Ground Water Pollution and Emerging Environmental Challenges of Industrial Effluent Irrigation: A Case Study of Mettupalayam Taluk, Tamilnadu

Sacchidananda Mukherjee and Prakash Nelliyat

Madras School of Economics, Chennai, Tamil Nadu, India, Madras School of Economics, Chennai, Tamil Nadu, India

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MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

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Sacchidananda Mukherjee**
Research Scholar

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Prakash Nelliyat
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** *Corresponding author*
Tel.: +91-44-2235 2157; 2230 0304; 2230 0307; Cell: +91 9840699343
Fax: +91-44-2235 2155; 2235 4847
E-mail address: sachs.mse@gmail.com

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MADRAS SCHOOL OF ECONOMICS
Gandhi Mandapam Road
Chennai 600 025
India

Phone: 2230 0304/ 2230 0307/2235 2157
Fax : 2235 4847 /2235 2155
Email : info@mse.ac.in
Website: www.mse.ac.in

GROUND WATER POLLUTION AND EMERGING ENVIRONMENTAL CHALLENGES OF INDUSTRIAL EFFLUENT IRRIGATION: A CASE STUDY OF METTUPALAYAM TALUK, TAMILNADU

Sacchidananda Mukherjee*
and
Prakash Nelliyat

Abstract

Industrial disposal of effluents on land and subsequent pollution of groundwater and soil of surrounding farmlands – is a relatively new area of research. Environmental and socio-economic aspects of industrial effluent irrigation have not been studied as extensively as domestic sewage based irrigation practices, at least for developing countries like India. Disposal of treated and untreated industrial effluents on land has become a regular practice for some industries. Industries located in Mettupalayam taluk, Tamilnadu dispose their effluents on land, and the farmers of the adjacent farmlands have complained that their shallow open wells get polluted and also the salt content of soil has started building up slowly. This study attempts to capture the environmental and socio-economic impacts of industrial effluent irrigation in different industrial locations at Mettupalayam taluk through primary surveys and secondary information.

This study found that continuous disposal of industrial effluents on land, which has limited capacity to assimilate the pollution load, has led to groundwater pollution. Ground water quality of shallow open wells surrounding the industrial locations has deteriorated, and the application of polluted groundwater for irrigation has resulted in increased salt content of soils. In some locations drinking water wells (deep bore wells) also have high concentration of salts. Since the farmers had already shifted their cropping pattern to salt tolerant crops (like jasmine, curry leaf, tobacco etc.) and substituted their irrigation source from shallow open wells to deep bore wells and/or river water, the impact of pollution on livelihood was minimised.

Since the local administration is supplying drinking water to households the impact in the domestic sector has been minimised. It has also been noticed that in some locations industries are supplying drinking water to the affected households. However, if the pollution continues unabated it could pose serious problems in the future.

Acknowledgement

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I. Introduction

With the growing competition for water and declining fresh water resources, the utilisation of “marginal quality water”[1] for agriculture has posed a new challenge for environmental management. In water scarce areas there are competing demands from different sectors on the limited available water resources. Though industrial use of water is very low as compared to agricultural use,[2] the disposal of industrial effluents on land and/or on surface water bodies make water (ground and surface) resources unsuitable for other uses.[3] Industry is a small user of water in terms of quantity, but has a significant impact on quality. Over three-fourth of fresh water draw by the domestic and industrial sector, return as domestic sewage and industrial effluents which inevitably end up in surface water bodies or in the groundwater, affecting water quality. The “marginal quality water” could potentially be used for other uses like irrigation. Hence the reuse of wastewater for irrigation using domestic sewage or treated industrial effluents has been widely advocated by experts and is practiced in many parts of the world, particularly in water scarce regions. However, the environmental impact of reuse is not well documented, at least for industrial effluents, particularly in developing countries like India where the irrigation requirements are large.

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[1] Marginal-quality water contains one or more chemical constituents at levels higher than in fresh water.

[2] Water accounting study conducted by the MIDS (1997) for the Lower Bhavani River basin shows that industrial water use (45 million cubic meters) is almost 2 per cent of total water use of 2341 Mm^3 of the basin and agriculture has the highest share more than 67 per cent or 1575 Mm^3. Also see Kumar *et al.*, 2005; Gupta and Deshpande, 2004; Vira *et al.*, 2004 and Chopra, 2003 for all India estimates of industrial water use.

[3] See Buechler and Mekala, 2005, Ghosh, 2005; Behera and Reddy, 2002 and Tiwari and Mahapatra, 1999 for evidence.

Reuse of industrial effluents for irrigation has become more widespread in the State of Tamilnadu after a High Court order in the early 1990s which restricted industries from locating within 1 kilometre of a river or any other surface water body. The intention of this order was to stop the contamination of surface water sources by industries. Apart from the High Court order, industrial effluent discharge standards for disposal on inland surface water bodies are stringent as compared to disposal on land for irrigation.[4] Therefore, industries prefer to discharge their effluents on land. Continuous irrigation using even treated effluents (which meet the standards) may lead to ground water and soil degradation through the accumulation of pollutants.[5] Apart from disposal of industrial effluents on land and/or surface water bodies, untreated effluents are also injected into groundwater through ditches and wells in some industrial locations in India to avoid pollution abatement costs (see Ghosh, 2005; Behera and Reddy, 2002; Tiwari and Mahapatra, 1999 for evidence). As a result, groundwater of surrounding areas become unsuitable for agriculture and/or drinking purposes. Continuous application of polluted surface and ground water for irrigation can also increase the soil salinity or alkalinity problems in farmlands.

Industrial pollution in Mettupalayam taluk of the Bhavani River[6] basin is very location specific and occurs mainly in Thekkampatty, Jadayampalayam and

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[4] Specifically for Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Residual Chlorine and heavy metals (see CPCB, 2001 and Table 17 in Annexure 1 for more details).

[5] Since the pollution load often exceed the assimilation capacity of the land and/or surface water body.

[6] The Bhavani River is the second largest perennial river of Tamilnadu, and one of the most important tributaries of the Cauvery river.

Irumborai villages. These areas are in the upstream segments of the Bhavani River basin located immediately after the thickly forested catchments of the river, upstream of the Bhavanisagar dam (see Map 1 in Appendix 1). Around ten industrial units, which include textiles and paper and pulp, are located in the Mettupalayam area. These water intensive units are basically large and medium scale units[7] which meet their water requirement (around 10 million litre per day) directly from the Bhavani River. Most of the units discharge their treated / partially treated effluents (about 7 mld) on land ostensibly for irrigation. Over time, the effluents have percolated to the groundwater causing contamination. As a result, farmers in the adjoining areas have found the groundwater unsuitable for irrigation. In some cases, drinking water wells have also been affected. Continuous application of polluted groundwater for irrigation has also resulted in degradation of soil quality. To some extent farmers are coping with the problem by cultivating salt tolerant crops or by using other sources such as river water for irrigation. Since the local administration is supplying drinking water to households the impact in the domestic sector has been minimised. It has also been noticed that in some locations industries are supplying drinking water to the affected households.

The purpose of this paper is to raise public awareness about this particular issue and to find ways and means to mitigate the problems. Increasing the awareness of various stakeholders about industrial effluent irrigation and its environmental impacts, may lead to the consideration of various alternatives

[7] The manufacturing industries are divided into large/medium and small scale industries on the basis of the limit of capital employed in plant and machinery. Units below the prescribed limit of Rs. 1 Crore are called small-scale industrial (SSI) units, while the rest are called large and medium scale units.

which are environmentally more sustainable and could reduce the potential for conflict amongst users.

The next section deals with the issues associated with industrial effluent irrigation. In Section three, descriptions of the study sites and profile of the industries are provided; Section four explains the methodology and data sources. Sections five and six give the results and discussion and conclusions respectively.

II. Issues Involved with Industrial Effluent Irrigation

Domestic wastewater has always been a low cost option for farmers to go in for irrigated agriculture in water scarce regions of the world. Apart from its resource value as water, the high nutrient content of domestic wastewater helps the farmers to fertilise their crops without spending substantial amount on additional fertilisers.[8] Both temporal and spatial water scarcity, along with rising demand for water from competing sectors (growing population, urbanisation and industrialisation) have also forced the farmers to go for wastewater irrigation. However, safe utilisation of wastewater for irrigation requires proper treatment and several precautionary measures in use, as it may cause environmental and human health hazards (see Butt *et al.*, 2005; Minhas and Samra, 2004; Bradford *et al.*, 2003; Ensink *et al.*, 2002; Ensink et al., 2002; Van der Hoek *et al.*, 2002; Abdulraheem, 1989 for evidence). Since most of the developing countries cannot afford to make huge investment in infrastructure for collection, treatment and

[8] It is to be noted that nutrient value of domestic sewage in terms of nitrogen 30mg/l, phosphate 7.5 mg/l and potassium 25 mg/l have been adopted by the CPCB (1997), in assessing the daily wastewater nutrients load for the Metrocities, Class-I Cities and Class- II Towns of India (see Table 18 in Annexure 1).

disposal, wastewater is mostly used without proper treatment and adequate precautionary measures. In developing countries like India, industrial effluents often get mixed with domestic sewage[9] and it is not collected or treated properly even in Metrocities.[10] When treatment is not adequate, application of domestic wastewater on land might cause various environmental problems, like groundwater contamination (bacteriological and chemical), soil degradation, and contamination of crops grown on polluted water (see McCornick *et al.*, 2004, 2003 and Scott *et al.*, 2004). Irrigation with treated/untreated industrial effluent is a relatively new practice, since it is seen - (a) as a low cost option for wastewater disposal, (b) as a source for irrigated agriculture, especially in water starved arid and semi-arid parts of tropical countries, (c) as a way of keeping surface water bodies less polluted; and also (d) as an important economic resource for agriculture due to its nutrient value.

Instances of industrial effluent disposal (mostly untreated or partially treated) on land for irrigation are very limited in developed countries. In India having the option to dispose effluents on land encourages the industries to discharge their effluents either on their own land or on the surrounding farmlands in the hope that it will get assimilated in the environment through percolation, seepage and evaporation without causing any environmental hazards. However, continuous disposal of industrial effluents on lands leads to

[9] Unlike developed countries where industrial effluents often mixed with domestic sewage to dilute industrial pollutants and toxicants for better/easier treatment, in developing countries like India mostly urban diffused industrial units (mostly SSIs) dispose their effluents in public sewers as a regular practice to avoid the costs of effluent treatment.

[10] In India only 24 per cent of wastewater is treated (primary only) before use in agriculture and disposal into rivers (Minhas and Samra, 2003), also see Table 2 in Annexure 1 for more details.

percolation of pollutants to the groundwater through seepage and leaching, causing contamination. As a result, farmers in the adjoining areas find the ground water unsuitable for irrigation. Drinking water wells may also get affected. Environmental problems related to industrial effluent disposal on land have been reported from various parts of the country. Disposal on land has become a regular practice for some industries and creates local/regional environmental problems (see for example, Kumar and Shah, undated; Ghosh, 2005; Behera and Reddy, 2002; Biradar *et al.*, 2002; Salunke and Karande, 2002; Kumar and Narayanaswamy, 2002; Barman *et al.*, 2001; Singh *et al.*, 2001; Kisku *et al.*, 2000; Gowd and Kotaiah, 2000; Pathak *et al.*, 1999; Tiwari and Mahapatra, 1999; Singh and Parwana, 1998; Kaushik *et al.*, 1996; Narwal *et al.*, 1992; Kannan and Oblisami, 1990). There is substantial literature on benefits and costs of domestic sewage based irrigation practices (see for example, Scott *et al.*, 2004; Keraita and Drechsel, 2004; Van der Hoek *et al.*, 2002; Jimenez and Garduño, 2001; Qadir *et al.*, 2000 among others). However, the disposal of industrial effluents on land for irrigation is a comparatively new area of research and hence throws new challenges for environmental management (see Buechler and Mekala, 2005; Ghosh, 2005, Bhamoriya, 2004; Behera and Reddy, 2002 and Tiwari and Mahapatra, 1999 for evidence). Environmental and socio-economic aspects of industrial effluent irrigation have not been studied as extensively as irrigation using domestic sewage. Studies focused on different aspects of industrial effluent irrigation, with special reference to environmental, human health and livelihood impacts are rare.

Water quality problems related to the disposal of industrial effluents on land and surface water bodies, are generally considered as a legal problem – a violation of environmental rules and regulations. However, Indian pollution abatement rules and regulations provide options to industries to dispose their effluents in different environmental media, e.g., on surface water bodies, on land for irrigation, in public sewers or marine disposal according to their location, convenience and feasibility. There are different standards prescribed for different effluent disposal options (see CPCB, 2001). As far as industries are concerned, their objective is to meet any one of those standards which is feasible for them to discharge their effluents. The standards are set with the assumptions that the environmental media have capacities to assimilate the pollution load so that no environmental problems will arise. However, when assimilative capacities of the environmental media (surface water bodies or land) reach/cross the limits, large-scale pollution of ground and surface water occurs. Such instances have been recorded from industrial clusters in various parts of the country (Tiruppur, Vellore – Tamilnadu; Vapi, Vadora – Gujarat; Thane, Belapur – Maharashtra; Patancheru, Pashamylaram, Bollarum, Kazipally – Andhra Pradesh; Ludhiana, Jalandhar, Nangal - Punjab etc.). Since all the prescribed disposal standards are effluent standards, the impact on ambient quality cannot be directly linked to disposal or *vice versa*. It has become increasingly evident that in countries like India with extensive agricultural activities, industrial and urban water pollution could directly affect agriculture, drinking water, or other sectors. Like in many other countries in India, industry and agriculture coexist in the same geographical area and share the same water resources of the basin. When industries or towns withdraw large quantities of water for their use and/or discharge almost equivalent amount of wastewater, they cause an "externality" problem to other users. Their action(s) has an economic impact on other users in the basin. Any pollution sheltering activities or avoidance of pollution abatement costs in terms of disposal of untreated, partially treated or diluted industrial effluents on land or surface water bodies could transfer a large cost to society in terms of environmental pollution and related human health hazards.

Water Use in Agriculture

In India, the supply of fresh water resources is almost constant and even if it is not falling, from which the agriculture sector draws the lion's share (80-90 per cent) (see Kumar *et al.*, 2005; Gupta and Deshpande, 2004; Vira *et al.*, 2004 and Chopra, 2003). Hence, with the growing demand and rising scarcity for water, in future all the demands for agricultural use cannot be met by fresh water resources alone, but will gradually depend on marginal quality water or refuse water from domestic and industrial sectors (Bouwer, 2000). However, both domestic sewage and industrial effluents contain various water pollutants, which need to be treated before use for irrigation. Water quality is a key environmental issue facing the agricultural sector today. Meeting the right quantity and desirable quality of water for agriculture is not only essential for food security but also for food safety. Irrigation with untreated or partially treated wastewater and effluents could create environmental and human health hazards.

Quantity and Quality Linkages

Concerns about water quality issues have been less articulated as compared to problems related to water provision, which are critical. However, with a gradually larger share of water being abstracted from the river and from groundwater sources and with an increasing application of chemicals and other harmful substances in industry, households and agriculture and with very limited treatment and inefficient production technologies, the volumes of effluents and sewage will increase. Parallel with a decrease in availability of fresh water resources, an increasing concentration of deleterious substances may cause considerable damage to water resources.

Point Sources can act as Nonpoint Sources

When industrial disposal of effluents exceed the assimilative capacity of the land there is contamination of the soil and groundwater. Continuous disposal of industrial effluents on land could exceed the hydraulic and pollution loading of the environment. As a result, the effluents can end up in the groundwater through leaching and sub-surface flow. Apart from effluents, during the rainy season industrial wastes (solid wastes and solid sludge of the effluent treatment plants) also end up in the groundwater as nonpoint source pollution, as they are openly dumped within the premises of the industries. The concentrations of pollutants in those sludges are comparatively higher than the effluents. As a result during post-monsoon season period groundwater pollution is expected to be as high or higher as compared to pre-monsoon period. So, it is to be noted that point sources can act as nonpoint sources. If proper pollution management/abatement practices are not in place, other uses of water are affected.

To understand the environmental impacts of industrial discharge of effluents on land for irrigation, an extensive groundwater and soil quality study has been taken up across five industrial locations in Mettupalayam taluk, Tamilnadu. To understand the livelihood impacts of pollution, household questionnaire survey has been carried out for all the locations. The survey also captures the farmers’ perceptions about irrigation and drinking water quantity and quality. A multi-stakeholder meeting has been arranged to understand the underlying issues and the farmers’ concerns.

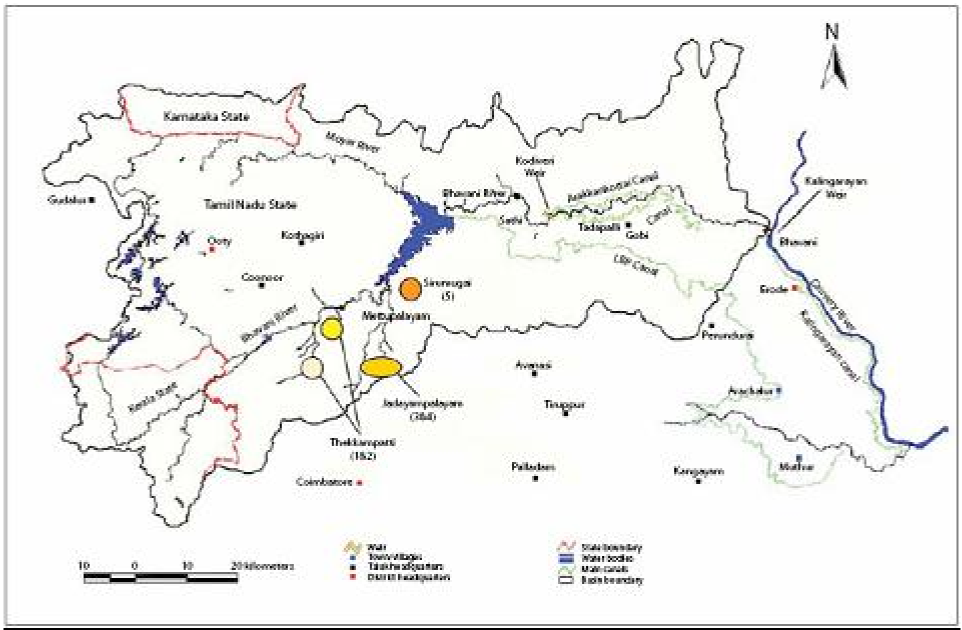
III. Description of Study Area and Industrial Profile of Mettupalayam Taluk

Most of the major water consuming and polluting industries, located in Thekkampatty and Jadayampalayam village of Mettupalayam taluk (upstream of the Bhavanisagar Dam), belong to textile bleaching and dyeing and paper industries. These industries are meeting their water requirements from the Bhavani River, and disposing their effluents on their own land for irrigation. Out of ten industrial units, eight are large, one is medium and another one is small (see Table 1 in Appendix 2). Based on Tamilnadu Pollution Control Board (TNPCB) classification, seven are in the red category (highly polluting) and three in the orange category (moderately polluting). Except two, all the industries were established during the 1990s.

Out of ten units, seven units are extracting 10 million litre daily (mld) of water from the Bhavani River and the remaining three units depend on wells. Most of the units are located at the upstream of the river. Since the industries are water-intensive industries, these locations are strategic to meet their water requirements throughout the year. The total quantity of effluents generated by these units is estimated to be 7.2 mld (see Table 2 in Appendix 2). Except one bleaching unit, all the units are using their partially treated effluents to irrigate their own land. The bleaching unit, which is the oldest unit, directly discharges its effluents (1.6 mld) to the Bhavani River. All the units have their own effluent treatment plants (ETPs). The total annual pollution load discharged by the units is estimated, based on TNPCB data, to be 1,316 tonnes of Total Dissolved Solids (TDS), 94 tonnes of Total Suspended Solids (TSS), 169 tonnes of Chemical

Oxygen Demand (COD), and 2 tonnes of oil and grease (see Table 3 in Appendix 2).

Map 2: Industrial Locations in Mettupalayam taluk



At present since most of the units are not discharging their effluents into the river, there is very little deterioration of the surface water quality due to industries in Mettupalayam area. However, there is river water contamination due to the discharge of sewage from Mettupalayam municipality.[11] The pollution

[11] Annual wastewater pollution load of Mettupalayam municipality constitutes 61 tonnes of TDS, 50 tonnes of TSS, 7 tonnes of BOD, 18 tonnes of COD, 19 tonnes of Chloride and 1 tonne of Sulphate (MSE, 2005).

load discharged by the bleaching unit[12] has a negligible effect, especially during good flow time, on the river water quality. The discharge of effluents on land and its usage for irrigation has had a significant effect on groundwater quality in the vicinity of the industries.

In Sirumugai town, a major pulp and viscose rayon plant used to draw 54 mld water from the Bhavani River and discharge an equivalent amount of partially treated effluents into the river. The discharge of highly toxic effluents affected the river water quality substantially and also fisheries activities downstream at the Bhavanisagar dam. Over the years due to protest by the downstream farmers, local NGOs and the intervention of the Court, the unit was forced to consider other options for effluent disposal. With the permission of the TNPCB, the plant started discharging their coloured effluents on their land (purchased or under contract with the farmers) at Irumborai village (through a 5 Km. long pipeline from the plant to the village).[13] Continuous disposal of partially treated effluents resulted in soil and groundwater pollution not only in the effluent irrigated land, but also the surrounding farmlands, through leaching/percolation and run-off from the effluent irrigated land. Contamination of both soil and groundwater (shallow and deep aquifers) quality were quite evident, since the drinking water turned brown due to lignin in the affected areas (Sundari and Kanakarani, 2001). The unit had made a huge investment in

[12] 494 tonnes/year of TDS, 22 tonnes/year of TSS and 24 tonnes/year of COD (MSE, 2005)

[13] Initially farmers of water scarce Irumborai village welcomed the proposal, since it was an opportunity to irrigate their crops. Since the village is far away from the river, the farmers used to cultivate only rain fed crops.

terms of pipeline infrastructure and the purchase of land based on the advice of experts in wastewater irrigation.

However, due to the efforts of the farmers, Bhavani River Protection Council and the intervention of the Supreme Court the scheme was abandoned and finally the plant was forced to close, but the ground water remains still polluted due to residual pollution. Consecutive droughts during 2001-2003, and low groundwater recharge, has led to severe water quality problems apart from scarcity. Although drinking water is affected, the farmers in the affected area are able to cultivate selected crops.

IV. Methodology and Data Sources

The current study attempts to understand some of the underlying issues related to the livelihood of the affected farmers in Mettupalayam taluk, Tamilnadu. Both environmental assessment (soil and groundwater quality) and livelihood impact studies have been carried out.

To understand the environmental impact of industrial effluent irrigation on soil and groundwater quality of the surrounding farmlands, samples were collected for laboratory analysis by the Water Technology Centre (WTC), Tamilnadu Agricultural University (TNAU). All together 83 groundwater (from shallow open wells) and 83 soil samples were collected from farmlands located to the vicinity of the five industrial sites/locations (shown in Table 4). To address both spatial and temporal aspects of environmental quality, water quality sampling and analysis has been carried out for the same well both for pre- and post-monsoon periods (for common pollutants only[14]). During post-monsoon period another six control samples were taken up from three villages (Thekkampatti, Jadayampalayam and Irumborai) to understand the natural background level of pollutants. The locations of the control wells were away from the affected farms. However, soil samples were taken and tested once only (pre-monsoon), as it was expected that unlike shallow groundwater quality, soil quality will not change so fast or soil quality is not so flexible as compared to shallow groundwater quality.

To substantiate and compare our primary groundwater quality results/findings, we have also collected secondary groundwater quality data from Tamilnadu Water Supply and Drainage (TWAD) Board, Central Ground Water Board and State Ground and Surface Water Resources Data Centre, Public Works Department for analysis. While the TWAD Board regularly tests the water quality of the deep bore wells (fitted with hand pumps or power pumps) to monitor the drinking water quality of the regions, the other data sources are irregular and monitor irrigation water quality, as the water samples are collected from dug wells or open wells.[15] Information on industries and their effluents characteristics were collected from the District Environmental Engineer's office of the TNPCB, Coimbatore.

[14] For soil samples pH, EC, N, P, K are tested. For water samples pH, EC, anions (CO_3, HCO_3, Cl, SO_4), cations (Ca, Mg, Na, K), NH_4^-N, NO_3^-N, F and heavy metals (Zn, Mn, Fe, Cr, Ni, Pb, Cu and Cd) are tested.

[15] Locations of the observation wells (bore or open) for a region are different for different agencies.

To understand the impact of pollution on the livelihood of the farmers and their perceptions about irrigation and drinking water quality, a questionnaire survey was administered to 55 households, purposively selected on the basis of their pre-monsoon groundwater quality information. Of the 55 sample households, 5 households which were not affected by the pollution (as they are located away from the industrial area) served as control samples for the analysis. The survey also captures the farmers' perceptions about irrigation and drinking water quantity and quality. In Table 4, the distributions of the samples across the five industrial clusters for three ranges of groundwater EC concentration (in dS/m) are shown.

Table 4: Household Questionnaire Survey: Sample Size and Distribution according to Water Quality [EC in deciSiemens per metre (dS/m)]

Site	Location	< 1.5 dS/m	1.5 - 2.25 dS/m	>2.25 dS/m	All	Control	Total
Site – 1	Thekkampatty Cluster – I	4	7	1	12	0	12
Site – 2	Thekkampatty Cluster – II	0	0	8	8	1	9
Site – 3	Jadayampalayam Cluster- I	1	0	8	9	0	10
Site – 4	Jadayampalayam Cluster – II	2	2	5	9	2	10
Site – 5	Sirumugai Cluster	0	1	11	12	2	14
	All Locations	**7**	**10**	**33**	**50**	**5**	**55**

The stakeholder initiatives to overcome the pollution problem and the need for a multi-stakeholder approach integrating water quantity and quality concerns in the region was also part of the study. Therefore, discussions with the NGOs along with a multi-stakeholder dialogue were organised. The

Stakeholder meeting provided some insights on different views and concerns about water quality and environmental problems in the region.

V. Results and Discussion

Groundwater Quality

Electrical Conductivity (EC in dS/m) of water, as a measure of total dissolved solids, is one of the most important water quality parameters which affects the water intake of the crops. Irrigation water having EC value less than 1.5 dS/m is considered to be safe for crops, however EC more than 2.25 dS/m is considered dangerous (see Table 5). The results show that the concentration of EC has gone up in the post-monsoon samples, which implies that soil leaches salts to the groundwater during the rainy season. Secondary groundwater data (TWAD Board's regular observation well data) also show that post-monsoon samples have high concentration of EC (>2.25 dS/m)[16] as compared to pre-monsoon samples.

Table 5: Interpretation of Irrigation Water Quality based on EC measurement

EC (dS/m at 25°C)	Water Class	Interpretation
<0.25	Low salinity (C_1)	Safe with no likelihood of any salinity problem developing
0.25 – 0.75	Medium salinity (C_2)	Need moderate leaching
0.75 – 2.25	High salinity (C_3)	Cannot be used on soils with inadequate drainage since saline conditions are likely to develop
2.25 – 5.0	Very high salinity (C_4)	Cannot be used on soils with inadequate drainage since saline conditions are likely to develop

Source: WTC, TNAU (Personal Communication)

Figures 1 and 2 show that 70 per cent of the pre-monsoon samples and 74 per cent of the post-monsoon samples have EC concentration greater than

[16] TDS (in mg/l) = 670 * EC (in dS/m or millimhos/cm). 2.25 dS/m ≈1,507mg/l of TDS

2.25 dS/m. For all the sites the EC concentration of the post-monsoon samples was as high or higher than the pre-monsoon samples. Jadayampalaym cluster – I (site 3) has high salinity (>2.25 dS/m) both for pre- and post-monsoon samples (see Tables 6 and 7).

Figure 1: Concentration of EC (in dS/m) in Groundwater Samples – Pre-Monsoon

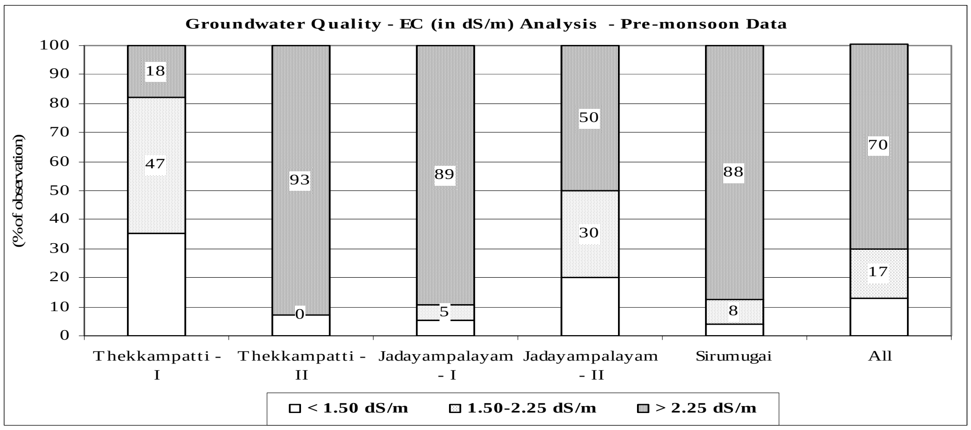
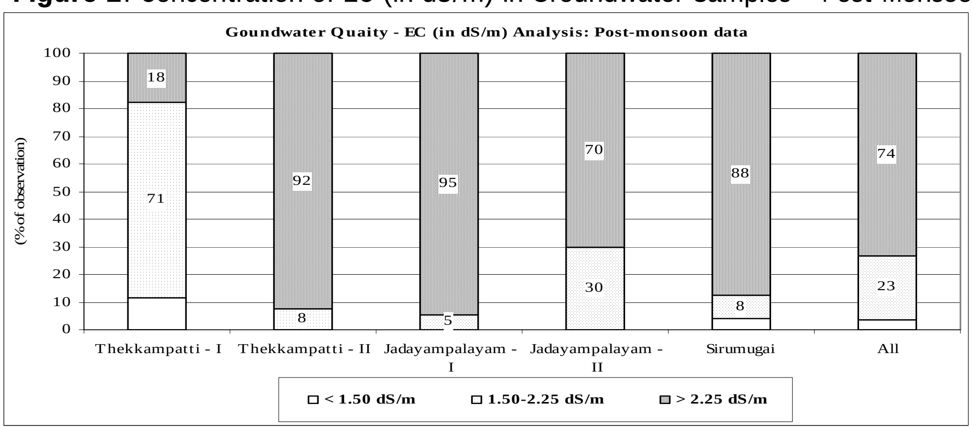


Figure 2: Concentration of EC (in dS/m) in Groundwater Samples – Post-Monsoon



Source: Primary Survey by TNAU

For sites 2, 3 and 5, both for pre and post-monsoon almost 90 per cent of the samples have EC concentration greater than 2.25 dS/m. For both the periods the maximum concentration is reported at a site in Jadayampalayam cluster, 9.6 and 10.4 dS/m respectively. Among all the sites, site 1 in Thekkampatty is comparatively less polluted, however post-monsoon samples show higher concentration of EC.

Table 6: Groundwater Quality based on EC (dS/m) Measurement: Pre – Monsoon Samples

Sampling Location – Industries	No. of Samples	Range (dS/m)	Average	Percentage of Samples [Having EC (dS/m)]		
				Low Salinity	Moderate Salinity	High Salinity
				< 1.50	1.50-2.25	> 2.25
Thekkampatty Cluster – I	17	1.00 – 3.16	1.83	35.3	47.1	17.7
Thekkampatty Cluster – II	13	1.44 – 4.72	3.03*	7.7	0.0	92.3
Jadayampalayam Cluster – I	19	0.82 – 9.56	5.77	5.3	5.3	89.5
Jadayampalayam Cluster – II	10	0.91 – 3.82	2.36	20.0	30.0	50.0
Sirumugai Cluster	24	0.10- 5.02	3.59	4.2	8.3	87.5
All – Sites	**83**	**0.1 – 9.56**	**3.49**	**13.3**	**16.9**	**69.9**

Note: * implies that average is significantly (statistically) different from the post-monsoon value

Source: Primary Survey by TNAU

Table 7: Groundwater Quality based on EC (dS/m) Measurement: Post – Monsoon Samples

Sampling Location – Industries	No. of Samples	Range (dS/m)	Average	Percentage of Samples [Having EC (dS/m)]		
				Low Salinity	Moderate Salinity	High Salinity
				< 1.50	1.50-2.25	>2.25
Thekkampatty Cluster - I	17	1.33 - 3.32	2.01	11.76	70.6	17.7
Thekkampatty Cluster -II	13	1.82 - 5.87	3.77*	0	7.7	92.3
Jadayampalayam Cluster - I	19	1.58 - 10.38	6.24	0	5.3	94.8
Jadayampalayam Cluster - II	10	1.58 - 4.62	2.96	0	30.0	70.0
Sirumugai Cluster	24	0.14 - 5.41	3.87	4.17	8.3	87.5
All - Sites	**83**	**0.14 - 10.38**	**3.91**	**3.61**	**22.9**	**73.5**

Note: *implies that average is significantly different (statistically) from the pre-monsoon value

Source: Primary Survey by TNAU

During post-monsoon another 6 groundwater samples were taken up as control samples (two each from three villages), where the sample open wells were situated far away from the industrial locations (see Table 8). Apart from Sirumugai samples, average concentration of EC for Thekkampatti and Jadayampalayam village samples is far below the affected samples, which shows that impacts of industrial pollution are evident for Thekkampatti and Jadayampalayam village. In the case of Sirumugai, perhaps the residual pollution from the pulp and viscose rayon plant's irrigated area has affected the aquifers, which has affected the whole area.

Table 8: EC (dS/m) Concentration for Control Samples: Post-Monsoon

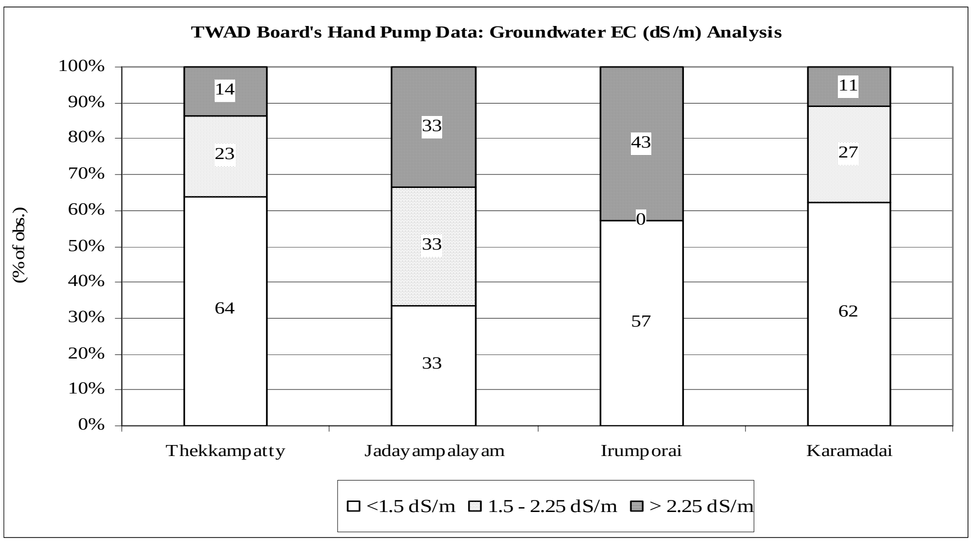
Locations	No. of Samples	Average	Minimum	Maximum
Thekkampatti	2	0.96	0.76	1.16
Jadayampalayam	2	1.07	0.79	1.35
Sirumugai (Irumborai Village)	2	3.57	2.98	4.15

Source: Primary Survey by TNAU

Apart from primary groundwater quality study, an assessment of groundwater quality has also been carried out using secondary data – from Central and State government agencies. The assessment highlights the parameters of our concern, as well as the variations of concentration over time and space.

TWAD Board's hand pump data (2001-2002) analysis shows that the EC level for three villages, Thekkampatty, Jadayampalayam and Irumborai, are high as compared to the EC level for Karamadai block as a whole. So, natural background level of EC is comparatively low as compared to the EC level of our study sites. For Jadayampalayam 33 per cent and Irumborai 43 per cent of the samples have EC concentration more than 2.25 dS/m. In Irumborai, the area formerly irrigated by the pulp and viscose rayon plant's effluents continues to be polluted even though the plant closed down more than two years earlier. The post-monsoon levels do not differ much from the pre-monsoon levels, indicating that there is not much effect of dilution or groundwater recharge.

Figure 3: Groundwater Quality Analysis of Mettupalayam Area – Hand Pump Data



Source: TWAD Board's Hand Pump data (2001-2002)

To understand the impact of pollution on water quality of the deep aquifers in our study villages, TWAD Board's regular observation wells (OBWs) (bore wells) data were collected for the period January 1992 to May 2005 and temporal and spatial analysis have been done. There are four regular OBWs which fall in Karamadai block, for which water quality analysis has been done by the board twice in a year (pre-monsoon sampling is done during May/June and post-monsoon during January/February). Out of four OBWs, two fall in our study villages, one each in Thekkampatty and Irumborai village. Other two (Bellathi and Kalampalayam) fall far away from the industrial locations and could serve as control wells. The data for Thekkampatty, Irumborai and the other two places (clubbed together as Karamadai block) are given in Table 9.

Table 9: Groundwater Quality (EC in dS/m) Analysis: TWAD Board's Regular Observation Well Data (January 1992 to May 2005)

Descriptions		**Thekkampatti**		**Irumporai**		**Karamadai Block**	
		Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
No. of observation		14	12	14	11	26	22
Average EC (in dS/m)*		1.42	1.40	2.24**	2.62**	1.65	1.65
Range		0.8 - 2.9	0.8 - 2.9	1.5 - 3.6	1.1 - 4.2	0.8 - 3.4	0.8 - 4.1
% of obs having EC Conc. (in dS/m)	< 1.5	71	75	7	18	27	41
	1.5 - 2.25	14	8	50	9	15	14
	> 2.25	14	17	43	73	8	9

Note: *The pre- and post-monsoon averages are not significantly different (statistically)
**implies average value is significantly different from the corresponding average value for Karamadai block

Source: TWAD Board's Regular Observation Wells (OBWs) Data (2005).

Table 9 shows that both for pre- and post-monsoon, percentage of observations having EC concentration greater than 2.25 dS/m is higher for Thekkampatty and Irumborai villages as compared to Karamadai block. However, for Thekkampatty on an average EC concentration (for both the periods) is lower than Irumborai and Karamadai block. Unlike shallow wells, the deep aquifer is less polluted.

Soil Quality

The pH of the soil samples collected from the polluted areas of the farmers' field varied between 5.44 to 9.17 and the EC between 0.07 to 2.08 dS/m. High EC values are observed in several fields in Jadayampalayam Cluster – II and Sirumugai cluster. This may be due to continuous irrigation using polluted well waters for raising the crops. If the polluted well water is used continuously for irrigation it may create salinity/alkalinity problems in the soil in due course. The high EC in the soils are commonly noticed wherever the fields and wells are located near the industries.

Pollution Impacts on Livelihood

Socio-economic background of the sample households

The average years of residency of the households in our study sites is 63 years, which shows that the households have long experience with the environmental situation/conditions of the area in both the pre and post industrialisation eras, as most of the industries were set up during the 1990s. The average age of the respondents (head of the family) is 54 years. We have found that, even though the farmers have limited exposure in formal education (average years of education of our respondents is 6 years only), they are innovative and advanced farmers.[17] The average family size is 5 of which at least two members are economically active. In most of the cases, we have found that women also participate in on-farm activities apart from looking after their

[17] Innovations of the farmers are captured here through their cropping pattern changes, irrigation source substitution strategies and agricultural management practices (see Buechler and Mekala, 2005 for more details).

livestock and other household chores. High female workforce participation helps in diversifying household's income opportunities, which not only significantly contributes in total income but also can help to withstand against natural calamities/disasters by securing livelihood. Most of the sample farmers are small and medium farmers, with an average area of cultivation of 4 acres.

Table 10: Socio-economic background of the sample households

Descriptions	Site-1	Site-2	Site-3	Site-4	Site-5	All Sites	Control
Number of sample households	12	8	9	9	12	50	5
Average age of the respondent	49	47	54	58	59	54	71
Average years of education	6	9	6	8	6	6	6
Average years of residency	55	20	60	76	87	63	63
Average family size	5	4	4	4	5	5	5
Average number of economically active persons	2	2	3	2	3	3	2
Av area of cultivation (in acres)	4	6	3	2	6	4	5

Source: Primary Survey by MSE

Apart from agriculture, animal husbandry contributes significantly to total income of the households; on an average its share in total income is 18 to 25 per cent. The results show that average agricultural income for the samples having groundwater EC concentration 1.5-2.25dS/m is comparatively low and significantly different from that of the samples having EC concentration < 1.5dS/m. However, the average agricultural income for the samples having EC concentration > 2.25dS/m is low but not significantly different from that of the samples having EC concentration <1.5dS/m, which might be due to the fact that affected samples have a cropping pattern, which constitutes mostly of salt tolerant crops (see Table 12) and also farmers of the affected farms already substituted their irrigation source from open wells to deep bore wells and/or river water. Total income from all sources differ significantly for the samples having EC concentration ≥ 1.5dS/m from that of the samples having EC concentration <1.5dS/m. It is to be noted that samples having EC concentration <1.5dS/m have similar pattern of income (both in magnitude and composition) that of the control samples.

Table 11: Average Income of the Households according to their Groundwater Quality

	< 1.5 dS/m	**1.5 - 2.25 dS/m**	**> 2.25 dS/m**	**Control Samples**
Number of Sample Households (Number)	7	10	33	5
Average Income from Agriculture (Rs./Family/Year)	42,857 [75] (20,000 – 56,000)	31,950* [82] (22,000 – 50,000)	35,409 [78] (22,000 – 88,000)	40,000 [74] (28,000 – 65,000)
Average Income from Animal Husbandry (Rs./Family/Year)	14,214 [25] (8,500 – 32,000)	7,020* [18] (4,000 – 14,200)	10,125 [22] (0 – 25,000)	14,000 [26] (12,000 – 16,000)
Average Total Income from All Sources (Rs./Family/Year)	57,071 (52,000 – 66,000)	38,970* (28,000 – 55,000)	45,227* (22,000 – 1,13,000)	54,000 (43,000 – 77,000)
Average Per Capita Income from All Sources (Rs./Person/Year)	13,936 (9,429 – 19,000)	8,959* (2,818 – 15,000)	10,504* (4,222 – 22,000)	13,603 (4,700 – 30,000)

Note: Figures within the first bracket show the range for the corresponding value
Figure in the second bracket shows the percentage of total income
* implies value is significantly different from the corresponding value for the sites having EC concentration < 1.5 dS/m, at least at 0.10 level.
Source: Primary Survey by MSE

Among all the samples, average per capita income for the samples having EC concentration 1.5-2.25dS/m are comparatively low as compared to the other two categories and that of the control samples. It is to be noted that per capita income has different value for different sites and are significantly different (statistically) from that of the samples having EC concentration < 1.5dS/m.

Table 12 shows the major crops cultivated across the samples having different groundwater EC concentration. The table shows that large numbers of crops are cultivated (which constitute 86 to 90 percent of total cultivated area) and crops are mostly salt tolerant and plantation crops. Traditional crops like paddy and cereals are virtually absent and mostly cash crops are cultivated. With the rise in groundwater EC concentration, cropping pattern changes from less salt tolerant crops (like banana, coconut etc.) to more salt tolerant crops (curry leaf, tobacco etc.). It is also observed that control samples have cropping pattern which is similar to the affected farms, so cropping pattern change may not be the response due to the rising pollution problems.

Table 12: Major Crops Cultivated Across the Samples having Different Groundwater Quality (figures are in percentage of cultivated area)

Crop	< 1.5 dS/m	1.5 - 2.25 dS/m	> 2.5 dS/m	Control Samples
Banana	44	42	24	10
Coconut	31	19	11	8
Arecanut	--	--	5	--
Jasmine	6	4	6	--
Curry Leaf	--	5	19	10
Tobacco	4	6	15	10
Cholam	6	2	7	41
Chilli	0	9	5	--
Total	**90**	**86**	**88**	**84**

Source: Primary Survey by MSE

Since the numbers of crops cultivated in our study sites are very large and most of these crops are plantation crops like jasmine, curry leaf, coconut, arecanut etc., the estimation of production function and the impacts of pollution on productivity of the crops cannot be estimated for the present study. Therefore, the analysis of livelihood impacts of pollution has mostly restricted to the income as revealed by the respondents.

Farmers' Perceptions About Irrigation Water

A perception study of the farm-households on quantitative and qualitative aspects of water has also been carried out. The results of the study show that, on an average over the last 6 years farm-households are facing various environmental problems. Previously water quality was comparatively good for irrigation and other uses. Apart from water quality problems which have affected all the five study sites, availability of irrigation water is also a major problem for some regions, mostly for site 4 and 5. In all the sites, though shallow open wells are polluted, almost all the farmers depend on their own sources (open well and bore wells) for irrigation. However, some farmers have stated that they pump river water (lift irrigation) to irrigate their croplands conjunctively with the open well water to dilute the concentration of pollutants. Farmers from sites 1 and 2 did not agree that they use water from distance source(s) to irrigate their croplands; it might be due to the fact that they have option to use deep bore wells to irrigate their farmlands and/or since the lift irrigation may be illegal they do not want to disclose that to us. However, 33 per cent of respondents from site 1 stated that they depend on distance source(s) for irrigation as their own sources are polluted. Some farmers from the control samples also use water from distance source(s), but that not due to pollution problems. Since the farmers had already substituted irrigation source from open wells to deep bore wells and/or to the Bhavani River water, which helped them to mitigate/manage the pollution. The farmers also agreed that their shift to alternative sources of irrigation is not the response due the pollution problems. It is also observed that both in unaffected and affected areas, farmers cultivate salt tolerant crops, which has also helped them to manage the rising salinity of soil and irrigation water. In all the locations control samples have adequate amount of good quality water for irrigation, as that has not been affected by any industrial discharge of effluents.

Table 14: Perceptions about Irrigation Water

Descriptions	Site-1	Site-2	Site-3	Site-4	Site-5	All Sites	Control
Number of Sample households	12	8	9	9	12	50	5
Percentage of farm-households satisfied with the *availability of irrigation water*	33	75	63	22	0	36	60
Availability of water in wells (open wells & bore wells) (5: Very Good, 3: Fair & 1: Very low)	3	3	3	2	2	2	3
Percentage of farm-households satisfied with the *irrigation water quality*	0	13	0	0	0	2	100
Water quality of the wells (open wells & bore wells) (5: Very Good, 3: Fair & 1: Very Bad)	1	1	1	1	1	1	3
Water quality of wells (open wells and bore wells) started deteriorating during last (in years)	6	7	6	7	5	6	0
Water quality of the irrigation wells (open wells & bore wells) before the period from which water quality started deteriorating (5: Very good, 3: Fair & 1: Very bad)	3	4	3	3	3	3	4
Percentage of households depend on distance source(s) for irrigation, as their own source(s) are inadequate to meet their irrigation demand	0	0	33	56	38	24	25
Percentage of households depend on distance source(s) for irrigation, as their own source(s) are polluted	33	0	78	67	70	50	0
Percentage of farm households have adopted irrigation source substitution strategy as a pollution management option	0	0	0	11	8	4	0
Percentage of farm-households have changed their cropping pattern as a pollution	0	25	22	22	17	16	0

management option							

Source: Primary Survey by MSE

Substitution of Irrigation Sources and Rising Costs of irrigation

Earlier farmers used to irrigate their farmlands from shallow open wells, where average depth of the well varies from 41 to 52 feet. Old open wells have high concentration of EC as compared to new wells. Average age of the wells varies from 15 to 36 years. On an average in the last 10-12 years farmers shifted their irrigation source from open wells to deep bore wells. Which shows that water quality of the shallow open wells started deteriorating after the industrial operations started in the Mettupalayam area during the 1990s. Growing dependence on deep bore wells put a huge financial burden on farmers, as their initial investment for bore wells are huge. The average depth of the bore wells varies from 276 to 363 feet which is 7-8 times higher than the depth of the open wells, even though farmers are not very satisfied with their irrigation water quality. Farmers mostly irrigate their farmlands either blending their open wells water with bore wells water or with the Bhavani River water. Some farmers either individually or with the cooperation of other farmers started bringing water from the Bhavani River with a sizeable investment for infrastructure, however it is not a response due to the pollution problem, as river pumping is an old practice in this part of the Bhavani River basin.

Table 15: Sources of Irrigation and Associated Costs

Descriptions	< 1.5 dS/m	1.5 - 2.25 dS/m	> 2.25 dS/m
Average depth of the open wells (in feet)	41 (30 - 60)	52 (35 - 80)	47 (25 - 80)
Average age of the open wells (in years)	15 (15 - 15)	26 (19 - 33)	36 (20 - 45)
Average depth of the bore wells (in feet)	282 (245 - 300)	276 (25 - 480)	363 (40 - 650)
Average initial investment on bore wells (Rs.)	76,667 (30,000 - 1,00,000)	53,125 (2,500 - 1,00,000)	94,950 (12,000 - 3,00,000)
Average age of the bore wells (in years)	11 (9 - 13)	12 (10 - 16)	10 (3 – 21)
Average age of the river pumping system (in years)	--- ---	9 (1 - 14)	7 (7 - 7)
Average length of the pipeline laid down to bring water (in feet)	--- ---	4,111 (20 - 8202)	1,728 (320 - 6562)

Note: Values in the parenthesis show the range for the corresponding average value
Source: Primary Survey by MSE

Sources of Drinking Water and Water Quality Perceptions

Public stand-posts and house connections mostly serve as drinking water sources for the households in all our study sites. The farmers are increasingly becoming dependent on centralised public water supply system, since their own sources (open wells and bore wells) are polluted. Though the quality of the supplied water is not very good, as reflected by the farmers' perception of drinking water quality, still they depend on public sources, as they do not have any other option. Water quality of the public hand pumps are not very good, which shows that industrial pollution has started affecting the deep aquifers and could pose a serious threat in future. A limited number of farm-households (without access to house connection) have the access to drinking water supplied by the industries (on an average 49 per cent of the households). After long persuasion and strong protests by the local people and NGOs, some industries have agreed to supply drinking water to a limited number of the surrounding farm-households. But the households are not very satisfied with the drinking water quality, and also the quantity supplied by the industries is not adequate (only 12 litre, equivalent to 1 vessel per household). Control samples have reported that their drinking water quality is bad, it may be due to some other pollutants not related to industrial sources.

Table 16: Sources of Drinking Water and Perceptions about Water Quality

Descriptions	Site-1	Site-2	Site-3	Site-4	Site-5	All Sites	Control
Percentage of households have *House Connection* as a source of drinking water	8	13	89	78	0	34	80
Percentage of households depend on *Public Stand Post* as a source of drinking water	92	88	11	22	100	66	20
Percentage of households satisfied with *drinking water quality*	17	33	25	13	0	16	100
Quality of the supplied drinking water (5: Very Good, 3: fair & 1: Very Bad)	3	3	3	3	3	3	2
Drinking Water Quality of Public Hand Pumps (5: Very Good, 3: fair & 1: Very Bad)	3	3	3	3	3	3	2
Percentage of households collect water, as their own drinking water source(s) are polluted	92	88	100	89	100	94	0
Percentage of households who have access to drinking water supplied by industries	50	40	25	0	100	49	0
Percentage of households satisfied with the quality of drinking water supplied by industries	20	33	0	0	9	11	0

Source: Primary Survey by MSE

Since the farmers had already shifted their cropping pattern to salinity tolerant crops and substituted their irrigation water source from open wells to deep bore wells and/or river water, they have managed to cope up with the pollution. Since their own source(s) of drinking water, open wells and bore wells, are polluted most of the farmers depend on public water supply to meet their drinking water needs. There are also cases where industry has provided households with free water through a hosepipe, which could be seen as a tacit acceptance by the industry that it is responsible for contaminating the neighbouring wells.

Observations from Multi-stakeholder Meeting

A multi-stakeholder meeting was organised as a means of disseminating the primary findings, raising awareness and finding ways and means to mitigate the problems. The participants expressed their views which are broadly classified under the following heads.

Physical Deterioration of Environment

Continuous irrigation using partially treated effluents has the potential of causing deterioration of the soil and groundwater quality, not only in the irrigated land but also in the surrounding area. Normally during the initial period of irrigation the pollutants will settle in the soil then gradually percolate to the groundwater especially in the rainy season. The groundwater flow and other hydro-geological aspects influence the migration of pollutants in the aquifer. Hence ground water pollution may occur even at distant locations. More detailed studies of pollutant transport within a radius of 0.5 Km. of the industrial region are needed to gain a better understanding.

Livelihood Impact of Pollution

The impact on livelihoods has been minimised in the "hotspots", because farmers have adopted certain coping practices. In the Mettupalayam area farmers had already changed their cropping pattern from food crops (rice, banana, vegetables, etc.) to commercial crops (jasmine, curry leaves, tobacco, etc.) even before the pollution impact occurred. In some areas, they were able to use river water directly or by mixing with ground water. Since these options may not exist in other areas, the livelihood impact in other areas may be more serious. A long term Impact study on crop productivity and soil quality was recommended.

Scientific Approach Towards Effluent Irrigation

Since industrial effluents contain toxic elements including heavy metals, adequate level of treatment should be ensured. The enforcement agencies need to strictly monitor all the units and make sure the treated effluents meet the standards. For certain pollutants like TDS even if the treated effluents meet the standard of 2,100 mg/l, continuous irrigation may increase the salinity of ground water and soil in the irrigated areas and in the surrounding area. It must be pointed out that industrial effluents are discharged continuously, whereas irrigation requirements are periodic. Hence, the estimation of hydraulic loading and pollution loading need to be made. Adequate scientific investigations need to be carried out before approving the use of effluent for irrigation. Research on safe disposal methods for effluents / sludges needs to be taken up.

Re-cycle or Re-use of Effluents by Industries

Given the environmental problems caused by effluent irrigation, recycling the wastewater in industrial sector may be a better option. Since the high TDS concentration is the major problem in both the textile and tannery industries, these units need to decrease TDS by reverse osmosis (RO) or other technologies. Industries can also reduce the pollution load in their effluents through cleaner production technologies which consume less water and chemicals.

Rain Water Harvesting in Pollution Affected Areas

Recharge of freshwater through traditional as well as modern rainwater harvesting methods will help to reduce the level of pollution through dilution. In this respect construction of more check dams and percolation ponds and reclamation of tanks and other degraded water sources, could help to overcome the problem. Characteristics of rainfall, and groundwater recharge capacity play crucial role for pollutant transport and concentration in the groundwater.

Awareness and Public Participation

There is need to create more awareness regarding the adverse consequences of effluent irrigation among different stakeholders (industrialists, farmers, concerned government departments and NGOs). Collective efforts towards pollution management have not taken place in many parts of the country. In the Mettupalayam case the local NGOs have been raising the issue in various forums, but have not been able to find a solution to the problems faced by the farmers.

Local Area Environmental Committee (LAEC)

In response to the issues raised in the IWMI study and by the NGOs, the Tamil Nadu Pollution Control Board, constituted a local area environmental committee for Mettupalayam taluk. It will be the responsibility of the LAEC to monitor the pollution impact in the area and suitably advise the Pollution Control Board to take necessary action. The formation of the committee makes the process more transparent and the Board more accountable to the public. It is upto the stakeholders in the area to effectively utilise this new institution to improve the quality of the environment in the Mettupalayam area.

IV. Summary and Conclusions

Based on farmers' complaints and the available secondary information, three villages at Mettupalayam taluk in Tamilnadu have been identified as one of the industrial pollution "hot spots" in the Bhavani River basin for detailed environmental and socio-economic study under the IWMI project. There are some large and medium scale industries, mostly textile bleaching and dyeing; and pulp and paper industries, located in Thekkampatti and Jadayampalayam villages. These industries draw water from the Bhavani River and discharge their effluents on land for irrigation. Apart from these two villages, there is another village, Irumborai where a major pulp and viscose rayon plant from Sirumugai town used to discharge their coloured effluents on land for irrigation. Unlike the first two locations, where the industries are still discharging their effluents on land for irrigation, in Irumborai village the land disposal of effluents has stopped, as the pulp and viscose rayon plant was closed down after the Supreme Court order during October, 2001.

To understand the environmental impacts of industrial effluent irrigation on soil and groundwater quality of the surrounding farmlands, an extensive soil and groundwater quality study has been carried out using both primary and available secondary information for all the three industrial locations. The results show that disposal of industrial effluents on land, which has limited capacity to assimilate the pollution load, has led to groundwater pollution. Continuous application of polluted groundwater for irrigation has resulted in increased salt content of soils. In some locations drinking water wells (deep bore wells) also have high concentration of salts. In Irumborai village, the area irrigated by a pulp and viscose rayon plant effluents continues to be polluted even though the plant closed down more than two years ago.

To understand the socio-economic impacts of pollution on farm-households, a livelihood impact survey along with a perception study has been carried out for 55 households. The survey of the farmer households revealed that most of them were able to cultivate salt tolerant crops. The cropping pattern consisted of banana (29.6 per cent), coconut (15.5 per cent), curry leaf (13.9 per cent) and jasmine (4.8 per cent). However, it must be stressed that most of these crops are also raised in the unaffected areas. In other words, the cropping pattern is not a response to the marginal quality water as such.

The study shows that environmental impacts of industrial effluent irrigation is different for different sites, which is mainly due to the fact that different industries have different pollution potential; and different locations have different assimilative capacities to absorb the pollutants. Since the farmers had already shifted their cropping pattern to salt tolerant crops and/or substituted their irrigation source(s) from open wells to deep bore wells and/or the Bhavani River water, most of the farmers are able to cope to a large extent with the pollution of the ground water and hence their livelihoods are not significantly affected. This shows that availability of coping options play a crucial role to mitigate pollution problems, however the degree of severity of the pollution is also a crucial factor which determines the feasibility to adopt averting behaviour. This study shows that *ex ante* adoption of precautionary measures (averting behaviour) could mitigate the environmental problems related to pollution.

The perception survey has clearly brought out the fact that well water quality has deteriorated significantly and as many as 50 per cent of the farmers depend on a distant source such as the river water for irrigation. The situation with regard to drinking water quality is much worse. 94 per cent of the sample households have said that their own source of drinking water is polluted and they have to rely on the public supply – street taps or house connections. In few cases, the industries are supplying river water to the neighbouring households.

The less stringent effluent discharge standards for land application as well as the Tamilnadu High Court's restriction on locating near a river may have motivated the industries to buy land and use effluents for irrigation. This is a direct threat to the soil quality. Alkalinisation of the soil can result in poor structure and decreased availability of essential trace elements like zinc and copper. Thus there is urgent need for regulation of water quality for land application. The experience from the irrigation with a saline and coloured effluent at the now closed pulp and viscose rayon plant at Sirumugai, is a further argument for restricting the use of land application of industrial effluents.

It is not only water use that must be under control. Also land use has implications for water and environmental quality. The close linkages between land and water in the basin means that a degradation in one of them will also infringe on the other with potential repercussions on human health, yields, product quality, aquatic ecosystems and, generally socio-economic opportunities and sustainability.

Water quality is critical for the future development along the Bhavani River. Also industry is aware of and acts to avoid quality problems when looking for suitable location for water using processes. An increased interest has therefore been seen towards establishing factories in the upper part of the basin. Since this area is generating freshwater for downstream urban clusters, farmers and environmental groups are trying to stop such development. However, strict regulatory measures are required to stop conversion of catchments areas of the river for industrial uses.

Water is a scarce resource, thus any reuse of water is desirable as long as the costs (both direct and indirect) associated with the reuse of it is less than the benefits of using it. Detailed cost – benefit studies (both environmental and human health hazards) are essential before going in for effluent irrigation.

Volume of industrial effluent will increase with economic growth; therefore in future the land disposal option could be a serious environmental threat for agriculture. Hence, it is essential for the concerned authorities to consider the environmental and socio-economic aspects of using industrial effluent irrigation, before giving approval to such projects. For developing countries like India, it is better to follow the precautionary approach in the case of industrial effluent irrigation, as the long term environmental and human health risks/implications of using marginal quality water are not known.

Joint monitoring and community monitoring institutions such as Local Area Environmental Committee could strengthen active participation of the stakeholders and also aid in conflict resolution.

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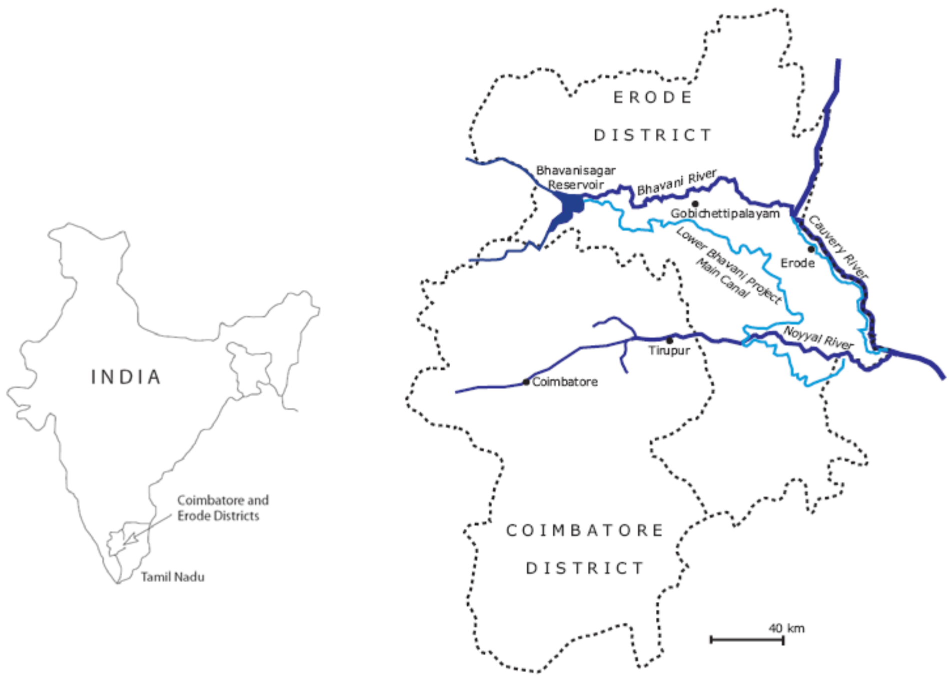
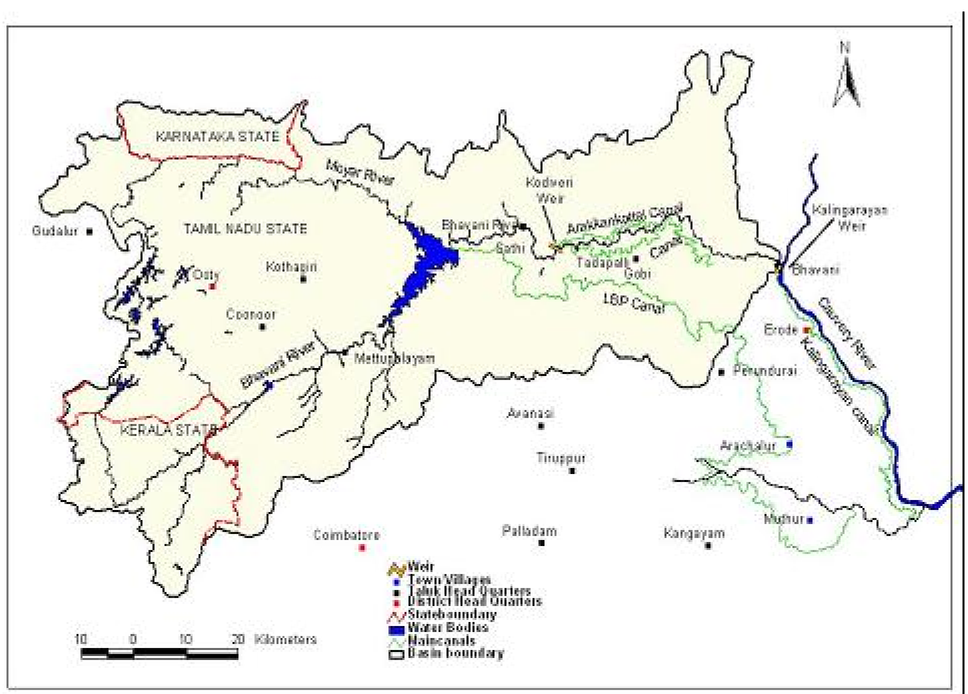
APPENDIX – 1

Map – 1: Location Map



The Bhavani River Basin, Tamilnadu



APPENDIX – 2

Table 1: Industrial Profile – 1 (Mettupulayam Study Area)

S. No.	Name of the unit	Location	Year of Est.	Activity	Size	Category	GFA (Rs. Crore)	Qty. Production T/M
1	Pulp and Paper Unit - 1	Thekkampatty	1997	Paper Board	Large	Orange	243	7424
2	Textile Bleaching & Dyeing Unit – 1	Thekkampatty	1994	Terry Towel	Large	Red	28	100
3	Textile Bleaching & Dyeing Unit – 2	Mettupalayam (M)	1953	Bleaching & Dyeing	Large	Red	7.6	530
4	Textile Bleaching & Dyeing Unit – 3	Jadayanpalayam	1995	Bleaching & Dyeing	Large	Red	10	72.5
5	Textile Bleaching & Dyeing Unit – 4	Jadayanpalayam	1995	Bleaching & Dyeing	Small	Red	0.7	21.75
6	Textile Bleaching & Dyeing Unit – 5	Jadayanpalayam	1995	Bleaching & Dyeing	Large	Red	89.6	21 Lakhs/Mt/M
7	Pulp and Paper Unit – 2	Jadayanpalayam	1991	Paper	Large	Orange	5.02	840
8	Wattle Unit	Mettupalayam (OR)	1967	Wattle	Medium	Red	4.47	NA
9	Chemical Unit	-do- (Manidur)	1994	Synthetic chemicals	Large	Red	8.52	NA
10	Water Park	-do- (Odanthurai)	1997	Water park	Large	Orange	20	--

Source: TNPCB, Coimbatore, 2004.

Table 2: Industrial Profile - 2 (Mettupulayam Study Area)

S. No.	Name of the unit	Water Consumption (KLD)	Source of Water	Distance from the Bhavani River	Quantity of Effluents (KLD)	Year of Est. of IETP	Mode of Effluent Discharge	Annual Water Cess (Rs)
1	Pulp and Paper Unit - 1	5025	Bhavani R	4.2 Km.	2610	1997	O.L Irrigation	1,87,000
2	Textile Bleaching & Dyeing Unit – 1	620	Bhavani R	1.5Km.	600	1994	O.L Irrigation	64,800
3	Textile Bleaching & Dyeing Unit – 2	1700	Bhavani R	Adj. River	1668	1991	Bhavani River	36,883
4	Textile Bleaching & Dyeing Unit – 3	225	Bhavani R	2 Km.	221.5	1995	O.L Irrigation	13,122
5	Textile Bleaching & Dyeing Unit – 4	41.5	Bhavani R	2.2 Km.	40.1	1995	O.L Irrigation	4,320
6	Textile Bleaching & Dyeing Unit – 5	1342	Bhavani R	1.5 Km.	808	1994	O.L Irrigation	39,324
7	Pulp and Paper Unit – 2	1001	Bhavani R	0.8 Km.	981	1991	O.L Irrigation	74,888
8	Wattle Unit	50	Well	1.0 Km.	50	1989	O.L Irrigation	5,400
9	Chemical Unit	59	Well	-	35	1994	O.L Irrigation	2,520
10	Water Park	150	Well	-	150	1997	O.L Irrigation	1,463
	Total	**10,214**			**7,164**			**429,720**

Note: O.L. Irrigation implies Own Land for Irrigation
Source: TNPCB, Coimbatore, 2004.

Table 3: Annual Pollution Load Discharged by Industries in Mettupalayam Area (Tonnes/Year)

S. No.	Name of the unit	Location	TDS	TSS	COD	BOD	Oil &Grease
1	Pulp and Paper Unit - 1	Thekkampatti	272.66	25.85	70.52	4.7	0.58
2	Textile Bleaching & Dyeing Unit – 1	Thekkampatti	132.27	13.14	12.26	1.31	0.21
3	Textile Bleaching & Dyeing Unit – 2	Mettupalayam (M)	494.36	21.91	24.35	4.74	0.6
4	Textile Bleaching & Dyeing Unit – 3	Jadayanpalayam	116.09	3.88	14.22	1.09	0.08
5	Textile Bleaching & Dyeing Unit – 4	Jadayanpalayam	32.2	1.11	0.3	0.48	0.01
6	Textile Bleaching & Dyeing Unit – 5	Jadayanpalayam	70.78	2.35	2.35	1.17	0.29
7	Pulp and Paper Unit – 2	Jadayanpalayam	166.14	15.75	42.96	2.86	0.35
8	Wattle Unit	Mettupalayam (OR)	17.59	3.06	1.84	0.09	0.01
9	Chemical Unit	-do- (Manidur)	13.43	0.71	0.3	0.04	0.01
10	Water Park	-do- (Odanthuru)	-	6.35	-	1.31	-
		TOTAL	**1315.52**	**94.11**	**169.1**	**17.79**	**2.14**

Source: MSE (2005) (Estimation Based on TNPCB Data).

ANNEXURE – 1

Table 17: Maximum Permissible Limits (mg/litre) for Industrial Effluent Discharges

Parameter	Into Inland Surface Waters	On Land for Irrigation	Into Public Sewers	Marine Coastal area
Biological Oxygen Demand (for 5 days at 20^oC)	30	100	350	100
Chemical Oxygen Demand (COD)	250	-	-	250
Suspended Solids	100	200	600	-
Total dissolved Solids (inorganic)	2100	2100	2100	-
Total Residual Chlorine	1	-	-	1
Cadmium (as Cd)	2	-	1	2
Hexavalent Chromium (as Cr^{+6})	0.1	-	2	1
Copper (as Cu)	3	-	3	3
Lead (as Pb)	0.1	-	1	1
Mercury (as Hg)	0.01	-	0.01	0.01
Nickel (as Ni)	3	-	3	5
Zinc (as Zn)	5	-	15	15
Chloride (as Cl)	1000	600	1000	-
Selenium (as Se)	0.05	-	0.05	0.05
Ammoniacal Nitrogen (as N)	50	-	50	50

Source: CPCB (2001)

Table 18: Wastewater Generation, Collection and Treatment in Indian Metros, Cities and Towns

	Metrocities #	Class I Cities $	Class II Towns @
Number of Urban Agglomerations/Cities/Towns	23	299	345
Population	65,885,285	128,113,865	22,375,588
Total Water Supply (million litre daily)	12,738	20,607	1,936
Population Covered by Organised Water Supply	59,567,211	112,774,883	18,732,165
Per Capita Water Supply (lpcd)	214	183	103
Percent of Population Covered by Organised Water Supply	*90*	*88*	*84*
Total Volume of **Domestic** Wastewater Generated (mld)	8,893	16,271	--
Total Volume of **Industrial** Wastewater Generated (mld)	382	392	--
Total Volume of Wastewater Generated (mld)	**9,275**	**16,663**	**1,650**
Total Volume of Wastewater Collected (mld)	7,471	11,938	1,090
Total Volume of Wastewater Treatment Capacity	2,923	4,037	62
Wastewater Generated as % of Total Water Supply	**73**	**81**	**85**
Wastewater Collected as % of Wastewater Generated	81	72	66
Wastewater Treatment Capacity as % of Wastewater Generated	**32**	**24**	**4**
Nitrogen (N) Load of Wastewater Generated (tonnes per day)	278	500	49
Phosphate (P) Load of Wastewater Generated (tonnes per day)	70	125	12
Potassium (K) Load of Wastewater Generated (tonnes per day)	232	417	41
Total NPK Load of Wastewater Generated (tonnes per day)	**580**	**1,041**	**103**
Land Used for Sewage Farming (in ha)	**19,072**	**6,909**	**112**
Average Sale Price of Sewage (Rs./ha/year)	188	188	80

Source: # CPCB (1997), $ CPCB (2000a) and @ CPCB (2000b)