for cultivating vegetables. Most of the farmers use the wastewater for irrigation and also depend on the rain. Usually they use 100 percent untreated wastewater for irrigation purposes. Table 15 shows the value addition per hectare per year using wastewater

Urban wastewater use in wetland for agriculture and aquaculture provides significant income for sustaining livelihoods of the poor residing in the wetlands. It contributes 60-100 percent of their total household incomes. The livelihood pattern crosses over and employs people from remoter places. Hence, in reality, aquaculture and agriculture practised through wastewater has resulted in the creation of a livelihoods network, and well-connected to the market, it is economically viable. Interestingly, Kolkata remains the only case study where aquaculture is the dominant mode of livelihood and diversification of occupation takes place within the gamut of one major activity. Wastewater economy has ensured livelihoods for a vast majority of people in the area and since negative impacts are really minimal, Kolkata stands out as a successful example of wastewater reuse and management. *(See Box 1, ECW- Mapping People's Perceptions)*

Table 14: Correlation between Productivity of Fish and Wastewater based Aquaculture

	Productivity of Fish (kg/acre/month)	**Wastewater based Aquaculture done**
Productivity of fish (kg/acre/month)-Pearson Correlation	1.0	0.448*
Wastewater based aquaculture done	0.448*	1.0

* Correlation is significant at the 0.01 level (2-tailed)

	Productivity of Fish (kg/acre/month)	**Wastewater Mixed with Freshwater**
Productivity of fish (kg/acre/month)-Pearson Correlation	1.0	-0.296*
Wastewater mixed with freshwater	-0.296*	1.0

* Correlation is significant at the 0.01 level (2-tailed)

Table 15: Value Addition per Hectare per Year using Wastewater

Produce	Value addition/hectare/month (Rs)	Value Addition/Hectare/Year (Rs)
Fish	2754.486	33,053.832
Paddy	24791.443	1,48,748.658
Vegetables	7046.97	84,563.64

*Note: Annual value of the wetland, roughly, stands around **Rs 924.53 million per year** for **10,1342.2 ha** of land, where 4779.21 hectares is used for aquaculture, 4887.89 hectares for paddy cultivation and another 467.1 hectares for vegetable cultivation.*

BOX 1: **EAST CALCUTTA WETLANDS - MAPPING PEOPLE'S PERCEPTIONS**

The East Calcutta Wetlands (ECW) being a hotspot for sewage water use in fish cultivation is one of the most unique examples of social engineering tools in action. The profitability of aquaculture operations in the ECW is evident from what a respondent of the Nalban Fisheries had to say:

"The fishery employs 120 fishermen as permanent employees and labours are also hired on contract basis when additional work is done in the fisheries or when they are cleaned. Apart from the fishermen, maintenance workers like night guards and weed cleaners are also employed on a permanent basis. There are separate fish carriers who take the catch to the auction market and they are private individuals who are not employees of the fishery. They earn Rs 30–40 daily for three to four hours of work. Office work involves a few people who are permanent employees under the state government, as the Nalban fisheries belong to the state fisheries department. Wage payment alone involves Rs 4, 00,000 in Nalban fisheries."

Private players also eke out their livelihood from wastewater based aquaculture. An auctioneer in the Chingrighata Auction Market says that fish is sold at the auction market at prices ranging between Rs 20-30 per kg, depending on the availability.

However, a traditional occupation, such as paddy cultivation no longer being as profitable as aquaculture, is losing space, in more ways than one. A paddy field owner in Krolberia says that most of the other owners sold off the paddy fields nearer to the city when urban expansion was taking place. This has caused a reduction in the number of paddy fields. Many paddy field owners also engage in fishing activities in their own *bheris* (ponds for breeding fish) or in *bheris* owned by other individuals. Paddy is cultivated twice a year generally. During the rest of the year vegetables like corn, cauliflower, cabbage, and spinach are grown. Earnings from the paddy cultivation are no longer sufficient.

Further down the line, an agricultural labourer gets Rs 30 per day and two kilos of rice for his labour. His only other livelihood source is the *bheri that* is if jobs are available. He is indebted to his employer and every month a portion of his pay goes into repayment which, at times, he needs to supplement by working at the employer's house. He is unable to educate his children and had to pull his only daughter out of school, so that she could work at home since both parents were out looking for work.

7.0 Chain of Economic beneficiaries

The case studies provide interesting insights into the chain of economic beneficiaries in the agriculture and fish produce marketing chains. With the exception of wastewater users in Delhi, it brings to the fore the hardship faced by wastewater users in selling their produce and traces the middlemen perceived to corner a large share of the profits from the sale of produce. It was difficult to estimate the magnitude of profits earned by middlemen as the chain became too diffused to trace ahead. The data collected was through FGDs with community groups from wastewater irrigated areas. The chain of economic beneficiaries is described for select case studies from Kanpur, Delhi and Kolkatta:

Kanpur

There are 2770 farmers involved in wastewater agriculture with a total landholding of 2500 ha of which 333 (112 lessees + 211 encroachers) practice agriculture on 414.6 ha of land owned by Kanpur Nagar Nigam (KNN). KNN owns 511.58 ha of land in wastewater irrigated areas. Hence, the average landholding for lessees and land owning farmers are 1.25 ha and 0.81 ha, respectively.

The Lessees are tenants practicing wastewater agriculture on KNN land for decades. Most of them live in the town and are engaged in government or private service or business. According to the lessees, the Jajmau land was barren land acquired by the municipality for development into a sewage farm. People were invited and allotted land for agriculture. Originally, 250 ha of land were delineated and the land was divided into 2 ha plots. Each plot was connected to a road so that the farm produce could be conveniently transported. The sewage supply was assured throughout the year at the rate of 5,000 gallons per acre per day (1.7 m irrigation depth over a year). The land was prepared for agriculture and then handed over to the lessees.

The plots were leased out for the first time in 1951 for a period of 7 years. Lessees were required to pay @ Rs. 120/- per acre (USD 6.70 per ha) per annum which has now been increased to Rs. 625/- per acre (USD 35 per ha). This included the rental and irrigation charges. Transfer of the lease or subletting was not allowed. The Development Board (now KNN) leased the land on the condition that the lessee would not overuse the sewage, making it sewage sick. If observed, the Board could exercise the right of terminating the lease. The Board also put restrictions on the cultivation of vegetables that were consumed raw.

An agricultural expert was also appointed by the Board as the Farm Manager to provide technical assistance and suggest crops and cropping patterns to the lessees. An experimental model farm was also started under the Farm Manager.

There is however a conflict between KNN and KDA (Kanpur Development Authority) on the ownership of the sewage farm, with KNN wanting to sell the land presently being used for wastewater farming. However, a change in the land ownership will reduce the land area for wastewater disposal considerably. KNN is also presently considering an increase in the land rental and irrigation charges from the present Rs. 625/- to 970/- per acre per annum.

The lessees have been growing two crops every year namely, paddy and wheat (fodder). From a production figure of 45-50 quintals/ha of paddy and wheat they now obtain only 30-35 quintals/ha. This decrease in productivity was noticed since the early nineties when the Ganga water was replaced by the tannery effluent under the new dispensation of the Ganga Action Plan. Very few farmers now grow wheat (fodder) due to the reduction in its productivity by half and also because the crop produce gets damaged due to excessive irrigation.

The selected villages are close to the sewage channel and have assured irrigation 365 days a year. Also the land in these villages is suitable for the cultivation of vegetables and flowers. Majority of the farmers own livestock and they sell the milk. For example, in Motipur, a village dominated by the Yadavas whose traditional occupation is livestock, almost all the families own buffaloes and derive a significant part of their household income by selling milk.

The marginal farmers, owning less than three bighas[70], are hardly left with any surplus grain to sell in the market. Most of surplus production, if any, is sold in the village itself.

[70] 1 bigha = 2327 Sq.m.

There are traders in the villages who purchase the produce. Some farmers take their produce to Lal Bangla market located at a distance of 5 km from the nearest village and 10 km from the remotest village to sell the paddy and wheat to whole sellers. The whole sellers, in turn, sell the paddy to rice mills and the wheat to retailers. Very few farmers have storage facilities and are therefore forced to sell their produce when the rates are the lowest during the season. Those who store their produce, earn more by selling their produce during the off-season. Farmers prefer to sell their paddy and wheat to local traders in the village instead of transporting the same to the market. The crop residue of paddy and wheat is mainly used as fodder and very little is sold. Farmers who have surplus fodder sell it to traders and those with fodder-cutting machines in the market. They either sell the standing crop to the trader or take it to market. The fodder cutting traders further sell it to dairies in Kanpur.

Farmers in Pyondi, Sheikhpur, and Jaana grow vegetables on small pieces of land (less than 0.2 hectare). They grow a variety of vegetables like pumpkin, cucurbits, bottle gourd, cabbage, cauliflower, ladyfinger etc. and carry their produce to the market on bicycles. Vegetables are a good supplement to their income and are sold to whole sellers in the market early in the morning. The whole sellers sell the vegetables to vendors who sell the same to consumers. The market places in Lal Bangla, Defence Colony, and Rama Devi are at the distance of 5-10 km from these villages.

Farmers in the above mentioned villages also grow flowers on small pieces of land (less than 0.2 hectare). Earlier the area was known for its roses but now very few farmers grow them. The farmers sell the flowers at Shiwala, Bara Chauraha (informal market places) or temples and take their produce to the markets on their bicycles. The market places are at a distance of 15-20 km. They get a good return during festivals when the demand for flowers is high. However when there is no demand, they even have to throw their produce. The flowers are further sold to malis in the wholesale market. The Malis either sell it at temples or supply it to fixed customers at their houses.

In Madarpur, Kishanpur and Jaana, there are some fishermen/ boatmen (mallah or nishad) who are involved in fishing. They fish in the river Ganga and catch a variety of fish like the padna, pyora, khabdi, china, sour, chamerguch, chilva, balm, padahin, rohu etc. They sell their catch to vendors in markets like Sheetla bazaar, Purani chungi, Nai chungi, Rama devi, old subji mandi and Lal bangla which are at distances of 5-10 km. The vendors further sell it to consumers.

Kolkata

It was initially felt that all fish in this region are sewage-fed. However during the survey it was learnt that small fish are first reared in freshwater before the fishermen working in the fisheries as daily wage labour, release them into the sewage water. Fish are caught by them continuously for four hours and are simultaneously weighed. These fishermen are able to earn upto Rs 2,500 per month from the fisheries. In fisheries owned by private individuals, their employment is not permanent. Fish sellers gather there and the fish is auctioned. The manager of the fishery is usually the auctioneer. The fish is given to the highest bidder which he sells in the market. Most of the sellers receive some amount of fish. These fish sellers often sell it in the auction market or in the retail market. Working within each fishery, apart from the fishermen, are night guards, maintenance workers, net maker, boat makers, accountants and others. They earn upto Rs 2500 per month. Problems faced by the fisheries are the availability of adequate amounts of sewage water and labour problems. Another serious problem is theft. Fish are stolen from the fisheries during the night by slum dwellers and anti-social elements living around the fishery. Sometimes the workers themselves indulge in theft.

However, one striking characteristic of these fishermen is that desipite remaining in sewage-water for four continuous hours, they rarely fall ill. They do not develop any skin infection or water-borne disease. They apply a homemade ointment, usually made out of locally available herbs, all over themselves while in the water and seem to have developed natural immunity. This may be also be because of solar rays, which destroys the harmful microbial activities up to 4-5 ft below water. Though physical filth is observed, microbes that cause infections and other water-borne disease are not common to these people. Their food comprises mainly of rice, fish and vegetables. They do not take much of pulses. Communication to the city from these areas is difficult.

Paddy cultivators have decreased in number over the last 10 years. Most of them have sold their land for reclamation of the city. There however seems to be an ambiguity regarding the ownership of the land. Initially, most of the land belonged to the Zamindars of Sealdah and Shyambazar. Some were vested under the Land Ceiling Act while some were abandoned by zamindars and forcibly occupied by settlers from Bangladesh (erstwhile East Pakistan). Later the State Government issued a notification that the land would be taken over for the purpose of development, thereby preventing further sale. However, large paddy fields still exist in Panchannagram, Krolberia, Bamonhata, Durgapur and Saintola. Around these areas people mostly work as agricultural labourers. Very few of them have their own land. Many have unviable pieces of land and as a result they are also forced to work as agricultural labourers. They live in mud huts with tiled roofs. Farmers were quite hospitable and were not as hostile as the bheri workers. Paddy cultivation takes place twice a year. Both Aman and Boro crops are grown. The rest of the year is utilized for vegetable cultivation. Most of the farmers use the wastewater for irrigational purposes and also depend on rain. They usually use 100% wastewater for irrigational purposes. There are a few government irrigational schemes that are not available to all farmers. Freshwater is also mixed with wastewater for irrigational purposes in areas where the wastewater is too poisonous.

Family members usually carry out the vegetable cultivation themselves in and around Dhapa. They usually do not hire labourers, as the areas of the fields they own are too small. They grow mainly corn, cauliflower, cabbage, brinjals and other green vegetables. Women carry the produce to the markets in large baskets.

Most of the fish caught in the wetland area is sold at the fish auction market at Chingrihata close to the Eastern Metropolitan Bypass. The fish sellers go to this market with the catch bought from the bheris and sell their catch there. Local fish sellers bid for the fish here. The fish is sold to the highest bidder after which it reaches the consumer at the local market. The whole procedure is completed by 8'o clock in the morning. There is a considerable amount of product tie-in with wholesalers advancing money to bheri owners against a promise of fish delivery, especially during the dry season, when the fish catch is low.

Delhi

The farmer group in Delhi is mainly divided into contractors (who take the land on rent) and labourers (who work on daily wages). It was observed that most of the labourers are a part of the floating population who come from nearby states to work. They are hence not counted under the census surveys.

The scenario for landless labourers is more critical. These groups are employed full time in agricultural activity. Often these groups are the poorest of the poor who are not skilled in other work sectors. Their agricultural income alone runs their family expenditures. It was also observed that often their jobs and daily wages which range from Rs 50-70 are also susceptible to their work, i.e. the total amount they are able to generate out of the land on which they work. Since wastewater provides increased yield per unit of land, a certain degree of security in terms of income is offered to these masses. Also since the agriculture produce fulfils the food requirement of the people working on the land, they are able to save most of their earnings or divert it for other purposes like the education of their children.

8.0 Legislative and Policy Framework

Wastewater use in agriculture is age old, but efforts to develop mechanisms to control its negative impacts are relatively recent. One major initiative was the World Health Organization's (WHO's) international guidelines on wastewater reuse in agriculture and aquaculture and recommendations for wastewater treatment and crop restrictions.

(See Annexure 17 for WHO recommended microbiological quality guidelines for wastewater use in agriculture)

Similarly, growing public awareness and concern for controlling water pollution in the USA led to the enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the Clean Water Act. The Act established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry. The Clean Water Act also continued requirements to set water quality standards for all contaminants in surface waters. The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. It also funded the construction of sewage treatment plants under the construction grants program.[71] (See Annexure 18 for EPA Guidelines for Wastewater Quality for Reuse Options)

However, these broad international policy frameworks are considered by many governments as a legal framework, though they are not intended for absolute and direct application in every country. While focusing on treatment and crop restrictions, the WHO guidelines pay inadequate attention to the problems of high cost involved in construction and operation of treatment plants. Authorities are therefore faced with two difficult options: either treat rapidly growing volumes of wastewater and bring them within safe limits for agricultural use, or try to stop wastewater use among the users, which would deprive many households of their livelihood. The result is often that wastewater use and users are ignored and the practice of untreated wastewater use is denied.

[71] http://www.epa.gov/region5/water/cwa.htm

The management of India's water resources falls under the jurisdiction of a number of government agencies *(See Annexure 19 for details)*, although the primary responsibility for the development of water belongs to the individual states. The Central Government oversees the implementation of the national policy on resource development and exploitation as well as manages inter-state and international rivers and river valleys. It also provides technical advice to individual states on development, flood control, navigation, coastal erosion, dam safety, navigation and hydropower if required. The Ministry of Water Resources (MoWR) is the principal agency responsible for water in India and, as such, oversees the planning and development of the resource from policy formulation to infrastructure support.

The National Water Policy (NWP) is the primary document stating the position of the Government of India (GOI) on water resource issues ranging from drought and flood management to drinking water provision. The NWP, *2002* calls for intensifying research through recycling and re-use of water. It calls for better water management practices and improvements in operational technologies. The policy also calls for adopting participatory approach to water resources management. Specifically it calls for involving not only the various governmental agencies but also the users and other stakeholders, in an effective and decisive manner, in various aspects of planning, design, development and management of the water resources schemes.

While the state governments, and more specifically the local bodies in urban areas carry the prime responsibility for providing drinking water and sanitation facilities, the Centre allocates funds and ensures that funds are provided in State budgets and Five-year Plans. The 10th Five-year Plan of the GOI emphasizes conservation and reuse of urban wastewater. The document specifically mentions that "practice of focusing on water supply to the exclusion of sanitation and wastewater treatment, should be given up in the Tenth Plan. The document aims to broad base the Centrally- Sponsored Accelerated urban water Supply Programme (AUWSP) and recommends for enlarging the scope of the scheme to include sanitation, especially basic sanitation such as wastewater. This plan establishes the need for further research and development on technologies for the treatment of sewage and the health effects of sewage water used in agriculture and horticulture.

Draft *National Environment Policy*, 2004 recognizes strong environment-poverty linkage and lays emphasis on community participation, access to safe water and sanitation services and improving health of communities. Specifically it calls for enhancing reuse of treated sewage and industrial wastewater before final discharge to water bodies. The Policy document calls for a mechanism for cooperation in Research and Development for clean technologies as well as promoting the dissemination of the new technologies.

Despite the growing attention to water supply and sanitation sectors in Five- year Plans *(See Annexure 20 for details)*, the resource crunch related to providing infrastructure services continues to top the discussions at most platforms. Urban infrastructure in India is financed broadly through three sources:

a) Budgetary allocations of Central, State and local governments
b) Grants and loans from multilateral and bilateral agencies
c) Institutional lending

Monitoring and implementation of guidelines and rules usually lies on both Central and state bodies. However, field analyses throw up multiple issues regarding proper implementation of such guidelines. Lack of clarity regarding areas of operation often leads to overlapping of different departments. Most importantly, management issues are not being scrutinized carefully; a backlog of work pertaining to maintenance and management of wastewater treatment and infrastructure remains. Since wastewater use in agriculture shows benefits in the form of livelihoods and income generated, there is a need to define a legislative framework for large-scale implementation of the same. A coherent national policy for wastewater use in agriculture and various other sectors is essential. With respect to the same, sufficient attention must be given to the bottlenecks/key issues in institutional handling of wastewater.

The following points sum up the various issues related to policy and their impacts:

- **Ambiguity in information regarding water quality**

  For example, in Delhi, the CPCB selection criteria for monitoring locations of the Yamuna are unclear. CPCB monitors the water of River Yamuna at five locations – Palla, Agra Canal (Madanpur Khadar), Agra Canal (Okhla), meeting point of Shahadra drain, and Nizamuddin. The selected sites are: (a) intake points from the river (intake for agriculture, drinking water, etc); (b) interstate borders; and (c) joining point of tributaries.

- **Wastewater generation and treatment values given in different publications of the CPCB do not match**

  The CPCB publication for November-December 2003 (Performance Evaluation of Sewage Treatment Plants in Delhi), when compared to another CPCB publication of June 2002 (Status of Water Quality in River Yamuna-NCT of Delhi), show contradicting results. (See Table 16)

Table 16: Wastewater Data Disparity

Parameter	June 2002 Report	November-December 2003 Report
Estimated sewage generated	3,600 MLD	3,167 MLD
Total treatment capacity (Combined for all STPs)	2,009 MLD	2,330 MLD
Actual treatment	1,723 MLD	1,478 MLD

Observations:
A decrease in sewage generated when the city population is growing.
Increase in treatment capacity yet a decrease in the actual treatment given.

- **Unavailability of data**

  The data for monitoring the effects of metal content for River Yamuna is not available. The document "Yamuna Water Quality Status for Year 2000" has data only up to the year 1999. Data was refused on the argument that it was not available for public. Similarly, data for monitoring metals in drains and treated effluent, especially in the context of health impacts of the same, is not available. Also, data for monitoring Faecal Coliform in treated effluent from STPs is unavailable.

- **Development of action-oriented plans**

  In Kanpur, the Ganga Action Plan was launched in 1985 to reduce the load of pollution on River Ganga. Before GAP, about 240 MLD of sewage and 5-6 MLD of tannery wastewater was generated in Kanpur. Wastewater from the city as well as effluent from the tannery was flowing into the Ganga without being treated. Therefore, interception, diversion and treatment of wastewater were accorded top priority under GAP. Through this plan, a large number of treatment plants were set up to deal with the sewage and effluents entering the Ganga. (See Box 2 for details on the Ganga Action Plan)

  Similarly, to deal with sewage specifically, the sewage farm scheme was launched by the Central Government in 1951 to check pollution of the Ganga waters and increase agricultural production in the area. The scheme was named as Sewage Utilization Scheme under which infertile lands were acquired along river Ganga in the east of Jajmau area. The acquired lands were allotted for agriculture at rate of Rs. 120 per acre per annum (US$ 6.7 / ha/ year). This cost was inclusive of land as well as sewage irrigation costs. At present, 522.25 ha of land is owned by Kanpur Municipal Corporation out of which 424.31 ha is being used for agriculture by lessees. Exact information is not available about the total wastewater irrigated land area owned by farmers. In 1962, approximately 1700 ha of land used to be irrigated with wastewater, and 1250 ha was irrigated in 1992 while the irrigation capacity then was 4583 ha of land, told the Secretary, Sewage Farm Holders Association.

- **Contradictory information provided by the authorities**

  The exact area under wastewater irrigation is not known in the sewage-irrigated areas which also include highly polluting leather factories. Different government departments provide different data regarding the land area irrigated with wastewater in their respective reports.

- **Lack of clarity on monitoring procedures**

  CPCB should publish both monitoring results and the monitoring procedures followed to arrive at the results together.

Box 2 - Ganga Action Plan
Department of Environment, in December 1984, prepared an action plan for immediate reduction of pollution load on the river Ganga. The GAP (Ganga Action Plan) was approved in 1985 as a 100 per cent centrally sponsored scheme. The GAP-I envisaged to intercept, divert and treat 882 mld (Million litres per day) out of 1340 mld of wastewater, generated in 25 class-I towns (including Kanpur) . GAP-I was scheduled for completion by March 1990, but was extended progressively up to March 2000. While the GAP-I was still in progress, it was decided in February 1991 to take up the GAP-II, covering the pollution abatement works (a) On the tributaries of river Ganga, *viz*. Yamuna, Damodar and Gomati.(b) In 25 class-I towns left out in Phase-I and (c) In the other polluting towns along the river. The GAP, launched in 1985, with the objective of bringing water quality of river Ganga and its tributaries to bathing levels, was not able to achieve its objectives, despite a total expenditure of Rs 901.71 crore over a period of 15 years. **Under GAP-I completed following schemes were completed in Kanpur:** • **Cleaning of trunk and main sewers** • **Interception of 16 drains** • **Construction of 160 mld main sewage pumping station at Jajmau** • **Construction of 130 mld domestic wastewater treatment plant (activated sludge process)** • **Construction of 5 mld UASB pilot treatment plant under Indo-Dutch assistance** • **Construction of 36 mld UASB treatment plant for combined tannery and domestic wastewater under Indo-Dutch assistance** • **Construction of a separate open drain collection system and taping of 4 nalas in the tannery district under Indo-Dutch assistance**

8.1 Bottlenecks and Required Policy Changes

Listed below are the **bottlenecks** and the **required policy changes** in the Indian scenario:

8.1.1 Lack of central planning

- The division of responsibilities among the ministries involved and authorities is not well established
- Absence of a law governing decentralized wastewater treatment and reuse of treated effluent
- Lack of well-defined standards for wastewater reuse in various sectors. Also, the irrigation standards defined under the Environment (Protection) Rules, 1986, are not comprehensive enough. For e.g. Rule 3 Schedule I – IV stipulates emission standards for various industrial pollutants but remains silent on the parameters that would help allow monitoring of wastewater quality. Serious efforts from the government are required.
- Existing command and control policies in almost all sectors must be substituted by other market-based instruments such as tax charges, etc. A blend of both could be a more feasible option

8.1.2 Lack of public awareness

- Awareness among the farmers regarding best and safe practices of using wastewater in agriculture is lacking. This forms the prime reason for the farmer population being the target for various health risks
- Awareness regarding safety measures such as wearing boots and gloves while on the field, washing of hands after field work, washing of vegetable produce from the field before selling or self consumption, types of crops to be grown (crops to be eaten after cooking, crops based on type of wastewater), best irrigation practices must be given to farmers in these areas
- The consumers of these vegetables are generally not aware of their source and, hence, often do not take precautionary measures such as washing of vegetables. Since the vegetables produced in these areas get distributed in various markets of Delhi and, hence for an untraceable part of the food chain, the public in general must be made aware of the same.

9.0 Significance and extent of wastewater use in India

A National assessment was carried out to assess the current national level situation on the extent and quality of wastewater used for agriculture in India. The results from this national assessment are based on secondary data on quantities of urban wastewater generated, nature of treatment, extent and significance of use in select urban centres in India, and primary data generated through surveys conducted as part of four case studies—Kanpur, Kolkata, Ahmedabad and Delhi.

9.1 Wastewater generation, and treatment status in Indian cities

Overview: The report entitled "Status of Water Supply & Wastewater Generation, Collection, Treatment and Disposal in Class I cities, published by the Central Pollution Control Board (Feb 2000) states that surface water is the major source for organised water supply in Indian cities. The data covers 88% of the total municipal population of class I cities under organised water supply. Out of 299 class I cities, 77 cities are with 100% water supply coverage. In 158 cities there is 75% coverage and above, and in 43 cities 50% coverage and above. In 10 cities the water supply is below 50%. The national average per capita water supply for class I cities is 183 lpcd. This figure has increased from 147 lpcd in 1988 to 183 in 1995.

Studies indicate that the total wastewater generated in 299 class I cities was around 16,662 million liters a day (MLD). However for the total sample surveyed, 44% of the cities could not furnish the wastewater generation data and hence for such cities, wastewater generated has been estimated at 80% of the volume of water supply, which is based on "The manual on sewerage and sewage treatment of CPHEEO". The details of Wastewater, generated, collected and percentage sewerage coverage in class I cities is given in *Annexure 21.*

The statistics related to the treatment facility available shows that wastewater treatment capacity is around 4,037 MLD that is about 24.2 % of total wastewater generated. Out of the total wastewater generated about 59% is generated by 23 metropolitan cities. Maharashtra alone contributes about 23%, while the Ganga river basin contributes about

31% of the total wastewater generated in class I cities. Out of 299 class I cities, 160 have a sewerage system for more than 75 % of the population, while 92 cities have more than 50% of population coverage. On the whole 70% of the total population of class I cities is provided with sewerage facilities. Among the metropolitan cities, Delhi remain the highest generator of wastewater (3167 MLD), followed by Mumbai at 2456 MLD and Kolkata at 1432 MLD. In terms of percentage, sewerage coverage is lowest for Nashik around 25%, followed by Delhi at 45%. The highest coverage is for Mumbai at 90%.

Treatment & Disposal: Out of 16662 MLD of wastewater generated, only 24% is treated before being released, the remaining 66% is disposed off untreated. 27 cities have only primary treatment facilities, and 49 have primary and secondary treatment facilities. Treated or untreated wastewater is disposed off into natural drains joining rivers, lakes or seas or used on land for irrigation/fodder cultivation or a combination of these by the municipalities. Some municipal corporations have sewage farms organized by private/farmers and controlled by private/municipality/irrigation departments. The details of Sewage farming in class I cities are given in *Annexure 22.*

The central Pollution control Board has been producing these statistics periodically every decade to review the situation with regards to urban wastewater**.** The wastewater generated in class I cities has increased from 7,006 MLD in 78-79 to 12,145 MLD in 89-90 to 16,662 MLD in 1994-95. While there was a drop in the statistics of wastewater collected from 78 to 89, there has been a sharp increase in wastewater collected in 94-95 ie: 72% of the total wastewater generated. The situation varies from city to city drastically. Analysis of the Indian scenario reveals that some of cities, inspite of having the required treatment facilities are not able to utilize the sewage treatment plants fully.

The total wastewater generated in Delhi is estimated to be 3167 MLD. The installed treatment capacity in Delhi is 2330 MLD, out of which only 1478 MLD reaches the sewage treatment plants and gets actually treated. The main reason for the low utilization of the sewage treatment facility is the lack of a proper conveyance system for municipal sewage. About 55% of Delhi's population does not have a proper sewerage system and hence the waste generated from these areas goes untreated into the river or natural streams.

Kanpur, the largest and most important industrial city of Uttar Pradesh, on the banks of the river Ganga has 75% sewage coverage. Although the water supply to the city has been increased as per the demand, little attention has been paid to the augmentation of the sewerage system or technical remodelling to cope with the increased flow of wastewater, thereby making the system function beyond its optimum capacity. The total wastewater generated in Kanpur is 390 MLD, out of which only 160 MLD of sewage and 9 MLD of tannery wastewater is collected and treated under the Ganga Action Plan. The rest is disposed off in the rivers, Ganga and Pandu.

Ahmedabad (as per 1994-95 statistics) generated a total of 556.0 mld (domestic and industrial) of wastewater, out of which only 445 mld (80%) was collected and subjected to primary and secondary treatment. Statistics of 1997 showed that the city generated 740 MLD of sewage as against a treatment capacity available with the municipality of only 630 MLD. The remaining wastewater along with the treated wastewater found its way directly into the Sabarmati river. Sewage waste in the city flows through a vast network of sewers and pumping stations to be transported for treatment to the treatment plant at Vasna which is located in south eastern part of the city. The sewage from the entire Ahmedabad Municipal Corporation area is transported with the help of 12 pumping stations to this site for treatment. As Ahmedabad has a flat terrain, the sewage network is supported by 20 drainage pumping stations that help transport the sewage from all parts of the city. However, over the years, due to the considerable increase in population, the energy expenditure incurred to pump the high quantities of waste has also considerably increased.

The Water supply and sewerage division of the Mumbai Municipal Corporation manages the sewerage for Mumbai. The city generates 2671 MLD of sewage and 6256 MTD of solid waste. Water pollution in Mumbai also goes unchecked as the treatment capacities are limited and untreated water is discharged in rivers and creeks than eventually merged with the sea, making it polluted and unfit for bathing, water sports and commercial fishing.

In Hyderabad, the Musi River, which carries most of the city's sewage, is in bad shape. The river runs about 20 kms within the city limits and passes downstream through a length of about 150 kms before joining the River Krishna. In Hyderabad, only 62% of the city is covered by the sewerage network. Due to the limited sewerage treatment facilities, the rest of the waste is discharged untreated into the river.

On account of the increase in the industrial need for water, wastewater from Industries is also going up continuously. Discharge of effluents from industries to water bodies pollutes enormously larger quantity of unpolluted water. As per the Central Statistical Organization (CSO), there are about 32 lakh industries in India as of 1998-99 of which 1,35,551 are registered manufacturing industries. The total wastewater generated from all major industrial sources in the country is 82,446 MLD, which includes thermal power plants (24%), pulp and paper (14%), engineering (32%), textile (13%), steel (8%) and others (9%).

External reports estimate that presently only 10% of the wastewater generated in the country is treated; subsequently, severe water pollution coupled with the depletion of ground water reserves remains a serious problem and immediate challenge in India. The problem gets all the more severe when industrial effluent, being more contaminated and polluted, gets mixed with domestic waste through its discharge in to the same sewer network and nalas that serve the city. The market for adoption of advanced technologies for wastewater use arising from industries and municipal corporations' accounts for the largest percentage of the total environmental market in India. As per a survey by the US Trade Department, the total market potential for water and wastewater treatment, including the requirements of Municipal and Industrial sectors, is estimated at US $ 900 million and is expected to grow at approximately 14% each year in the mid-term. Industrial wastewater treatment is arguably; the largest segment, accounting for nearly half of the total market sizes. The water and wastewater treatment sector also accounts for the highest environmental spending within both the public and private sectors.[72] With the functioning and operating of Wastewater treatment plants being a costly affair, local bodies need to look at alternate ways of disposing off or recycling wastewater generated by the growing population.

[72] Market Report: Opportunities for Environmental Technology in India. Focus on Water, Air and Hazardous Waste

9.2 Nationwide estimation of wastewater use in Agriculture and Aquaculture

Scattered evidence is available that shows the predominant use of urban wastewater for agriculture and aquaculture practices in the Indian context. All four cities covered by the primary survey, show the use of wastewater for agriculture/ aquaculture. Apart from this, the secondary literature review also shows extensive wastewater reuse for irrigation in Hyderabad, Indore, Nagpur, Chennai, Kanpur, Mumbai and Vadodara. In the following paras we present a typology for assessing the extent of wastewater use in India.

9.2.1 Typology for National Assessment of wastewater use in agriculture in India

For assessing wastewater use a modified typology presented by Wim van der Hoek[73] is applied. The author classified wastewater use into three types: direct use of untreated wastewater, direct use of treated wastewater and indirect use of wastewater. The modification pertains to combining the two types of direct uses into a single type referred to as **direct use.** This is essentially due to the fact that treated wastewater in some of our case study areas is noted to contain contaminants that produce adverse health impacts to users. Typology of **indirect use** is used as defined by van der Hoek to carry out national assessments. Owing to limitations in data availability the assessment is restricted to Class I cities. Based on this typology and data obtained for select cities from secondary and primary sources, a ratio is worked out for the area irrigated by wastewater to unit volume of wastewater for each of the two types—direct use and indirect use. Table 18 shows that the ratios for direct use and indirect use in India are 6 and 39, respectively. The ratio for indirect use is high, perhaps, due to the fact that wastewater gets mixed with natural stream/river flows before it is drawn through pumping or irrigation projects through a network of canal distribution. For assessing the extent of wastewater use at the national level, these ratios are multiplied by the volume of wastewater supplied to sewage farms (Table 19), obtained from secondary data, for direct use and by the volume of wastewater generated also obtained from secondary sources (Table 20). The computations are shown in Table 17. It shows that the estimate of total area irrigated using wastewater directly and indirectly in India is 6.5 lakh ha.

[73] Hoek, Wim van der : "A Framework for a Global Assessment of the Extent of Wastewater Irrigation: The Need for a Common Wastewater Typology", Chapter 2, Wastewater Use in Irrigated Agriculture, Scoot C.A, et al (ed) 2004, IWMI, IDRC, CRDI, CABI, U.K.

Table 17: Estimate of wastewater use in agriculture in India

Type of use	Ratio (area/ volume of wastewater) (ha/MLD)	Volume of wastewater (MLD)	Estimate of area irrigated by wastewater (ha)
Direct use	6	1492	8952
Indirect use	39	16452	641628
Total			**650580**

Table 18: Direct and Indirect use of wastewater for agriculture in select cities

Cities	Total Area under wastewater irrigation (ha)	% of population covered by sewer system	Volume of wastewater (MLD)[74]	Type of use (direct/ indirect) [75]	Wastewater treatment/ use	Reference
Case of twelve sewage farms from Ahmedabad, Amritsar, Bikaner, Bhilai, Delhi, Gwalior, Hyderabad, Jamshedpur, Kanpur, Chennai, Madurai and Trivandrum	6473 (command area of sewage farms)		795	Direct use (Sewage channels)	Only four farms show some level of primary/secondary treatment while rests do not undertake any treatment at all	Shende (1988)
Delhi	1,700		963	Direct use [Sewage channels]	Treated (industrial water mixed with sewage)	Final Report: Urban Wastewater: Livelihood, Health and Environmental Impacts in India (December 2004)
Kanpur	2,500		130	Direct use	Partially treated (industrial wastewater mixed with sewage)	Ecofriends (2005): Case Study report
Kolkatta	4,887		716[76]	Direct use	Untreated	Gupta, Gautam (2005): Case study report

[74] For direct use design capacity of sewage channel or sewage treatment plant (as available) providing irrigation is considered. For indirect use the figure refers to wastewater generated by the city.
[75] Direct use is the application to land of wastewater directly from a sewerage collection system or sewage treatment plant in which control exists over the conveyance of the wastewater from the point of discharge from a treatment works to a controlled area where it is used for irrigation. Indirect use is the wastewater application to land from a water body receiving wastewater.
[76] assuming 50% of total 1432 used in Kolkatta as area under aquaculture and agriculture are almost same.

Cities	Total Area under wastewater irrigation (ha)	% of population covered by sewer system	Volume of wastewater (MLD)[74]	Type of use (direct/ indirect) [75]	Wastewater treatment/ use	Reference
TOTAL	**15560**		**2604**	**Ratio = 6**		
Hyderabad	40,600 (area in and around the city)	62	600	Indirect use [natural drainage course (river) through the city and from several points downstream]	Almost the entire area indirectly uses mixed treated and untreated wastewater	Buechler, Stephanie and Gayathri Devi. 2004
Six class I cities, Indore, Nagpur, Jaipur, Ahmedabad, Banglore and Chennai (with Chennai as an exception where wastewater is not used for irrigation but for industrial purpose)	35970 excluding Ahmedabad		1922 excluding Ahmedabad	Indirect Use [Natural drainage courses (rivers and nalas)]	Mix of Primary, Secondary, and Primary and Secondary treatment	Londhe, Archana *et. al* (2004)
Vadodara	20247 (across 100 villages in and around city from		200	Indirect use [sewage use along stretch of three rivers and		Bhamoriya, Vaibhav. 2002

Cities	Total Area under wastewater irrigation (ha)	% of population covered by sewer system	Volume of wastewater (MLD)[74]	Type of use (direct/ indirect) [75]	Wastewater treatment/ use	Reference
	sewage (14567 ha) and industrial wastewater 5680 ha)			along an effluent channel for industrial wastewater]		
Hubli-Dharwad				Indirect Use [Natural drainage courses (nalas and river)]	Untreated	Bradford, Andrew, et al
Ahmedabad	33,600		633	Both--Indirect use [along river banks till Watrak tributary confluences with it] and direct use [irrigation command area of the reservoir	Both treated and untreated (industrial wastewater mixed with sewage).	Final report: Impact of Wastewater on Livelihoods, Health and Environment: Ahmedabad Case Study, 2005

Cities	Total Area under wastewater irrigation (ha)	% of population covered by sewer system	Volume of wastewater (MLD)[74]	Type of use (direct/ indirect) [75]	Wastewater treatment/ use	Reference
				which receives wastewater]		
TOTAL	**130417**		**3355**	**Ratio = 39**		

Table 19: **Details of Sewage Farming in Class-I Cities**

Sr.No.	Name of the class-I city	Quantity of wastewater collected (mld)	Quantity of wastewater supplied to sewage farms (mld)
1	Ahmedabad	445	NA
2	Anand	10.4	2.6
3	Bangalore	300	NA
4	Bhagalpur	30	8
5	Bhopal	95	13.6
6	Bombay	2210	20
7	Calcutta	1075	817
8	Chandigarh	209.8	136.2
9	Coimbatore	46	NA
10	Delhi	1270	NA
11	Gandhi Nagar	43.5	41.86
12	Hyderabad	288	40
13	Indore	118	127.3
14	Jaipur	165	22.7
15	Kanpur	150	NA
16	Kochi	46	NA
17	Lucknow	80	NA
18	Ludhiana	47	NA
19	Madras	257	10
20	Madurai	40	NA
21	Nadiad	10	2
22	Nagpur	168	NA
23	Patna	184	NA
24	Pune	367	80
25	Rajkot	48.7	40
26	Surat	112	1.3
27	Tiruchirapalli	52.7	8
28	Tirunelveli	44.8	18
29	Tuticorin	1.2	1
30	Vadodara	105	20
31	Varanasi	127	82
32	Visakhapatnam	55	NA
	Total	**8,201**	**1,492**

Table 20: Status of Wastewater Generation in Class-I Cities in Different States & Union Territories

Sr.No.	Name of the state/union territory[77]	No. of class-I cities	Population	Domestic (mld)	Industrial (mld)	Total (mld)
				Volume of wastewater generated (mld)		
1	Andhra Pradesh	32	10845907	896.8	25	921.8
2	Bihar	17	5278361	938.5	NA	938.5
3	Gujarat	21	8443962	1110.4	65.4	1175.8
4	Haryana	12	2254353	220.4	NA	220.4
5	Himachal Pradesh	1	82050	10	NA	10
6	Karnataka	21	8283498	744.5	25	769.5
7	Kerala	14	3107358	296.8	0	296.8
8	Madhya Pradesh	23	7225833	784	NA	784
9	Maharashtra	27	22731865	3365.5	227.9	3593.4
10	Orissa	7	1766021	263.2	NA	263.2
11	Punjab	10	3206603	360.5	NA	360.5
12	Rajsthan	14	4979301	763.2	NA	763.2
13	Tamilnadu	25	10745773	771.9	NA	771.9
14	Uttar Pradesh	41	14480479	1557.7	NA	1557.7
15	West Bengal	23	13943445	1574.7	48.4	1623.1
16	Chandigarh	1	504094	217.9	NA	217.9
17	Pondichery	1	203069	24	NA	24
18	Delhi	1	8419084	2160	NA	2160
	Total	**291**	**126501056**	**16060**	**392**	**16452**

Source: Status of Water and Wastewater Generation, Collection, Treatment and Disposal in Class I cities, Central Pollution Control Board, 2000, New Delhi

9.2.2 Aquaculture

The potential of wastewater in enhancing the yields of fish and agricultural crops is well established (Hickling 1971; Jhingram and Ghosh 1988; Hauck 1978). Allen and Hepher (1979), in a review of wastewater aquaculture indicated that wastewater fed ponds

[77] It is assumed that wastewater irrigation is not prevalent in north-east states as it was not found in literature, hence these states are not included.

produce high fish yields because of the increase in the natural food organisms through fertilization by inorganic manner. The single major factor that differentiates the environment of sewage fed culture and conventionally fertilized one is the presence of large amount of organic matter in the former, which controls most of the chemical and biological properties of that system. Sewage effluents in the fish pond act in the same manner as inorganic fertilizers and liberate nitrogen, phosphorous and trace elements which stimulate the production of fish food organisms in the culture system. (Hepher 1962). Apart from releasing nutrients to stimulate the growth of fish food organisms, the organic content of the effluents exhibits other ways of enhancing the productivity levels. Mann (1972) reported that smallest particles of organic waste provide a direct source of food.

Commenting on public health aspects of wastewater fed aquaculture, Apurba Ghosh in his paper titled “Environmental and Sanitary Aspects of Wastewater Recycling for Productive Use” concluded that possibility of bio accumulation of some metals in toxic amounts in food materials is a matter of concern to the scientists dealing with waste recycling process.

- One of the major areas of sewage fed fish culture is in Calcutta, popularly known as the Bidhayari Spill area, with an annual total production of about 7,071 t of fish. Some temple ponds and rock pools in South India are hypereutrophic; partly because of sewage inputs Vellore fort moat is heavily polluted by sewage and develops a permanent bloom of algae. It is used for aquaculture and yields an average of 6940 kg/ha/yr, mostly tilapia. Calcutta is the only place where raw sewage is used for aquaculture.[78]
- Effluents from well-drained sewage farms may also be collected and used for aquaculture eg. the Madurai Sewage farm. In Madhya Pradesh, treated or untreated wastewater is used for agriculture and aquaculture. Most of the tanks and ponds in and around those towns where the disposal of domestic waste is through open drains and natural channels are sewage fed. Sewage is introduced either purposefully to fertilize the ponds; or incidentally due to location in low lying areas. Although fish production from these ponds is much higher than from unfertilized ponds, health

[78] Krishnamoorthi, K.P. 1990. Present status of sewage fed fish culture in India, with special reference to experimental studies in Maharashtra State, Proceedings of International Seminar on Wastewater Reclamation and Reuse for Aquaculture, Calcutta, India.

hazards cannot be ruled out as most of the tanks are community ponds used for bathing, washing and to a limited extend even for drinking water. In some extreme cases uncontrolled flow of sewage and accumulation of sludge over a number of years have resulted in excessive growth of aquatic vegetation and algae rendering the ponds shallow and ultimately converting them in to swamps. Sewage fish culture exists in number of cities in Madhya Pradesh like Bhopal, Bilaspur, Durg, Jabalpur, Jagdalpur, Raipur, Rewa, Satna and Seoni.

- Survey conducted in Delhi indicates some practices of treated and raw wastewater. The types of fish produced are Mangur and Catfish. Total number of 60 owners produce 460 tons of fish annually priced at Rs 12,000,000 (Rs 25/kg). The use of wastewater for Aquaculture has not only increased the yield but calls for low requirement of fish food since nutrients present in wastewater suffice for the same.

The above examples reveal that wastewater irrigation is practiced in many Indian cities either formally or informally. In most of the cases, it is a regulated practice of selling wastewater/ sewage through the STP, but a larger part of peri urban areas, which tend to be away from STP plants also use wastewater for irrigation.

9.3 Economic Importance of Sewage /Urban Wastewater in Class I cities

Municipal wastewater contains nutrients, which if not optimally reused may cause eutrophication in receiving water bodies, thus causing their premature ageing. Alternative use of this urban wastewater is its use for irrigation/fodder cultivation. In India around many urban centers, government and individual farmers use the treated or untreated sewage for fodder cultivation. The economic value of wastewater can be accessed based on its nutrient value and also water value.

- Central pollution control board has done analysis of concentration of nutrients in tonnes/day for the states in India. Based on this the value of nutrient in sewage assuming at the rate of Rs. 4220/- per tonne of nutrient (1996) works out to be 4.39 million/day. The total annual economic value of sewage generated from class I cities (2000) assuming there is no loss of nutrients after treatment, works out to be Rs. 1595.05 million.
- In Hyderabad, the farmers cultivating Jasmine through wastewater generates a lot of employment. The jasmine plantation gives flowers for 8-9 months per year and a

farmer can earn approximately Rs. 15,000 to Rs. 20,000 per ha for an 8-9 month flowering season. (Buechler and Devi, 2002).

- As per IWMI study, the total land under wastewater cultivation in five cities of Indore, Nagpur, Jaipur, Ahmedabad and Banglore is 53770 ha generating economy of Rs. 491.679 crores.
- A recent IWMI – TATA study (Bhamoriya, Vaibhav 2002) estimated the size of wastewater economy in the peri urban area of Vadodara. The idea of estimation was to analyze the cost of efficient wastewater discharge and reuse in agriculture vis a vis the benefits. It followed the thought that use of wastewater in agriculture was sustaining a large economy enough to justify the establishment of wastewater use as a variable in the decision making for establishing and design of water supply systems in urban context.
- The study calculates the total command area irrigated with industrial wastewater as well as domestic sewage and the corresponding sales worth of the crops produced through it. The results of agricultural economy sustained on wastewater flows concludes that wastewater flowing through the city of Vadodara sustains an agricultural economy worth Rs 825 million annually over 100 villages and 130 kms of linear distance.
- Treated wastewater irrigation is practiced in Delhi in areas around Keshopur STP and Okhla STP. Both the areas receive treated effluent from the STPs through a separate channel being provided by the STPs. An interview session of 80 farmers in the area revealed generation of net income of 15,700 per month from use of wastewater irrigation as compared to 7,200 per month from use of freshwater for irrigation per acre of land. Both Okhla and Keshopur have 205 and 1500 hectares of area under wastewater irrigation and generate a net annual income of 115005000 and 481500000 Rs. respectively. The Okhla area provides employment to 80 households and Keshopur around 600 households.
- In Kanpur wastewater is used both formally and informally for cultivating both Rabi and Kharif on 1253 acres of land. Wastewater discharged in rivers is used just downstream, untreated wastewater is also used from sewers/drains and directed to the field or pumped areas.

10.0 Options for Mitigating Negative Impacts of Wastewater Use

Wastewater use in agriculture benefits livelihoods and increases income generated, there is a felt need to define a legislative framework for large-scale implementation of wastewater use. It is very important to assess all possible policy and technical options that can reduce or eliminate the negative health effects and economic burden resulting from unregulated agricultural irrigation with wastewater. The type of remedial measures that should be evaluated includes the following:

10.1 Restrictions on the type of crops grown, or modifications and control of irrigation practices

The transmission of communicable diseases to the general public from irrigation with raw or settled wastewater can be reduced by a number of techniques. Some of this is to restrict the types of crops grown and others through modification and/or control of irrigation techniques, and by preventing or limiting the exposure of health sensitive crops to pathogens in the wastewater. Flood and sprinkler irrigation of salad and vegetable crops usually involves direct contact between the crops grown and the wastewater used for irrigation, and thus introduces a high level of contamination. Well-controlled ridge and furrow irrigation usually involves less direct contact and contamination, while drip irrigation has been shown to cause little contamination of vegetables growing above the surface. Another possible control measure is to discontinue irrigation with wastewater at a specified period before harvesting the crop. This is difficult from an agronomic point of view, since vegetable harvesting is difficult to control.

10.2 Protection of Occupational Health

The main diseases affecting farmers irrigating with wastewater could theoretically be overcome if farmers wore boots or shoes to protect their feet from the penetration of hookworms, and if they paid close attention to personal hygiene, particularly by washing their hands before eating. Among farmers with higher levels of education and improved socio-economic conditions, an educational program aimed at achieving such goals may yield results. Such programs could be especially effective on centrally organized sewage farms, where the management could provide boots, and a washing facility could be installed adjacent to special clean areas for resting and eating. Health education among the farmers could also be started. However, in the case of hundreds of small, one-family marginal wastewater farms or plots, common in Kanpur, such a program of improved occupational health would be difficult to implement.

10.3 Wastewater Treatment to Eliminate and Reduce the Concentration of Pathogens and Pollutants to Acceptable Levels

If wastewater can be treated effectively before it is used in agricultural irrigation, the negative health effects to both sewage farm workers and the public consuming crops can be reduced. Of the identifiable health effects associated with the use of wastewater, those of greatest concern for most developing countries are caused by the hookworm, beefworm, etc. These pathogens can, over long periods, damage the health of both the general public consuming the crops irrigated with wastewater and sewage worker and their families. An optimal wastewater treatment system should, therefore, be able to remove almost all helminthes while a somewhat lower degree of removal of bacteria and viruses might be tolerated.

10.4 Need to Explore Other Income Generating Reuse Options

With the aim of reusing wastewater at maximum possible levels and reaping maximum economic benefits in terms of livelihood generation, various other options like aquaculture, floriculture, community-based gardens, etc, should also be considered and adopted. Various wetland flowers and grasses could be cultivated and harvested for fodder purposes. In Delhi, aquaculture practices are common in slum settlements like the Yamuna Pushta where residents collect their wastewater and grow fish, which is a important source of livelihood. The benefits of these practices are immense in terms of livelihood. The income generation factor is higher than that of agriculture.

10.5 Rights Awareness

Both farmers and the public must be made aware of their rights as citizens. The Right to Information Act, 2005, enables an individual to get general information from various government bodies. The farmers/public can use it to get basic information like the quality of irrigation water, the quality of vegetable produce, etc.

11.0 Conclusions

The study has looked into livelihood, environmental and health impacts of use of urban wastewater in agriculture in four cities through field assessments. Of these four cities two (Ahmedabad and Kanpur) represent the case of cities severely polluted by industrial wastewater with one (Ahmedabad) in dry semi-arid region of western India and the other (Kanpur) in the largest river basin (Gangetic basin) in India. The case of Delhi represents lower levels of industrial pollution while Kolkata covers a typical case of wastewater used in large-scale aquaculture systems for disposal/treatment. In these cases the key issues presented include: perceptions of wastewater users regarding health, livelihood and environmental impacts; state of the environment—land and water resources through anecdotal evidences generated through laboratory results; and economic chain of beneficiaries of wastewater use.

A National assessment on the significance and extent of wastewater use in India was carried out based on results obtained from these four field assessments and secondary literature on wastewater use in and around cities in India. For this, a modified typology of wastewater use appropriate to the Indian context was developed and applied which categorises wastewater use into direct and indirect uses.

The field assessments and national assessment offer interesting and practical insights for developing policy and legislative frameworks for wastewater use in India.

11.1 Tradeoffs

The field assessments show that urban wastewater irrigation has a significant positive impact on livelihoods, especially in cities having low or no industrial development or where urban sewage is not mixed with industrial effluents. While in cities where industrial effluents are mixed with urban sewage the comparative returns from wastewater-irrigated agriculture are lower than that from freshwater agriculture. However, wastewater irrigation poses risks to human health and the environment, the degree being more in case of cities with higher industrial development. In such cities, another key factor that shapes the degree of impact, especially on environment, is the duration of wastewater irrigation practice. In areas where it has been practiced for 3-4 decades, the land and groundwater quality have degraded greatly requiring large-scale investments in reclaiming the natural resource base. The health impact in these areas is also severe. An analysis of pros and cons of wastewater use would help assess the tradeoffs in sustaining the livelihoods of wastewater users: do the benefits compensate the negative impacts of wastewater irrigation, and what should be the time frame. As the field assessments in India indicate, the benefits do outweigh the negative impacts, at least during initial periods, until industrial wastewater and urban sewage began mixed. Irrespective of scale of benefits the policy makers have the responsibility to protect wider public interest. There is need for developing guidelines for specific crop types irrigated with untreated and treated wastewater in India. Guidelines could be effective only if they take into account diverse wastewater use practices that determine the exposure route of risk to public health. The field assessments show various types of crops such as vegetables and foodgrains being irrigated using treated and untreated wastewater, which are eaten raw and/or cooked, having implications on permissible levels of contaminants in wastewater use for irrigation. In addition, the wastewater users are exposed to health risks depending upon type of irrigation practice—whether it is furrow or flood irrigation.

Sustainability of agriculture using urban wastewater is also dependent on land use policies. The tradeoff can be between using land for urban agriculture and urban development. Although policies in land management in India do provide for protecting productive agriculture land, urban agriculture will face challenging pressures from changing land use patterns for urban development. For instance, field assessments in Kolkata show that paddy cultivators have decreased in numbers over the last 10 years as most of them have sold off their land for the reclamation for developing the city. Hence, there is need for policy makers to take into account the livelihoods of communities dependent on urban wastewater for agriculture in urban land use planning decisions.

11.2 Data Issues

For designing effective measures to mitigate impacts and assess suitability of various reuse options (such as crop type and groundwater recharge) it is imperative to know the concentrations of key parameters of quality of wastewater, groundwater and soil, over a time period. There is need to expand the set of quality parameters, especially for wastewater, being monitored by government authorities to include human pathogens, trace and heavy metals, and trace organic compounds. Further, monitoring needs greater sampling points in the wastewater collection, treatment and disposal system to capture the nature and extent of contaminants.

11.3 Guidelines for health and environmental quality

There are very few standards pertaining to water quality requirement for irrigation in the Indian scenario. These standards are also not comprehensive enough and do not cover various parameters like standards for metals. The major environmental concerns in an urbanizing India relate to high levels of water pollution due to poor waste disposal, inadequate sewerage and drainage, and improper disposal of industrial effluents. While the overall benefits of wastewater use in agriculture are obvious, the technology and expertise to allow these to be accrued with minimal detriment to public health or environment need to be developed and promoted. Further, the government needs to control the process within the broader framework of a national effluent use policy that can form a part of national plan for water resources.

11.4 Significance of Wastewater Economics

The field assessments show contrasting economic patterns in wastewater irrigated agriculture between cities where industrial effluents mix with urban sewage to alarming levels and in cities where it does not. The profit earned by cultivators in the former case is significant. For example, in Delhi, the total profits earned by the cultivators dependent on wastewater from two sewage treatment plants itself comes to Rs. 596.5 million (13.5 million USD) for one crop cycle. In addition, wastewater irrigated agriculture seems to be yielding higher returns as compared to freshwater irrigation as seen in case of vegetable farming from wastewater which yield net returns twice that of freshwater irrigated areas. Contrastingly, in Kanpur due to reduced crop productivity the net return from wastewater areas is lower than freshwater irrigated areas essentially due to lower yields and lower market rates. Thus, enhancing livelihoods of communities dependent on wastewater, especially in industrialized cities, will require concerted efforts for appropriately treating industrial effluents and improving the natural resource base of wastewater irrigated areas.

11.5 Beneficiaries of Wastewater Use

Wastewater-based agriculture and aquaculture provides income to a wide variety of interdependent actors involved in production and marketing chains. The actual wastewater users who are central beneficiaries in the production chain have diverse kinds of dependence on wastewater for livelihood. Some groups occasionally do have alternate livelihood options like small transport businesses, dairy business etc. but agriculture forms the most important part of their livelihoods. In addition, landless labourers also form part of the production chain. Often these groups are the poorest of the poor who are not skilled in other work sectors and agriculture related income alone supports their families. With regards to fisheries, apart from the fishermen, maintenance workers like night guards and weed cleaners are employed on a permanent basis, while transporters and daily-wage labour are contracted on a need basis. As regard the marketing chain, especially for vegetables, in most cases the family members themselves carry them to markets. They usually do not hire laborers, as their landholdings are too small. The complex nature of these chains makes the assessment of economic significance of beneficiaries of wastewater use even more challenging. Another point in this context is that these chains distribute the incomes inequitably. There is need for further research in this area. Thus, policy on wastewater use in agriculture will need to include ways to address the inequities and take account of the diverse set of beneficiaries from agriculture by wastewater irrigation.

11.6 Engaging Policy Makers

There is a gap between the volume of wastewater generated and the amount actually treated. This gap might increase as water supply increases due to rapid urbanization. At the same time, there is a gap between the availability of research on wastewater related issues and the use of this research into decision-making processes. Though the National Water Policy talks about participatory decision-making in water related issues, there exists no institutional space for either primary users or other CSOs to influence water policy, much less its implementation. A critical need therefore would be to work towards creating multi-tiered institutional forums that can address relevant policy and regulatory and enforcement frameworks.

11.7 Options to Mitigate Impacts

Urban growth has outpaced development of sewerage collection, treatment and disposal systems in India. And, given that development of sewerage system is capital intensive with recurring expenditure on its operation and maintenance in situations where most of the urban bodies face paucity of funds, it is unlikely that effective sewerage systems will be developed in the near future. Hence, strategies to mitigate detrimental impact will need to be devised for short, medium and long terms: The short-term measures will need to address acute health risks to wastewater irrigators and consumers of agriculture produce from wastewater irrigation by imposing restriction on crop types, using appropriate methods of irrigation, and adoption of preventive measures by wastewater irrigators to control exposure. In the medium term the gap between available research and required research on various facets of wastewater use needs to be bridged while engaging policy makers and other stakeholders in research processes. Finally, the long-term set of options need to include, a) awareness generation among wastewater irrigators and consumers of agriculture produce from wastewater irrigation, on health risks and impacts of wastewater use in agriculture and options to mitigate them, and, b) treatment of wastewater to desired quality: of the identifiable health effects associated with the use of wastewater, those of greatest concern for most developing countries are caused by the hookworm, beef worm etc. These pathogens can, over long periods, damage the health of both the general public consuming the crops irrigated with wastewater and the agriculturists and their families. An optimal wastewater treatment system should therefore be able to remove almost all helminthes while a somewhat lower degree of removal of bacteria and viruses might be tolerated.

11.8 National Assessment

National assessments on extent of wastewater use are greatly dependent on typologies of wastewater use. Using the broad typology of direct and indirect uses of wastewater in agriculture in India, the arable land irrigated by wastewater is approximately 600,000 ha. Although it is an insignificant proportion of total area under irrigation from other sources (surface water reservoirs and groundwater), it needs adequate attention of policy makers for four reasons: it does provide critical income support to many urban and peri urban farmers; the producers as well as the consumers of their products and the environment are at a high risk; urban wastewater being three fourths of urban water used is potentially a considerable and reliable source of water, available year round and which is likely to grow exponentially with the projected rapid urbanization of India; and, given the urban water supply scenario in the foreseeable future, wastewater use is an option that we can ignore only at our peril.

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Annexures

Annexure 1: Comparative Study of Income Generation Using Ground Water vis-à-vis Wastewater of Income Generation Using Ground Water vis-à-vis Wastewater

S. No	**Factors**	**Use of fresh water for irrigation**	**Use of wastewater for irrigation**
1.	Area of land	1 acre	1 acre
2.	Crops Produced	Cucurbit (*Tori*)	Cucurbit (*Tori*)
3.	Crop yield (tonnes)/month (summer season vegetables)	***Tori* - 1.5**, *Ghiya – 1.5*, Eggplant - 2, Okra – 1.5)	***Tori* - 2.5**, *Ghiya – 2.5*, Eggplant – 3.5, Okra – 2.5)
4.	Cost of land (Approximate Lease cost /month)*****(Rs)	3000	3000
5.	Money invested in buying seeds (Rs)	100	100
6.	Money invested in irrigation water (Rs/month)	90-100	NIL/Negligible
7.	Money invested in fertilizers/month (Rs)	500	200
8.	Money invested in buying insecticides/month (Rs)	1,000	1,500
9.	Labour charges/month (average 2-3 laborers on 1 acre land)(Rs)	3000	4500**
10.	Equipment O & M cost (Rs)	100	Negligible*****
11.	TOTAL MONEY INVESTED/month (summation of 4,5,6,7,8,9,10)(Rs)	7,800	9,300
12.	TOTAL INCOME FROM SELLING OF CROPS/Month (Rs)****	15,000	25,000
13.	**NET INCOME GENERATED** (12-11) (Rs/month)	7,200	15,700

(Calculations in the table are made for Cucurbit (*Tori*) indicated in bold

*Assuming the land is taken on lease from the Government by the cultivator (which is true for most cases according to field observations) who further employs labourers to work on it.

** Additional cost of 1 labourer has been kept since more individuals are required on wastewater irrigated land for weeding purposes.

*** There are generally no diesel/pumping related costs associated with wastewater because it is supplied through a network of channels in the fields and hence no pumping of water is required.

****Assuming the average price of *Tori* to be Rs 10/kg *(Maximum profit conditions have been taken)*

Annexure 2: Milk Production in Kanpur: Comparison of freshwater and wastewater irrigated areas

Particulars	**Amount**		**Rate (Rs. / kg)**		**Total cost (Rs.)**	
	Fresh water irrigated	**Wastewater irrigated**	**Fresh water irrigated**	**Waste water irrigated**	**Fresh water irrigated**	**Waste water irrigated**
Concentrates	5 kg	7kg	6	7.8	30.00	55.00
Green fodder	15 kg	6kg	50 /quintal	50 /quintal	7.50	3.00
Dry fodder (straw)	10 kg	10kg	100 / quintal	100 / quintal	10.00	10.00
Mustard oil	300 ml/month	1000 ml/month	50 / litre	25 / litre	0.50	0.90
Salt / Gur	50 g /day		5		0.25	0.45
Maintenance cost /building /treatment /labour			15 /day		15.00	3.50
Total expenditure					**63.25**	**72.85**
Income						
Milk (litres/day /animal)	**8**	**10**	**@Rs. 10 /litre**	**@Rs. 14 /litre**	**80.00**	**140.00**
Dung (kg/day/ animal)	30	20	0.30	-	9.00	-
Income from calf			@500/- after 6 months		3.00	
Gross income					92.00	140.00
Cost of production / litre					7.90	7.30
Net profit /buffalo /day					28.75	67.15

Annexure 3: Sabarmati River Water/Soil/Grain Analysis: Heavy Metals (ppm)

Village	Cadmium	Chromium	Copper	Lead	Zinc	Arsenic
Galiyana River water	0.02	0.46	0.16	0.00	0.07	0.00
Sahij River water	0.02	0.49	0.28	0.16	0.08	0.00
Gyaspur River water	0.007	0.92	1.57	0.17	0.65	0.00
Vautha Bore well water	0.01	0.61	0.22	0.40	0.56	0.00
Soil						
Sahij Soil	0.15	25.04	19.4	0.98	36.59	0.00
Grain						
Vautha Wheat	0.00	0.00	0.00	2.675	0.00	0.00

Listed below are permissible limits of heavy metals for water - ISI Standards

	Cadmium	Chromium	Copper	Lead	Zinc	Arsenic
Permissible Limits	0.01	0.05	1.5	0.10	15.00	0.00

No trace of pesticides was found in any of the water, soil or grains samples analysed.

Analysis by: Consumer Education Research Centre, Ahmedabad

Annexure 4: Mean values for selected quality parameters of untreated wastewater during 1996, Kanpur

PARAMETER	**Mean**
TSS (mg/l)	962.0
PH	7.9
COD (mg/l)	578.6
DOM (%)	0.08
TKN (mg/l)	78.5
NH_3-N (mg/l)	48.5
Org-N (mg/l)	31.6
T Coli (MPN/100 ml)	**1.2E08**
F Coli (MPN/100 ml)	**1.2E08**
Salmonella (MPN/100ml)	**1.0E05**
Streptococcus (MPN /100 ml)	**8.3E06**

Source: ITRC, Lucknow

Annexure 5: Quality of Wastewater in selected Indian cities

	INDORE	NAGPUR	JAIPUR	AHMEDABAD	BANGLORE	CHENNAI	STANDARDS
Ph	8.2	8.26	8	**6.6**	7.3	7.57	5.5 – 9.0
TDS	841	1496	814	**8760**	1200	12844	Below 2100
BOD	110	320	70	**460**	160	42.92	Below 30

Source: Urban Water Authorities

Annexure 6: Mean of the metal levels in different environmental media near wastewater irrigated areas in Kanpur.

Media	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Surface Water (mg/l)	0.006	0.058	0.018	6.324	0.343	0.041	0.041	0.080
Ground Water (mg/l)	0.001	0.003	0.006	0.767	0.119	0.021	0.026	0.182
Soil (ug/g)	3.03	249.16	60.59	6700.25	297.71	38.01	89.59	169.92
Veg/Crops (ug/g)	0.002	0.278	ND	0.449	0.508	0.479	0.141	1.402
Food Grains (ug/g)	0.17	0.012	2.472	50.636	41.032	1.123	0.207	47.16

Source ITRC, Lucknow, 1996

Annexure 7: Water Quality of River Yamuna in Delhi Stretch[79]

Locations	YEAR	Parameters (Ranges)						
		PH	Total dissolved solids mg/l	Chemical oxygen demand mg/l	Bio-chemical oxygen demand mg/l	Dissolved oxygen mg/l	Total coliforms Nos./100 ml	Faecal coliforms Nos./100 ml
River water quality criteria		**6.0-9.0**	**-**	**-**	**3 (max)**	**4 (min)**	**5000 (max)**	**-**
1. Yamuna river at Palla	2001	7.18- 8.42	128-358	2-22	1-3	5.91-12.4	600-69000	34-5000
	2002	7.03-8.38	181-285	4-16	1-4	7.2-9.9	9800-102000	150-12200
2. Yamuna river at Agra Canal (Madanpur Khadar)	2001	7.00-7.46	187-590	14-96	4-29	Nil- 2.32	104000-14800000	1700-3700000
	2002	6.87-7.68	373-573	45-77	10-22	0.4-2.33	45000-18300000	23000-970000
3. Yamuna river at Agra Canal (Okhla)	2001	6.98-7.55	171-551	9-77	2-24	0.64-2.39	130000-15800000	1300-2610000
	2002	6.89-7.54	326-506	36-72	8-20	0.2-1.0	158000-3760000	7100-480000
4. Yamuna river at Okhla after meeting Shahdara drain	2001	6.91-7.43	226-937	28-199	6-77	Nil-2.01	88000-5,80,00,000	2000-5700000
	2002	6.92-7.64	647-847	80-221	25-67	Nil	207000-41500000	17800-44000000
5. Yamuna river at Nizamuddin	2001	6.94-7.55	185-594	13-156	6-54	Nil-3.7	80000-70000000	500-14100000
	2002	6.61-7.74	476-627	70-94	21-42	Nil	1060000-34000000	12100-10200000

[79] Trivedi, R.C. , Makhijani, S.D. , Bhardwaj, R.M., *Status of Water Quality in River Yamuna - NCT of Delhi*, Central Pollution Control Board

Annexure 8: Characteristics of soil in the wastewater irrigated area in Kanpur.

Parameter	PH (1:5)	EC (1.10) (umho/cm)	Bulk Density (g/cc)	Particle Density (g/cc)	Pore Space (%)	Org C (%)	Tot-N (ug/g)	P (ug/g)	Na (ug/g)	K (ug/g)	Ca (mg/g)	Mg (mg/g)
Mean	8.1	1160	1.22	1.88	35.56	1.50	738.5	5.96	148.3	93.7	3.36	0.81

Source ITRC, Lucknow-1996

Mean of the pesticide residues levels in different environmental media near wastewater irrigated area.

Mean	a-BHC	B-BHC	r-BHC	Tot-BHC	Op-DDT	pp-DDT	pp-DDD	pp-DDE	Tot-DDT
Surface Water (ug/l)	0.002	ND	ND	0.002	ND	ND	ND	0.011	0.013
Ground Water (ug/l)	0.016	ND	0.0124	0.028	ND	ND	ND	0.077	0.086
Soil (ug/g)	0.026	0.11	0.01	0.142	0.008	0.019	0.002	0.008	0.032
Veg/Crops (ug/g)	0.01	0.033	0.020	0.063	0.011	ND	0.0001	0.012	0.023
Food Grains (ug/g)	0.005	0.312	0.029	0.35	0.003	ND	ND	0.021	0.024

Source ITRC, Lucknow, 1996

Physico-chemical and elemental content in soil at different depths

Site	Soil depth Cms	pH 1:2.5	EC 1:2.5	OC %	OM %	N %
Paewandi	0-9 9-18	8.68 8.38	0.408 0.685	0.668 0.623	1.154 1.076	0.083 0.062
Sekhpur Site I	0-9 9-18	8.66 8.62	0.420 0.475	0.742 0.297	1.282 0.513	0.092 0.029
Sekhpur Site II	0-9	8.55	0.448	0.356	0.615	0.044

Site	Exchangeable cation capacity C mol Kg^{-1}			
	Na^+	K^+	Ca^{++}	Mg^{++}
Paewandi	4.61 5.30	0.31 0.21	9.0 7.0	2.07 2.86
Sekhpur Site I	3.30 4.69	0.36 0.25	9.0 7.0	1.72 1.98
Sekhpur Site II	3.39	0.31	7.0	1.74

Annexure 9: Presence of Sodium and Chromium in water and soil in study areas-Kanpur

Physico-chemical and elemental content in water used for irrigation and drinking purposes

Site	pH 1:2.5	EC_e 1:2.5	Exchangeable cat ionic capacity C mol Kg^{-1}				SAR	SSP
			Na^+	K^+	Ca^{++}	Mg^{++}		
Tannery effluent	**8.34**	**3.045**	**0.360**	**0.062**	**0.26**	**0.18**	**5.494**	**49.26**
Handpump water	7.6	2.737	0.322	0.040	0.20	0.14	4.893	46.08

Cr content (ug ml^{-1}) in the water and milk samples collected from Paewandi and Sheikhpur villages.

Water samples	Site I Peawandi	Site II Sekhpur
Ground water (Hand Pump)	0.155±0.002	0.17±0.001
Channel water	0.27±0.001	ND
Water in crop field	**0.17±0.002**	**ND**
Hand pump (Sekhpur village, 60 ft)	ND	0.16±0.002
Hand pump (Sekhpur village, 100 ft)	ND	0.15±0.001
Milk	0.0735±0.001	ND

Annexure 10: Ground water Quality in Study areas in Delhi [80]

S. No.	Parameters	Ground Water Quality at village Ranhaula	Ground Water Quality at Village Mundka	Ground Water Quality at Village Madanpur Khadar
1.	Salinity/EC in mhos/cm at 25^0	2200	3570	1790
2.	Sodium (Na) %	450	690	230
3.	Chloride (Cl) %	337	566	254
4.	Nitrate (NO_3) mg/l	38	32	42
5.	Boron (B) mg/l	Nil	0.44	0.40
6.	Copper (Cu) mg/l	0.040	0.040	0.060
7.	Lead (Pb) mg/l	0.019	0.019	0.019
8.	Zinc (Zn) mg/l	0.001	0.001	0.001
9.	Chromium (Cr) mg/l	0.025	0.025	0.070
10.	Cadmium (Cd) mg/l	0.0003	0.0003	0.00085
11.	Iron (Fe) mg/l	0.017	0.017	0.009
12.	Nickel (Ni) mg/l	Data unavailable	Data unavailable	Data unavailable
13.	Aluminium (Al) mg/l	Data unavailable	Data unavailable	Data unavailable
14.	Arsenic (As) mg/l	Data unavailable	Data unavailable	Data unavailable
15.	Beryllium (Be) mg/l	Data unavailable	Data unavailable	Data unavailable
16.	Faecal Coli	Nil	Nil	Nil

[80] Status of Ground Water Quality and Pollution Aspects in NCT-Delhi. January 2000. Central Ground Water Board & Central Pollution Control Board.

Annexure 11: Organochlorine Pesticide residue (ppb) in water, fruits and vegetables from the agricultural field, Jajmau, Kanpur

Pestcide Residue	Water	Pumpkin		Guava
		Kernel	Peel	
∝-HCH	0.0007	ND	0.0101	0.0036
γ-HCH	-	ND	ND	ND
β-HCH	0.0035	0.0029	0.005	0.10
δ-HCH	-	-	-	0.003
Aldrin	0.0023	-	-	0.002
Endosulphan	-	-	0.0018	-
DDE	0.0042	0.0179	0.0113	0.0354
Op DDT	-	-	-	-
pp DDD	-	-	-	-
Pp DDT	-	0.006	-	-

Source NBRI, 2000

Annexure 12: Biological Analysis of Fish grown in Fresh water and Wastewater

Parameters	Boinchitala (Near Dhapa)					
	Bone		Liver		Flesh	
Physical	1*	2**	1	2	1	2
Weight	2.8804gm	3.3216gm	0.1967gm	0.5725gm	80.2156gm	121.3565gm
Chemical	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg	Mg/kg
Copper	133.07	4.27	23.89	11.00	6.62	21.90
Zinc	28.50	29.28	220.13	20.34	26.15	35.16
Manganese	22.63	20.19	67.61	21.05	18.86	36.64
Chromium	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Lead	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Cadmium	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Mercury	BDL	BDL	BDL	BDL	BDL	BDL
Arsenic	BDL	BDL	BDL	BDL	BDL	BDL

*Sample no. 1 (fish collected from a bheri in East Calcutta Wetland)
**Sample no. 2 (fish collected from a freshwater pond in Garia)

On comparing the sample fish from the East Calcutta Wetlands with the control from fresh water source we find that copper content in fish bone is very high than the control. All the other parameters show virtually no difference. Concentration of manganese and zinc in fish liver is very high for the wastewater fish than for the freshwater one. The analysis of fish flesh shows higher concentration of copper, manganese and zinc in the freshwater fish than in the wastewater fish. However, arsenic and mercury are present below the detection limit for both the samples.

Annexure 13: Comparison table of drinking water quality standards with ground water quality in study areas in Delhi

Parameters	Water Quality Criteria for Drinking Purpose (IS:10500:1991)	Ground Water Quality at Village Ranhaula	Ground Water Quality at Village Mundka	Ground Water Quality at Village Madanpur Khadar
Sample Source	-------	HP	HP	HP
Depth in m	-------	10.0	13.0	8.0
pH	6.5-8.5	8.0	7.85	7.77
TDS (mg/l)	2000	1370	2410	1220
CO3 (mg/l)	200	Nil	Nil	Nil
Cl (mg/l)	1000	337	566	254
SO4 (mg/l)	400	105	540	235
NO3 (mg/l)	100	38	32	42
F (mg/l)	1.5	0.01	2.8	0.49
Ca (mg/l)	200	36	58	125
Mg (mg/l)	100	28	89	40
Na (mg/l)		450	690	230
K (mg/l)		1.6	17	27
B (mg/l)	5.0	Nil	0.44	0.40
Total Hardness as CaCO3 (mg/l)	600	911	510	475
Total Coliform/100 ml	Not more than 50 per 100ml	42	14	22
Fecal Coliform/100ml	Should not be detectable in 100ml sample	Nil	Nil	Nil
Heavy Metals (Average concentrations of city blocks where these villages are present are being given due to absence of data for village level sampling of heavy metals)				
Cadmium (mg/l)	0.01	0.0003	0.0003	0.00085
Chromium (mg/l)	0.05	0.025	0.025	0.070
Copper (mg/l)	1.5	0.040	0.040	0.060
Lead (mg/l)	0.05	0.019	0.019	0.019
Iron (mg/l)	0.001	0.017	0.017	0.009
Zinc (mg/l)	0.015	0.001	0.001	0.001

Annexure 14: Test results of ground water meant for drinking at Wajidpur, Sheikhpur villages at Jajmau

Sl No.	Parameters (Heavy Metals/ Pesticides)	Wajidpur (mg/L) ***	Sheikhpur (mg/L)	WHO* Standards (mg/L)	No of times greater/less than WHO Standards for Wajidpur	No of times greater/less than WHO Standards for Sheikhpur	Selective Potential health impact from ingestion of water
1.	Arsenic	Absent	0.64	0.01	NA**	64 Times	Skin damage or problems with circulatory systems and may have increased risk of cancer
2.	Cadmium	1.56	Absent	0.003	520 Times	NA	Kidney damage
3.	Mercury	0.11	0.12	0.001	110 Times	120 Times	Neurological toxicant
4.	Nickel	1.45	0.01	.05	72.5 Times	Below WHO Limits	Increased risk of cancer
5.	ChromiumVI	39.52	37.57	.05	790 Times	751 Times	Increased risk of cancer
6.	Alpha, Beta, Gamma BHC	0.013 Micro grams /Litre (Beta BHC only)	1.69Micro grams/ Litre (Alpha, Beta, Gamma BHC)	2 Micro grams/Litre	Below WHO Limits	Below WHO Limits	Liver or Kidney problems
	Endosulphane	Absent	0.22 Micro grams/Litre	Banned	NA	NA	Liver or Kidney problems
	Dieldrin	Absent	0.78Micro grams/Litre	.03 Micro grams/Litre	NA	26 Times	Liver or Kidney problems

Sl No.	Parameters (Heavy Metals/ Pesticides)	Wajidpur (mg/L) ***	Sheikhpur (mg/L)	WHO* Standards (mg/L)	No of times greater/less than WHO Standards for Wajidpur	No of times greater/less than WHO Standards for Sheikhpur	Selective Potential health impact from ingestion of water
7.	Sulphate	1327	1573.6	400****	3.3 Times	3.9 Times	Liver or Kidney problems
8.	Nitrate	1200	6400	50 (Acute)	24 Times	128 Times	Increased infant mortality (blue baby syndrome)
9.	Chloride	1285.4	595.56	1000***	1.28 Times	Below WHO limits	Liver or Kidney problems

***WHO: World Health Organisation**
****NA: Not Applicable**
***** mg/L: Milligram Per Litre**
****** Indian Standards**

Annexure 15: Livelihood Impact Matrix of Case Study Areas: Ahmedabad

S.N.	Village	Total Households Surveyed	% Farmers	% Landless Labourers	% Other Occupations	Community Composition	Livelihood Impacts
1.	Asamli	187	100	0	0	Baxi Panch, SC and others	20 years ago horticulture used to be the main produce. However, at present farmers have taken to growing paddy and wheat. They claim that with the water getting polluted, the fruit bearing capability of the orchards have reduced considerably over the years. Though initially continuous availability of water was seen as a blessing, prolonged use adversely impacted productivity. Income analysis of the period 2002 -2004 shows that income levels have fallen steadily
2.	Bakrol	178	54	38	8	Baxi Panch, SC and others	Degradation of top soil has resulted in losses and non-profitable agricultural activity. The decline in yields has resulted in loss of income. Moreover, in around 8-10% of the surveyed households the livestock has been affected by diseases, mostly skin disorders
3.	Chitrasar	168	60	30	10	Baxi Panch, SC and others	Yields having gone down over the years, income has also decreased steadily. 35% of the livestock population has been affected by diseases
4.	Fatehpura	151	87	13	0	Baxi Panch, SC and others	Yields have also gone down here and the farmers are even robbed of the option of using clean water from bore wells as even the groundwater has been polluted. One major change in the cropping pattern has

S.N.	Village	Total Households Surveyed	% Farmers	% Landless Labourers	% Other Occupations	Community Composition	Livelihood Impacts
							been the decline in the harvest of a second crop, cumin that used to fetch high prices. Moreover, due to the crops becoming easily vulnerable to pest attacks, the expenditure of pesticides have gone up dramatically. A major impact on the economy of the area has been a radical drop in milk production, which has been accompanied by miscarriages and animals aborting halfway through the gestation period
5.	Gyaspur	289	39	55	6	Baxi Panch, SC and OBCs	Initially, the wastewater released from treatment plants was beneficial since it led to higher yields. However, with untreated wastewater and industrial effluents being mixed with treated wastewater, the change in the quality of water for the worse has affected productivity and brought down the income levels in the village. Unlike other villages, Gyaspur has vegetables as its major crop
6.	Navapura	185	35	65	0	Mostly the thakore community	Adverse impacts on standing crops of vegetable, fodder, flowering plants, etc, and sudden drying of grain crops before harvest has impacted the income level but the variance is minimal
7.	Saroda	219	29	61	10	SC, Baxi Panch, and others	Though crop withering without prior symptoms has been reported, it has not caused noticeable fluctuation in income levels. This perhaps may be due to the fact

S.N.	Village	Total Households Surveyed	% Farmers	% Landless Labourers	% Other Occupations	Community Composition	Livelihood Impacts
							that only 9% of the cultivable land is irrigated
8.	Vautha	213	56	32	12	NA	Since 60% of the irrigation in the village is done through bore well water, the subsequent pollution of the underground aquifer has resulted in a decline in crop productivity. However, over the past three years the amount of land under paddy cultivation has doubled (2004 as compared to 2001)

Annexure 16: Ownership Patterns of Sewage-fed Fisheries

Type of Holding	**Percentage**
Private	93.14
Cooperative	0.86
Government	6.00

Note:
These percentages are liable to quick changes since the private bheris are often joined as partnership or cooperatives. Many cooperatives are also taken up as private ones. Division and sub-division of bheris due to inheritance and/or any other disputes is very common.

Annexure 17: WHO Recommended Microbiological Quality Guidelines for Wastewater use in Agriculture

Category	Reuse Condition	Exposed Group	Intestinal Nematodes (arithmetic mean, no. of eggs per litre)	Faecal Coliforms (geometric mean, no. of eggs per 100 ml)	Wastewater Treatment Expected to Achieve the Required Microbiological Quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≤1	≤1000	A series of stabilization ponds designed to achieve the microbiological quality indicated or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees	Workers	≤1	No standard recommended	Retention of stabilization ponds for 8-10 days or equivalent for helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pre-treatment as required by the irrigation technology, but not less than primary sedimentation

Source: WHO (1989)

Annexure 18: EPA Guidelines for Wastewater Quality for Reuse Options[81]

S. No.	Types of Reuse	Reclaimed Water Quality
1.	All types of landscape irrigation, vehicle washing, toilet flushing, use in fire protection systems, etc	pH= 6-9 BOD=10 mg/l Turbidity<2 NTU No detectable Fecal coli/100 ml 1 mg/l Cl_2 residual (min.)
2.	Agricultural reuse for food crops not commercially processed, including crops eaten raw	pH= 6-9 BOD=10 mg/l Turbidity<2 NTU No detectable Fecal coli/100 ml 1 mg/l Cl_2 residual (min.)
3.	Agricultural reuse for food crops commercially processed	pH= 6-9 BOD< 30 mg/l SS< 30 mg/l Fecal coli <200/100 ml 1 mg/l Cl_2 residual (min.)
4.	Agricultural reuse for non-food crops	pH= 6-9 BOD< 30 mg/l SS< 30 mg/l Fecal coli <200/100 ml 1 mg/l Cl_2 residual (min.)
5.	Construction uses (like soil compaction, washing aggregates making concrete)	BOD< 30 mg/l SS< 30 mg/l Fecal coli <200/100 ml 1 mg/l Cl_2 residual (min.)
6.	Industrial reuse in recirculating to cooling towers	Variable-Depends on recirculation ratio
7.	Wetlands, marshes, wildlife habitat, stream augmentation	Variable but not to exceed: BOD< 30 mg/l SS< 30 mg/l Fecal coli <200/100 ml
8.	Groundwater recharge by spreading or injection into non-potable aquifers	Site specific and use dependent.
9.	Groundwater recharge by spreading into potable aquifers	Site specific Meet drinking water standards after percolation through vadose zone
10.	Groundwater recharge by injection into potable aquifers	Includes, but not limited to the following: pH= 6-9 Turbidity<2 NTU No detectable Fecal coli/100 ml 1 mg/l Cl_2 residual (min.) Meet drinking water standards.
11.	Recreational Lakes	BOD< 30 mg/l SS< 30 mg/l Fecal coli <200/100 ml 1 mg/l Cl_2 residual (min.)

[81] Fact Sheet for Water and Sanitation for Health, US EPA 1980 Guidelines (Revised 1992)

Annexure 19: Departments related to Water Supply in India

Name of Central Department	Areas of Work
Ministry of Water Resources	Planning and Development of resource, policy formulation and infrastructure report
Ministry of Agriculture	Watershed development and Irrigation
Ministry of Power	Hydropower development
Ministry of Environment & Forests	Water quality
Ministry of Rural Development	Watershed development and drinking water provision
Ministry of Industry	Industrial uses of water
Ministry of Urban Development	Urban drinking water provision and sanitation
Central Pollution Control Board	Water quality monitoring
Indian council of Agricultural Research	Development of water management techniques

Annexure 20: Plan Outlays on Urban Water Supply and Sanitation in India (current price in Rs Billion)

Plan Period	Total Outlay Plan	Urban Water Supply & Sanitation	As % of Total Outlay
First Plan	33.59	0.43	1.28
Second Plan	67.69	0.44	.65
Third Plan	85.93	0.89	1.04
3 Annual Plans	-	-	-
Fourth Plan	159.32	2.82	1.77
Fifth Plan	392.46	5.49	1.40
Annual Plan	125.27	1.98	1.58
Sixth Plan	976.07	17.67	1.81
Seventh Plan	1797.42	29.66	1.65
2 Annual Plans	1366.17	17.21	1.26
Eighth Plan	4332.84	59.82	1.38
Ninth Plan	7800	117.00	1.50

Source: India – Water Resource Management Sector Review (World Bank Study)

Annexure 21: Status of Wastewater Generation, Collection and Treatment in Class-I Cities in Different States & Union Terrirorites

Sr.No.	Name of the state/union territory	No. of class-I cities	Population	Domestic (mld)	Industrial (mld)	Total (mld)	Volume of wastewater collected (mld)	Percentage wastewater collected	Wastewater treatment capacity (mld)
				Volume of wastewater generated (mld)					
1	Andhra Pradesh	32	10845907	896.8	25	921.8	708.4	77	208.00
2	Assam	4	878310	147	NA	147	88.2	60	NA
3	Bihar	17	5278361	938.5	NA	938.5	681.1	73	132.00
4	Gujarat	21	8443962	1110.4	65.4	1175.8	936.7	80	676.00
5	Haryana	12	2254353	220.4	NA	220.4	79.6	36	10.00
6	Himachal Pradesh	1	82050	10	NA	10	6	60	3.00
7	Karnataka	21	8283498	744.5	25	769.5	513.9	67	382.10
8	Kerala	14	3107358	296.8	0	296.8	183.6	62	NA
9	Madhya Pradesh	23	7225833	784	NA	784	545.3	70	219.70
10	Maharashtra	27	22731865	3365.5	227.9	3593.4	3139	87	481.40
11	Meghalaya	1	223366	24	NA	24	NA	NA	NA
12	Manipur	1	198535	19.2	NA	19.2	NA	NA	NA
13	Mizoram	1	155240	3.2	NA	3.2	NA	NA	NA
14	Orissa	7	1766021	263.2	NA	263.2	189.2	75	NA
15	Punjab	10	3206603	360.5	NA	360.5	266.3	74	NA
16	Rajsthan	14	4979301	763.2	NA	763.2	614.8	81	27.00
17	Tamilnadu	25	10745773	771.9	NA	771.9	438.8	57	283.00
18	Tripura	1	157358	17.6	NA	17.6	NA	NA	NA
19	Uttar Pradesh	41	14480479	1557.7	NA	1557.7	1048.9	67	246.20
20	West Bengal	23	13943445	1574.7	48.4	1623.1	1183	73	NA

Sr.No.	Name of the state/union territory	No. of class-I cities	Population	Domestic (mld)	Industrial (mld)	Total (mld)	Volume of wastewater collected (mld)	Percentage wastewater collected	Wastewater treatment capacity (mld)
				Volume of wastewater generated (mld)					
21	Chandigarh	1	504094	217.9	NA	217.9	45.4	21	90.80
22	Pondichery	1	203069	24	NA	24	NA	NA	NA
23	Delhi	1	8419084	2160	NA	2160	1270	59	1270.0
	Total	299	128113865	16271	391.7	16662.7	11938.2	72	4029.20

Annexure 22: Details of Sewage Farming in Class-I Cities

Sr.No.	Name of the class-I city	Quantity of wastewater collected (mld)	Quantity of wastewater supplied to sewage farms (mld)	Land used for sewage forming (ha)	Cost of sewage (Rupees /ha/year)	Total annual Income
1	Ahmedabad	445.00	NA	NA	NA	NA
2	Anand	10.40	2.60	20.00	NA	NA
3	Bangalore	300.00	NA	NA	NA	NA
4	Bhagalpur	30.00	8.00	60.00	NA	NA
5	Bhopal	95.00	13.60	44.50	30.60	1,362.00
6	Bombay	2210.00	20.00	NA	NA	NA
7	Calcutta	1075.00	817.00	NA	NA	NA
8	Chandigarh	209.80	136.20	1000.00	NA	NA
9	Coimbatore	46.00	NA	NA	NA	NA
10	Delhi	1270.00	NA	NA	NA	NA
11	Gandhi Nagar	43.50	41.86	500.00	100.00	50,000.00
12	Hyderabad	288.00	40.00	1,085.00	75.00	80,400.00
13	Indore	118.00	127.30	546.00	200.00	109,200.00
14	Jaipur	165.00	22.70	200.00	400.00	80,000.00
15	Kanpur	150.00	NA	NA	NA	NA
16	Kochi	46.00	NA	NA	NA	NA
17	Lucknow	80.00	NA	NA	NA	NA
18	Ludhiana	47.00	NA	NA	NA	NA
19	Madras	257.00	10.00	8.00	NA	NA
20	Madurai	40.00	NA	NA	NA	NA
21	Nadiad	10.00	2.00	140.00	80.00	11,200.00
22	Nagpur	168.00	NA	49.00	NA	NA
23	Patna	184.00	NA	34.40	NA	NA
24	Pune	367.00	80.00	NA	NA	NA
25	Rajkot	48.70	40.00	1,000.00	NA	NA
26	Surat	112.00	1.30	2.60	NA	NA
27	Tiruchirapalli	52.70	8.00	2.30	NA	NA
28	Tirunelveli	44.80	18.00	184.00	NA	NA
29	Tuticorin	1.20	1.00	13.46	NA	NA
30	Vadodara	105.00	20.00	1,000.00	120.00	120000.00
31	Varanasi	127.00	82.00	1,020.00	148.00	15122.00
32	Visakhapatnam	55.00	NA	NA	NA	NA
	Total	8,201.10	1,491.56	6,909.26		467,284.00

Annexure 23: Comparative returns from agriculture in freshwater and wastewater irrigated areas in Kanpur

Crops	**Cost of cultivation (Rs./ha)[82]**		**Gross Income (Rs./ha)**		**Net income (Rs./ha)**		**Remarks**
	Fresh-water	**Waste water**	**Freshwater**	**Wastewater**	**Freshwater**	**Wastewater**	
Rose	102681	47299	175000	112500	72319	65201	Mortality rate of the seedlings is 30 % in irrigated through wastewater. Yield gone down by 40 %.in wastewater irrigated areas.
Fodder	19630	5204	35000	7500	15370	2296	Lower yield in wastewater irrigated areas
Paddy	16470	8279	20925	18900	4455	10621	Lower yield and lower selling price of produce from wastewater irrigated areas
Wheat	20941	10287	29200	19500	8259	9213	Lower yield and lower selling price of produce from wastewater irrigated areas

[82] Includes cost of inputs (fertilizer, pesticide, labor, marketing, land rent , transportation charges to market