Compensating the Loss of Ecosystem Services Due to Pollution in Noyyal River Basin, Tamil Nadu

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Paul P. Appasamy and Prakash Nelliyat

Abstract

The loss of ecosystem services due to industrial pollution in the Noyyal River Basin was estimated through physical research studies of water and soil quality and bio-mapping followed by economic valuation. Estimates of the loss to the agriculture, drinking water, and fisheries sectors were made on an annual basis and also capitalized. Compensation was awarded by the Loss of Ecology Authority to the affected farmers to be paid by industry.

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INTRODUCTION

The Millennium Ecosystem Assessment defines an ecosystem as a "dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit". Humans are an integral part of ecosystems. Ecosystem services are the benefits people obtain from ecosystems, which include provisioning services such as food and water; regulatory services such as regulation of floods, drought, land degradation, and diseases; supporting services such as soil formation and nutrient cycling; and cultural services such as recreation, spiritual, religious and other non material benefits (MEA, 2003). Ecosystem services can be lost or diminished when there is over-extraction or mismanagement of ecosystems.

In countries where environmental regulation is weak, the wastes from different sectors are indiscriminately discharged into the ecosystems. The receiving ecosystems are seriously affected in terms of their functions. This is particularly true in the case of those ecosystems which are common property resources or in which property rights are not well defined. When the services provided by ecosystems are impaired, there is a reduction in productivity which ultimately impacts the well-being of people who depend on the ecosystems for their livelihood.

The most serious impact of pollution is on air and water resources and the associated ecosystems. The demand for water from different sectors is increasing at a rapid rate in proportion with the growth of population and the economy. Moreover, the structural transformation of the economy through the diversification from agriculture to the industry and service sectors has significantly influenced the allocation of water resources. Since water in the industrial and service/domestic sectors is 'non-consumptive', 80 per cent or more of water used in these sectors is returned as wastewater. Wastewater management strategies for both industrial effluents and domestic sewage are often not adequate in many developing countries. Hence the impact of wastewater on the receiving ecosystems (such as land, aquifers, rivers, canals, tanks, and reservoirs) are significant particularly when there is accumulation of pollutants. The ecosystem services which were available for centuries, are often lost or reduced.

Unfortunately in many pollution affected areas the impact on ecosystem services is not estimated basically due to the complexity in methodology and lack of data. Unless one carries out a damage assessment study, it is not possible to know the extent of the loss of ecosystem services. The valuation of ecological benefits and costs is a major area of research which enables estimation of the monetary value of ecosystem services as well as the cost of ecosystem degradation. Studies by Dixon (1986), Turner (1978), Markandya (1992), Winpenny (1991), and Pearce (1978) provide very good methods and examples related to the economic valuation of damage to ecosystem services.

Even if valuation of ecosystem damage has limitations in terms of coverage and accuracy, it attempts to capture the cumulative impact on the ecosystem in economic terms. The Brandon and Homman (1995) report on "The Cost of Inaction: Valuing the Economy-wide Cost of Environmental Degradation in India" provides a macro estimate of the magnitude of environmental (ecological) damage and the economic cost of not managing environmental problems. Yongguan *et al.,* (2001) estimated the environmental cost of water pollution in Chongqing, one

of the heavily polluted industrial cities in China. Behera and Reddy (2002) studied the environmental impact of water pollution on rural communities in general and agricultural production, human health, and livestock in particular with the help of primary data collected from pollution affected villages in Andhra Pradesh.

Both, valuation of ecosystem benefits as well as the loss of ecosystem services due to degradation are extremely important for framing ecosystem management policies such as compensation and payment strategies. Compensation can be provided either for those people who preserve ecosystems and forego certain immediate benefits, or those who suffer due to the degradation of ecosystems. The present case study discusses attempts to compensate farmers for the loss of ecosystem services caused by textile industrial pollution in the Noyyal River Basin in Tamilnadu, India.

The basic structure of this paper is as follows:

- Description of the Noyyal River Basin.
- The threats to ecological services in the Noyyal River Basin due to industrial pollution, primarily from the Tiruppur textile cluster.
- The loss of ecosystem services in different sectors such as agriculture, domestic water supply and fisheries.
- Compensating the loss of ecosystem services in the Noyyal River Basin and policy options for restoring the ecosystem.
- Emerging Trends – the impact of industrial pollution on agro ecosystems and rural livelihoods.

Methodology

A case study of the loss of ecosystem services due to industrial pollution was taken up to estimate the economic value of the loss to various stakeholders in a pollution affected area. This study of the Noyyal River Basin was funded by the Tamil Nadu Institute for Water Studies. Subsequently, a similar exercise was taken up by a government agency, the Loss of Ecology Authority to award compensation to the farmers in the affected area. The case study illustrates the complexity in identifying and valuing the damage (loss of ecosystem services) due to pollution. The institutional and policy response by way of compensation and restoration of the ecosystem would also be of interest to a wider audience interested in compensation for ecosystems services.

To identify the ecosystem services in the Noyyal River Basin, relevant information was gathered from various studies conducted by different government agencies and researchers at different time periods. In order to study the impact of pollution on water and soil quality in the basin, an extensive survey was conducted with the assistance of a government agency, the Soil Survey and Land Use Organisation. This study covered the entire length of the basin from the source to the confluence point using a band with a width of 5-7 km on the north and south sides of the river. A grid pattern was used for selecting the samples. A total of 619 water samples and 662 soil samples were collected and analyzed to understand the impact of water and soil quality.

The next step is the valuation of loss of ecosystem services in different sectors such as agriculture, domestic water supply and fisheries. Using the soil and water quality data, it was possible to estimate the

area affected by pollution. Subsequently we estimated the economic cost of industrial pollution on the agriculture sector in the affected area. Since the extent of area affected is large, we selected thirteen villages for a pilot survey and three villages for a detailed household survey. The impact on agriculture in the affected area was assessed through the “productivity loss” method[1].

The cost estimation on the drinking water sector covered the entire Tiruppur Municipal area and the textile pollution affected villages. In Tiruppur Municipality (52 wards), we carried out a perception study with the assistance of a local NGO (Centre for Environment Education). In some wards the ground water quality had deteriorated over the last ten years and the residents now have to rely on public supply and/or purchase water from tankers. The cost incurred by the households is one way of estimating the loss. For estimating the impact on rural areas a large database provided by the Tamilnadu Water Supply and Drainage (TWAD) Board was analysed. This database also confirmed the high level of pollution of the ground water. The cost of various schemes was estimated from the database. The impact on drinking water in the three case study villages was estimated through the “replacement cost” method[2]. An estimate was made of the total number of affected households who do not have access to a public scheme to determine the total cost to these households.

To study the impact on fisheries, a biological study along the course of the river was conducted with the assistance of the Research Department of Zoology, Erode Arts College. The biological diversity including plankton, zooplankton and fish diversity was studied and a bio-mapping exercise was attempted. Further laboratory studies on respiration and biochemical alterations due to pollution were studied. The valuation of damage in fisheries sector was done based on the productivity loss method with the data collected from the Fisheries Department.

After the completion of our study, the Loss of Ecology Authority commissioned an independent study by Anna University to assist them in computing the compensation to be paid to the affected parties. The methodology used was similar, except that affected villages were identified using the water quality data. It was assumed that the impact on all land owners in the village would be similar. Compensation was worked out in terms of Rs/hectare based on the cropping pattern in each village. The Authority also worked out the payment to be made by each industrial unit. Restoration of the ecosystem, in this case the Orathapalayam reservoir was required by the Court for which the industries had to make a separate payment.

DESCRIPTION OF THE NOYYAL RIVER BASIN

The Noyyal river is a tributary of the Cauvery, a large inter-state river which cuts through the States of Karnataka and Tamilnadu and enters the Bay of Bengal. The Noyyal flows through the districts of Coimbatore, Erode and Karur and the urban centres of Coimbatore and Tiruppur, in western Tamilnadu (see Map 1). A number of industrial units such as textile units, chemicals, and electroplating are located in the river basin which discharge their untreated and partially treated effluents into the river. In addition, sewage from Coimbatore and Tiruppur cities is also being discharged into the river without much treatment, making the Noyyal one of the highly polluted rivers in the country.

The Noyyal is a seasonal river which has good flow only for short periods during the North-East and South-West monsoons. Occasionally flash floods occur when there is heavy rain in the catchment areas. Apart from these periods, there is only scanty flow for most parts of the year. The river supplies water to several irrigation tanks located in and around Coimbatore town and downstream[3]. Nearly 6,000 acres of cultivable land in Coimbatore district are irrigated using the river water.

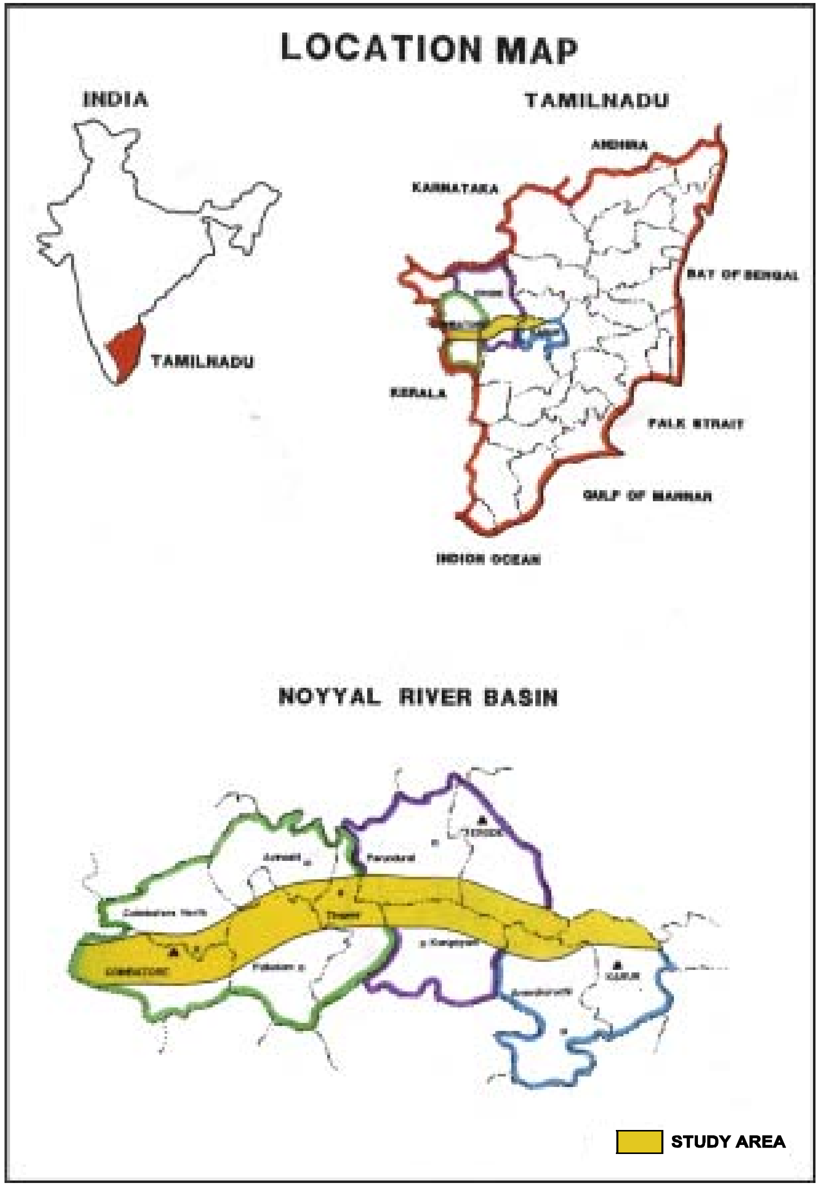
The Noyyal river basin covers a total area of 3510 km^2 and is located between north latitude $10^0$56' and $11^0$19' and east longitude $76^0$41' and $77^0$56'. The length of the Noyyal river is about 170 km from west to east. The average width of the basin is 25 km. The basin is widest in the central part with a width of 35 km.

The entire area of the basin is situated in the state of Tamilnadu, in parts of Coimbatore, Erode and Karur districts. The Noyyal confluences with the Cauvery River at Noyyal village.

Rainfall

In the Noyyal river basin the annual rainfall is highly varied. This is due to the orographic effect of the Western Ghats, which forms the western border of the basin. The upper reaches of the basin receive high rainfall of more than 3000 mm annually, while the eastern part receives only 600 mm. The pre-monsoon season period produces about 100 mm to 300 mm of rain and most of it is received during the months of April and May.

Map 1



Soil, Flora and Fauna

The type of soil that occur in Noyyal basin are many and varied, ranging from shallow red non-calcareous soils to very deep grey calcareous ones. A standard reconnaissance soils survey of Coimbatore district reveals the occurrence of 14 different soil series and their associations. These 14 series can be broadly classified in to five categories: red soil, grey soil, alluvial soil, colluvial soil and forest soil (Soil Survey and Land Use Organization, 2002).

The upper catchment of the basin is covered with forest. The natural forest in the basin consist of verity of flora. Around 34 species of plants were recorded of which: 3 are trees, 8 shrubs, 17 herbs, 3 climbers, 1 sedge and 2 grasses. The water bodies in the Noyyal River Basin support a large number of aquatic organisms. A number of phytoplankton and zooplankton species are present in the water bodies in the basin. However, it was found that in Tiruppur, where the river is more contaminated, only one zooplankton species (*Dahina species)* was observed. Generally, phytoplankton also has become more or less rare in the river in Tiruppur (PWD, 2001).

Agriculture

This basin was once fertile supporting various crops like paddy, sugarcane, banana, turmeric, coconut, grapes, cotton, vegetables, cereals and pulses. The cropping pattern has changed due to droughts and non-availability of water. Farmers are growing grapes with drip irrigation in the upper basin. Due to the industrial growth in Tiruppur, the discharge of untreated and partially treated effluents has adversely affected the agricultural development in the lower basin.

Irrigation Schemes

The Noyyal is a water deficit basin since the average rainfall is only 700mm with increasing water requirement to meet the needs of the rapidly growing population and industry. The water potential in terms of both surface and ground water has been fully exploited in the basin. River water has been harvested for irrigation by the construction of anicuts (weirs) and tanks since the 16th century. 31 tanks and 23 weirs were used to irrigate about 16250 acres or 6550 hectares of land (Map 2). Hence the livelihood of a large number of people in the basin, particularly the poor farmers, depends on the river ecosystem.

Except the 23 anicuts (weirs) there was no major reservoir in the Noyyal river basin till 1980 which very much restricted the extension of irrigation. After 1953 when the Lower Bhavani Project (LBP) canal - a fresh water canal from the river Bhavani in the neighbouring basin which irrigates the downstream part of Noyyal - came into being, the seepage waters of the scheme drained into Noyyal at the location where the LBP canal crosses the river Noyyal. This seepage water (about 2760 mcft or 78.45 Mm3 per year) flows into the Noyyal for many months every year. During the early 1980s, the government formulated the Noyyal Orathapalayam Reservoir Project (NORP) in two stages to utilize the heavy surplus water of the Noyyal that flows into the Cauvery.

The first stage scheme of NORP was formulated to utilize these surplus waters for irrigation and was approved by the government in 1981. Under this scheme a barrage of 119 metres length was constructed across the Noyyal river to store the seepage water and to divert it through a feeder canal (10 km. length) to a newly built reservoir in

Karur district to irrigate about 9,625 acres of dry area. Additional food grain production of about 9305 tonnes was anticipated through this scheme. This scheme was completed in 1991 at a total cost of Rs. 139 million.

The second stage of the NORP envisaged construction of a new dam across the Noyyal at Orathapalayam village to store the flood waters of the Noyyal. It was proposed to provide irrigation facilities to 500 acres of dry areas in Erode district through two head sluices located in the dam and another 10,375 acres of dry land in Karur district.

Orthapalayam reservoir consists of a stone masonry dam and spillway of length 99.50 metres across Noyyal river with eastern dam on both flanks for a total length of 2.19 km. The floodwater stored in this reservoir (of capacity 617 mcft) can be discharged into Noyyal river through a sluice built in the masonry dam. This project were started in July 1984 and completed in 1991 at a cost of Rs.199.8 million. Additional food grain production of about 10000 tonnes was anticipated from this scheme. The total expenditure incurred for both stages was projected to be Rs. 338.8 million for an irrigation target of about 20000 acres of dry areas in the basin. Due to the textile pollution from Tiruppur, NORP has completely failed in achieving its objectives.

Ground Water

The Noyyal basin comes mostly under hard rock. Water supply in the major portion of Noyyal river basin is derived from deep dug wells reaching 35-45 metres below ground level investing enormous amount of capital and labour which was a continuous process till the

1980s to keep pace with the receding water table. After electrification of wells there has been considerable increase in ground water withdrawals which in turn is depleting the groundwater level below 50-60 metres.

At this stage, borewell drilling machinery came to the market and rich farmers went in for bore wells which depleted the ground water table further in an alarming way. Most of the open wells have been abandoned and farmers have gone in for bore wells and pump the water through compressors. Even this is not successful unless groundwater recharge is taken up on a massive scale. In the industrial locations of the basin, particularly Tiruppur, ground water pollution is also significant.

Drinking and Industrial Water

Apart from agriculture, the water resources available in the basin are also used by the domestic and industrial sectors. Since the Noyyal river is not a perennial river there is no drinking water supply scheme with the Noyyal as the source. The two major cities, Coimbatore and Tiruppur receive water from the Bhavani in the neighbouring basin. But the villages in the Noyyal basin generally depend on ground water from public and private wells. The industries in Coimbatore and Tiruppur also depend on groundwater for their processing. In Tiruppur a ‘private water market’ is active, which supplies water for industries and domestic sectors through lorry tankers. Recently a mega public private water supply project was commissioned to supply 185 million litres per day (mld) of water from the Cauvery river to Tiruppur for both domestic and industrial use.

Map 2

MAP OF RIVER NOYYAL

INDUSTRIAL POLLUTION AND LOSS OF ECOSYSTEM SERVICES IN THE NOYYAL RIVER BASIN

In recent decades, the ecosystems particularly the water and land resources of this basin have been affected due to industrial effluents and domestic sewage. Apart from the large number of textile processing units in Tiruppur, several textile dyeing (175) and electroplating (195) units are located in the Coimbatore area in the upper part of the basin. These units discharge their effluents without any treatment in the Noyyal river and the surrounding lands. Hence the possibilities of accumulation of pollutants in tanks and ground water in this area are significant. The local people who live in and around Sulur tank (where most of the effluents discharged from Coimbatore gets concentrated) say that the water quality deterioration has occurred over a period especially after urbanization and industrialization of Coimbatore city. However, in this paper our emphasis is on the effluent discharged by textile bleaching and dyeing units at Tiruppur, and the impact on the Noyyal basin downstream of Tiruppur.

Tiruppur is a rapidly growing textile (knitwear) industrial cluster located on the banks of the Noyyal river, in Coimbatore district of Tamilnadu. Presently more than 9000 small-scale knitwear related units are functioning in Tiruppur which provide employment opportunities for more than 200,000 people. The annual export value from Tiruppur during 2004 was about Rs. 45,000 million. The pollution problems of the hosiery industry in Tiruppur are closely associated with the bleaching and dyeing (textile processing) segment of the industry. During 1981, only 68 textile processing units were functioning in Tiruppur. But, due to the growth in exports the number of units has

increased rapidly to 450 in 1991 and 700 in 2001. Correspondingly, the volume of effluents discharged by the processing units into the environment has also increased considerably and at present all the units together discharge more than 80 million litres per day (mld) of effluents without adequate treatment (Nelliyat, 2003). The existing effluent treatment plants were not designed for reducing total dissolved solids (TDS) particularly the chloride and sulphate salts.

In Tiruppur around 550 (78 per cent) textile processing units are functioning in non-industrial areas and discharge their effluents (around 62 mld) on land. Hence the possibility for contaminating the ground water in residential and agricultural areas is very high. Since 240 units are located at a distance of less than 300 metres from the Noyyal, the potential for polluting the river through direct discharge is also quite high. The river carries the effluents to downstream areas especially to the system tanks and the Orathapalayam reservoir. Hence the pollution is widespread even in distant areas, particularly in Erode and Karur districts. Pollution impacts are observed in different sectors like domestic water supply, agriculture, fisheries, bio-diversity, and public health.

The loss of ecosystem services in Tiruppur area is due to the accumulation of effluents in the ground water and soil. From 1980 to 2002, the cumulative TDS load discharged by the Tiruppur units alone is estimated to be 2.87 million tonnes. Besides other pollutants have also accumulated significantly during this period (Table 1). Around 80 per cent of the pollution load has accumulated in the Tiruppur area. Rainfall (annual average of 617 mm) has only a marginal effect in reducing the severity of the impact.

Table 1

POLLUTION LOAD GENERATED BY TIRUPPUR TEXTILE PROCESSING UNITS FROM 1980 to 2003 IN NOYYAL RIVER BASIN

(Quantity in Tonnes / Year)

Period	TDS	CHLORIDE	SULPHATE	TSS	COD	BOD	OIL&GREASE
1980-2003	2877066.17	1585933.8	161726.82	110928.95	104944.33	31990.55	1633.95

Note: TDS – Total dissolved solids
TSS – Total Suspended Solids
COD – Chemical Oxygen Demand
BOD – Biochemical Oxygen Demand

Source : Nelliyat (2005)

Water Quality Studies (Secondary Data)

Ground Water Pollution: - A number of studies have been carried out by academic institutions and government agencies in recent years[4]. The major conclusions of these studies are as follows:

- Open wells and bore wells in and around Tiruppur and the downstream stretch of Noyyal exhibit high levels of TDS (most areas > 3000 mg/l and some places even up to 11,000 mg/l) and chloride (generally > 2000 mg/l and certain areas upto 5000 mg/l) due to industrial pollution.
- The current values of pollution concentration are very much higher than the background levels for this region.
- Rainfall has only a marginal influence in reducing the concentration of TDS.
- High possibility in increase in pollution concentration in ground water in the near future if effluent discharge by textile processing units continues.
- High concentration of heavy metals in ground water including zinc, chromium, copper, and cadmium.

- The open and bore wells located around 4 kms radius of Orathapalayam reservoir are highly polluted with high TDS level and concentration of various salts.
- The establishment of effluent treatment plants in Tiruppur has not had any positive impact on the ground water quality.
- The studies also show that the available ground water is not suitable for domestic, industrial or irrigation use.

Surface Water Pollution: - The surface water studies done by Government Departments and researchers indicate similar findings[5]:

- The pollution (EC/TDS) concentration in Noyyal river is low till the river reaches Tiruppur. But it increases considerably in Tiruppur area, due to textile effluent discharge, and continues up to Orathapalayam. But after Orathapalayam there is some improvement in river water quality.
- Pollution concentration in the river is more in summer than winter.
- The existing moderate flow in Noyyal is not sufficient for diluting the pollutants.
- The Orathapalayam reservoir and system tanks have been badly affected by industrial pollution.
- High alkalinity, chloride, electrical conductivity, iron, phosphate and BOD in the water at Orathapalayam reservoir.
- River and reservoir are not fit for aquatic organisms including fish.
- Concentration of high TDS and chloride at the tail end of the Noyyal at the confluence point with Cauvery.
- Except for the rainy season when there is some dilution, the surface water is unfit for irrigation.

Although a number of studies are available on the water pollution issues of Tiruppur, these are not sufficient to estimate the loss of ecosystem services in the Noyyal river basin. A research study on water and soil quality was conducted for the physical estimation of damage in the affected area.

Primary Water and Soil Quality Survey

For convenience the basin was classified into four zones. Zone I is the upper reach of the basin from the origin of the river, which is free from pollution since there is no industry and few human settlements. Zone II is the next stretch where Coimbatore city is located. Large quantities of sewage along with industrial effluents are discharged into the river. The ecosystem degradation is significant in this stretch, but the effluents are not felt downstream because most of the pollutants have settled in the large tank at Sulur outside of Coimbatore. The river is relatively less polluted as it enters the town of Tiruppur. Zone III, wher Tiruppur town is located is the most polluted stretch of the river. From Tiruppur large quantities of textile effluents are discharged into the land and river. Most of the effluents collect at the Orathapalayam reservoir downstream of Tiruppur. Zone IV is from Orthapalayam to the confluence point with the Cauvery. The pollution impact in Zone IV is not serious when compared to Zones II and III.

The survey covered a band of about 5 km to 7km width on both north and south sides of the river from the source to the confluence point (see Map 3). Water samples were taken from wells, streams, tanks, bore wells and canals. The soil samples include surface and sub-surface. The water quality of samples were categorized in terms of the electrical conductivity: (i) Injurious (EC is >3 mmhos/cm) - water

is not recommended for irrigation, (ii) Critical (EC value of 1.1 to 3 mmhos/cm) – water quality is affected, but can be used for irrigation purposes and (iii) Normal (EC value upto 1 mmhos/cm) – water quality is not affected[6]. The soil quality assessment was based on the pH ie. the alkalinity and salinity of the soil.

Water Quality Results: Altogether 619 water samples were collected from different sources from the basin. The zone wise analysis of water samples (Table 2) shows that the level of pollution was relatively high in Zones II and III compared to Zones I and IV. The discharge of untreated effluents by textile and electroplating units located at Coimbatore area was the main reason for the high pollution in Zone II. The degradation of water quality in Zone III was basically due to the effluent discharged by Tiruppur textile Processing units. There were significant improvements in water quality in Zone IV for two reasons. Since the effluents collect at the Orathapalayam reservoir which was closed for most of the period, the possibility of water contamination downstream was less. There was also dilution of the pollutants by canal water from the Lower Bhavani Project canal in Zone IV. (See Map 4)

Table 2

WATER QUALITY STATUS OF NOYYAL RIVER BASIN

Zone / Water Quality	Normal	Critical	Injurious	Total
Zone I	3(25)	9(75)	-	12
Zone II	8(7)	48(41)	60(52)	116
Zone III	62(25)	106(42)	82(33)	250
Zone IV	136(56)	84(35)	21(9)	241
Total	**209(34)**	**247(40)**	**163(26)**	**619**

Note: ( ) indicates that the percentage of samples
Source: Madras School of Economics, 2002.

Map 3

Soil Quality Results: For soil quality analysis 662 surface samples and 662 sub-surface samples were collected (Table 2). Generally, the soil quality degradation was evident in the industrial areas in Zones II and III. An interesting finding here is that the soil degradation in terms of alkaline affected samples were much more in evidence in Zone IV compared to other Zones. It was observed that the farmers in Tiruppur area (Zone III) cultivated only rainfed crops like maize and ragi and were not using the contaminated water for irrigation. But farmers downstream cultivated different irrigated crops like paddy, banana, sugar cane, turmeric, and tobacco during early 1990s after the Orathapalayam project commenced. Occasionally farmers were using the polluted water. Since the irrigation sources were contaminated the possibilities of transfer of pollutants from water to soil are high.

Table 3

SOIL QUALITY ANALYSIS IN NOYYAL RIVER BASIN

Zone / Soil Quality	Category	Normal	Alkaline	Tending to Alkaline	Total
Zone I	Surface	1 (6)	7 (44)	8 (50)	16
	Sub-surface	-	9 (56)	7 (44)	16
Zone II	Surface	29 (16)	43 (24)	108 (60)	180
	Sub-surface	25 (14)	56 (31)	99 (55)	180
Zone III	Surface	62 (23)	65 (23)	152 (54)	279
	Sub-surface	147 (53)	75 (27)	57 (20)	279
Zone IV	Surface	13 (7)	117 (63)	57 (30)	187
	Sub-surface	10 (5)	126 (67)	51 (27)	187
Total	**Surface**	**105 (16)**	**232 (35)**	**325 (49)**	**662**
	Sub-surface	**182 (27)**	**226 (40)**	**214 (32)**	**662**

Note: ( ) indicates the percentage of samples.

Source: Madras School of Economics, 2002.

Biological Studies

A detailed biological study was undertaken to examine the impact of industrial effluents on the bio-diversity of different surface water sources in the Noyyal river basin. The study revealed that the Noyyal river water is highly polluted and is toxic to fish and other organisms in the stretch from Tiruppur to Orathapalayam. Consequently, there is a heavy loss of fisheries in river, system tanks and the Orathapalayam reservoir. There was also loss of biodiversity and damage to the aquatic ecosystem.

Plankton diversity (phytoplankton and zooplankton) study carried out at different stations revealed that greater number of species were observed in the river before and after Tiruppur. The maximum density was found in the downstream stretch of Noyyal in Zone IV (3678 individuals) while the least was recorded in Zone III (726 individuals) in the industrial area. Fish diversity was also adversely affected in the industrial pollution affected areas and no fish was found in the river in Zone III. But after Orathapalayam, the river supports seven species of fish. Apart from the physical data on biodiversity, the biological studies covered the fish toxicity studies also. A dose and time dependent decrease in the rate of respiration was observed in fishes when exposed to different concentrations of river water. The biochemical parameters such as muscle glycogen and liver glycogen were found to decrease while the blood glucose level increased due to stress, in the polluted stretch.

The biological study revealed that the Noyyal river has very poor life supporting nature in the industrial corridor of Tiruppur due to textile effluent discharge. But the river supports more life after Orathapalayam, since the dam is closed and there is influence of clean seepage water from the LBP canal. During the field survey it was noted that livestock were also affected in some of the villages.

Map 4

Loss of Ecosystem Services

The accumulation of pollutants due to continuous discharge of textile effluents by the processing units in Tiruppur has exceeded the assimilative capacity of land and water, and has severely affected the natural environment in and around the Tiruppur area and particularly the areas downstream of the Noyyal river. The level of pollution is high in the groundwater, in the surface water sources (river, tanks, and reservoir) and to some extent in the soil, which has resulted in the degradation of the ecosystem and the loss of various ecosystem services. According to Azeez (2001) "*the untreated textile effluent released to the environment is (a) aesthetically unpleasant, (b) unfit for drinking and other human use leading to human health implications from its use under duress, (c) unfit for irrigation, (d) unfit for livestock and (e) not conducive for aquatic organisms such as plankton, invertebrates and fishes. The effluent has made the Orathapalayam check dam an environmental disaster, adding to the miseries of the local people. The ecological consequences of the effluent are associated with degradation of the quality of the (i) surface water body that receives effluents, (ii) sediment and soil, and (iii) ground water".*

Despite the existence of several technical studies of pollution, the cost of loss of ecosystem services had not been estimated by any studies due to the data constraints and complexity in methodology[7]. The sectors experiencing loss of ecosystem services include: agriculture, fisheries, domestic water supply, human health, livestock and bio-diversity. But the economic valuation of the loss of services was undertaken only in three major sectors: agriculture, domestic water supply and fisheries.

Agricultural Sector

The area located on both sides of the Noyyal between Tiruppur and Orathapalayam (located in Tiruppur, Perundurai and Kangayam taluks) was identified as the area affected by textile effluents from Tiruppur and analysis was carried out for irrigated and unirrigated areas. Based on the Electrical Conductivity (EC) values of water (from the primary water quality study), the areas were divided as severely affected, moderately affected and unaffected, and output variations for different crops were estimated.

The average value of net output per acre was calculated using case study village data as explained below. If the farmers were not able to raise a particular crop in affected area, there may be the total loss of output. In the severely affected areas farmers were not cultivating paddy at all, and the study estimates the loss of not cultivating paddy. In the severely affected irrigated area the value of productivity loss per acre was estimated to be Rs. 7,362 per year which in the unirrigated area it was Rs. 2,910 per acre. In the moderately affected area, the damage was worked out based on the difference between output of unaffected and moderately affected area of paddy i.e., Rs. 2,600 per acre in the irrigated area and Rs. 2,910 in the unirrigated area. The study assumes that a single crop per year is cultivated.

Using GIS the total cultivatable area in the pollution affected zone was estimated to be 1,46,389 acres, of which 36,139 acres (24.7 per cent) could be classified as injurious, 53,938 acres (36.8 per cent) as critical and 56,312 acres (38.5 per cent) as normal for cultivation. Table 4 provides the taluk wise area and productivity loss[8].

Table 4

ANNUAL NET VALUE OF PRODUCTIVITY LOSS (TALUK-WISE)

(Area Affected in acres and Productivity loss in Rs Million)

Sl. No	Name of Taluk	Moderately Affected				Severely Affected				Total
		Irrigated		Unirrigated		Irrigated		Unirrigated		
		Area	Loss	Area	Loss	Area	Loss	Area	Loss	
1	Tiruppur	6253	16.3	9380	36.9	7124	52.4	10685	31.1	**136.7**
2	Perundurai	6697	17.4	10045	39.5	5176	38.1	7764	22.6	**117.6**
3	Kangayam	8625	22.4	12938	50.9	2156	15.9	3234	09.4	**98.6**
	Total	**21575**	**56.1**	**3236.3**	**127.3**	**14456**	**106.4**	**21683**	**63.1**	**352.9**

Source: Madras School of Economics, 2002.

The total area was classified into irrigated and unirrigated in moderately and severely affected villages. In all taluks the loss in severely affected area was more than the moderately affected area. The annual total loss in agriculture sector is estimated to be Rs. 352.9 Million of which Rs. 136.7 Million was in Tiruppur taluk, Rs. 117.6 Million in Perundurai taluk and Rs. 98.6 Million in Kangayam taluk. The capitalized value of damage at 12 per cent was estimated to be Rs. 2345.4 Million in 2000 prices.

Domestic Water Supply Sector

The domestic water supply sector is also affected by the textile pollution from Tiruppur. Domestic water supply includes the potable (drinking and cooking) and non-potable (bathing, washing, flushing and gardening) use of water.

Loss to Tiruppur Municipality: Tiruppur municipality consists of an area of 27.20 km^2 and is divided into 52 wards. According to the 2001 Census the total population of Tiruppur was nearly 300,000. Besides, the floating population of Tiruppur is very high and is estimated to be around 200,000 in addition to the resident population. Several water

quality studies have shown that the available water resources in the city are not fit for domestic use. According to Jacob *et al* (1999), "*it is significant to note that the level for certain physio-chemical parameters like EC,TDS, Chloride, Sulphate Hardness, Sodium BOD, COD of the groundwater exceeded the permissible level prescribed by the Bureau of Indian standards and World Health Organisation standards for drinking water".*

Tiruppur city had relied largely on ground water to meet its domestic water requirement. But, especially after the growth of the textile industry more people have migrated into the city while deterioration of local water sources due to pollution has occured at the same time. Ultimately more stress was experienced on the available local source of water. At present Tiruppur Municipality receives 33 million litres per day (mld) of water from the Bhavani river (Tiruppur Municipality, 2001). But it is not sufficient for the growing domestic and industrial water requirement of the city. In its water supply report dated 12/1/2000, Tiruppur Muncipality made the following observation about the need for a third scheme "*the groundwater within Tiruppur town is highly polluted and unfit for drinking purpose. The supply through the existing two schemes is inadequate to meet the requirement. As such another scheme to cater to the need of the public is inevitable*". (Tiruppur Muncipality, 2000).

To estimate the magnitude of pollution impact on households in Tiruppur Muncipal area, a detailed primary survey was conducted with the assistance of the Centre for Environmental Education (2002), Tiruppur. Around 510 households living in 52 wards were surveyed. Following are the major findings of the survey: (a) The well water quality which was good before, has deteriorated mainly during the last 10 years. (b) Since the municipal water supply is insufficient to meet the household requirements, people are purchasing water. (c) The amount spent for the water purchasing varies from Rs 200 to Rs 600 per month per households. It is clear that the households are purchasing water since they cannot rely on local groundwater to supplement the public supply due to pollution.

Based on the survey results the loss of drinking water services for Tiruppur Municipality is estimated (Table 5). It is assumed that Tiruppur has a population of 0.3 million or roughly 60,000 households. Thus, the annual expenditure spent by the household for purchasing water is Rs. 119.0 Million and the capitalized value of this expenditure at 12 per cent is Rs. 991.5 Million in 2002 prices.

Table 5

LOSS OF DRINKING WATER SERVICES IN TIRUPPUR MUNCIPALITY

% of Households	Total No. of H.H.	Average Amount / Month (Rs.)	Total Amount Per Year (Rs. Million)	Capitalised Value (Rs. Million)
60	36,000	100	43.2	360
35	21,000	300	75.6	630
05	3,000	500	00.2	01.5
100	**60,000**	**-**	**119.0**	**991.5**

Source: Madras School of Economics, 2002

Loss of Drinking Water Services in Rural Areas: Apart from Tiruppur municipality, the drinking water supply in the villages located in and around Tiruppur and the downstream part of Noyyal are affected by textile pollution. For estimating the loss of drinking water services, the cost of drinking water schemes as well as the cost of collection of freshwater was studied. In villages, most of the water supply schemes are executed by Tamilnadu Water Supply and Drainage (TWAD) Board and then transferred to the local government for maintenance. Generally there are many reasons for the introduction of a water supply scheme:

population growth, urbanization, industrialization and pollution. The study showed that there is a good positive relationship between the water quality deterioration and cost incurred for water supply schemes in the villages affected by pollution.

So far the TWAD Board has spent Rs. 271.6 million for drinking water supply schemes in the villages, which are located in the stretch between Tiruppur and Orathapalayam. The loss of drinking water services due to pollution was estimated by computing the total cost spent by the Board for those habitations which have TDS values greater than 3000 mg/l. It was assumed that the Board had to provide alternative drinking water schemes to the villages primarily due to the impact of pollution on local drinking water sources i.e. the loss is the “replacement cost” in terms of drinking water schemes. The loss to the affected villages was estimated to be Rs. 21.4 million (Table 6).

Unfortunately the water supplied through the schemes is not sufficient for many of the affected villages. When the local sources were polluted, villagers were forced to bring drinking water from the neighbouring sources where there is no pollution. However, villagers have been using the locally available water for non-potable purposes. Based on the household survey information of pollution affected villages, the cost of collecting drinking water (opportunity cost) is estimated for all the households, who live in the pollution affected area. From the survey it is clear that in the affected area the households had to spend time for collecting water from more distant sources. The average quantities of water collected per household was 44 litres, for which they have to spend 1.20 hour per day, i.e., 36 hours, per month. For valuing the cost of water the total time spent for collecting water is multiplied with the rural average wage rate per hour for agriculture labourers (Rs. 9). So the monthly cost would come to Rs. 324 per household. The study also estimated 2,423 households were not having the drinking water in their premises in and around Tirupur and the downstream. The total annual cost for fetching water for all the textile pollution affected households was Rs. 9.4 million and the capitalized value at 12 per cent would be Rs. 78 million in 2000 prices.

Table 6

DRINKING WATER COSTS FOR AFFECTED VILLAGES

BLOCK	PANCHAYAT	HABITATION	SOURCE	TDS	No of House Holds	Total Population	Cost of DWS Scheme (Rs)
Tiruppur	Chettipalayam	Angeripalayam	BW	4347	1200	2550	1110000
Tiruppur	Chettipalayam	Avanashigoundenpm	BW	3297	460	950	1091000
Tiruppur	Mangalam	Agraharapudur	BW	4102	450	1199	1467000
Tiruppur	Mangalam	Pukkilipalayam	BW	5460	218	368	2640000
Tiruppur	Mangalam	Vettuvapalayam	BW	5803	596	640	307000
Tiruppur	Mannarai	Kanjampalayam	BW	4795	460	1333	948000
Tiruppur	Murugampalayam	Murugampalayam	BW	3220	922	1843	1550000
Tiruppur	Murugampalayam	Sundamedu	BW	3150	372	1700	1640000
Tiruppur	Neruperichal	Bommanaickenpm	BW	3059	295	400	670000
Tiruppur	Neruperichal	Nallathupalayam	BW	5271	215	245	1310000
Tiruppur	Thottipalayam	Bharathinagar	BW	3220	1204	1865	1135000
Tiruppur	Thottipalayam	Chinabomanaickenpm	BW	3367	563	700	681000
Tiruppur	Thottipalayam	Kethampalayam	BW	3850	570	2783	1625000
Tiruppur	Thottipalayam	Pitchampalayam	BW	3395	NA	NA	NA
Tiruppur	Veerapandi	Bharathinagar	BW	3640	NA	NA	NA
Tiruppur	Veerapandi	Kuppandampalayam	OW	4088	810	2186	2028000
Kangeya	Keeranur	Keeranur	BW	3381	150	450	965000
Tiruppur	Mangalam	Chinnapudur	BW	3710	262	941	1080000
Tiruppur	Mannarai	T.Mannarai	BW	4921	500	1384	1212000
Tiruppur	Murugampalayam	Annanagar	BW	5754	NA	NA	NA
							21459000

Source: Madras School of Economics.

In brief, the overall capitalized loss of ecosystem services in the domestic water supply sector would come to about Rs. 1100 million of which about Rs. 1000 million is in Tiruppur town and Rs. 100 million in the affected villages, both in the form of drinking water supply schemes as well as the cost of fetching water from distant sources.

Fisheries Sector

Like the agriculture and domestic water supply sectors, fisheries is also seriously affected by textile pollution. The impact on fisheries is mainly in the Noyyal river (between Tiruppur and Orathapalayam), system tanks (which are located near Tiruppur and downstream)[9] and in the Orathapalayam reservoir.

Loss of Fisheries in the Noyyal River and System Tanks: In the early years, when the river was free from pollution, local fishermen heavily depended on the river for fish. Different varieties of fish thrived at that time. But after the deterioration of the river water quality and ecology, the fish stock was reduced considerably and fish mortality became a common phenomena. Generally, available fishes are small in size with colours (due to the effect of dyes) and are not edible, and hence are used only for manure (Interview with Fishermen and Villagers, 2001). The fish diversity study revealed that the Tiruppur stretch of the Noyyal river (Zone III) did not support any fish species due to the discharge of industrial effluents. But seven varieties of fish species thrived after Orathapalayam.

The annual fish catch in the Noyyal river declined from 2,174 kg. (1994-95) to 540 kg. (1997–98) and the corresponding value reduction was Rs. 27,175 to Rs. 6,210 in current prices (Directorate of Fisheries, 2000a). The Fisheries activities in eight system tanks of the river (between Tiruppur to Orthapalayam) were highly affected (Map 2). The Panchayat used to auction the fish catch in five of the tanks which had high yield. The auction rate is reduced in all Panchayats and the total annual reduction between 1999-2000 was Rs. 257,000 in current prices.

Fisheries Loss in Orathapalayam Reservoir : Immediately after the completion of the reservoir, the Fisheries Department started fisheries activities at Orathapalayam reservoir in 1993. The fingerlings stock at Orthapalayam reservoir was 385,000 in 1993. But the stock was increased to 700,000 during 1993-94 and 801,000 in 1996-97 (Directorate of Fisheries, 2000b). But in subsequent years no stocking took place in the reservoir. Towards the end of 1997, mass fish mortality occurred at Orathapalayam reservoir. In early December, dead fish were floating near the dam site, which caused serious health hazards. Subsequently the District Collector made arrangements to bury the dead fish, which came to several tonnes. The Government also ordered the Fisheries Department to make immediate arrangements for removing all the fish in the reservoir to avoid further fish mortality and health hazards. The PWD also requested the Fisheries Department to stop the fisheries activities in Orathapalayam. Subsequently the Director of Fisheries ordered the Regional Fisheries Office at Erode to stop the fisheries at Orathapalayam on 12/3/1998. (Directorate of Fisheries, 2000c).

After realizing the pollution implication on Orthapalayam reservoir the Commissioner of Fisheries conducted a detailed study. The study was conducted by the Hydrology Research Station, Department of Fisheries, Chennai (1996). The salient findings were: (a) River is unfit for aquatic organisms. (b) Fish landing was observed downstream of Tiruppur and Orthapalayam reservoir – *Tilapia* is the main variety, but size is small. (c) Plankton pollution was observed in huge quantity in reservoir. (d) Bio-assay test conducted revealed that the fishes are bleached. (e) Fish growth rate will be affected. (f) Survival

of *Tilapia* may not be a problem, but present condition is unsuitable for the growth of other carps. (g) Fish caught from the reservoir get spoiled in a short period of two hours. Hence fish cannot be marketed to distant places. (h) High possibility of frequent fish mortality in future. The fisheries activities at Orathapalayam reservoir (which was started by State Fisheries Department with great expectation in 1993) was completely stopped and continuation is also highly doubtful.

Possible Toxicity in Fishes: At present even though the river, tanks and reservoir are completely affected by textile pollution, some informal fishing is still taking place in the water bodies and the fish caught is sold in the local and neighbouring markets. Generally the inland fishing is extremely important in this area since the possibility of getting sea fish (Bay of Bengal and Arabian Sea are quite far) is low. Even the fish that survive in the Orthapalayam reservoir may be of doubtful quality. According to Azeez, (2001) *"Many dyes commonly used are known to have serious health implications. Azo dyes, which were used widely are banned recently due to harmful properties including carcinogenesis. It is found that many species of fish survive in the Orthapalayam reservoir where all the chemical wastes from Tiruppur get collected. It is quite possible that the fishes accumulate these chemicals and are transferred to human beings while consuming fishes."*

Based on the fish catch data, the estimated overall annual productivity loss in fisheries sector as Rs. 1.5 million (in which Rs. 14,000 in Noyyal river, Rs. 258,000 in system tanks and Rs. 1.2 million in Orathapalayam reservoir). The capitalized value of the loss in fish catch was Rs. 12.5 million in current prices.

Economic Value of Loss of Ecosystem Services

Table 7 provides the aggregate annual as well as the capitalized value of loss of ecosystem services in agriculture, domestic water supply and fisheries.

Table 7

LOSS OF ECOSYSTEM SERVICES DUE TO POLLUTION (In Rs. Million)

S.No.	Sectors	Annual	Capitalized
1	Agriculture	352.9	2345.4
2	Domestic Water Supply	130.5	1090.3
	(a) Urban (Tiruppur Municipality)	*119.0*	*991.5*
	(b) Rural (Water Supply Scheme)	*2.1*	*21.4*
	(c) Rural Households	*9.4*	*78*
3	Fisheries	1.5	12.5
	Total	**484.9**	**3448.2**

Source: Madras School of Economics (2002).

The above table provides an estimate of the economic value of the loss of ecosystem services to different stakeholders (farmers, fishermen and households) due to textile industrial pollution. The focal group discussions and survey conducted in the pollution affected area reveals the livelihood impacts especially to the poor due to ecosystem degradation. Some of the villagers who live in the periphery of Tiruppur and even in the distant locations are getting employment opportunities in textile industries. But in the downstream pollution effected villages, who are also not benefited by industries, the loss the ecosystem services is a serious concern. The farmers in these areas have demanded compensation for the loss of ecosystem services, particularly agricultural productivity.

COMPENSATING THE LOSS OF ECOSYSTEM SERVICES AND RESTORING ECOSYSTEMS

Court Case by Down Stream Farmers Organisation

When the magnitude of textile pollution impact increased in the Noyyal river basin, a downstream farmers' organization (Karur Taluk Noyyal Canal Agriculturalist Association) filed a court case during 1996. The main respondents were the Industry Associations, Tamilnadu Pollution Control Board and the Public Works Department. The writ petitions clearly express the downstream farmers grievances against the bleaching and dyeing units at Tiruppur. The importance of Orathapalayam irrigation project, the continuous efforts by the farmers for more than thirty years for the sanctioning of the project and the current failure of the project due to the textile pollution are explained in the petition. According to the petitioner "at present the areas (Noyyal main canal Command at Karur), which were starved for water are now objecting to release of water from the dam for the reason that it is causing immense pollution in that area. The agriculturists felt that the water coming from the dam is very bad for the crops and the sludge which gets settled is toxic. Hence the entire investment for the Noyyal Orthapalayam Irrigation Project (Rs. 320 million) is a waste" (Kuppusamy, 1996). The petitioner prayed the court to issue an order directing the Pollution Control Board to take action against the pollution of bleaching and dyeing units at Tiruppur area.

Construction of Effluent Treatment Plants

The processing units in Tiruppur generate/discharge around 83 mld of effluents. The effluents carry considerable volume of chemicals used in different processing stages in the units. Due to the continuous discharge of effluents over a decade the magnitude of pollution has increased in the Noyyal River Basin, resulting in loss of ecosystem services. In 1991, the Tiruppur Dyers' Association formed a company, Tiruppur Effluent Treatment Company (P) Ltd and initiated certain attempts towards the construction of effluent treatment plants. Unfortunately, progress towards the effluent treatment programme was negligible till 1996. Subsequently in 1997, after the Order of the Supreme Court industries which did not have effluent treatment facilities had to close and the remaining units decided to construct effluent treatment plants. At present, the units are treating their effluents either through Individual Effluent Treatment Plants (IETPs) or Common Effluent Treatment Plants (CETPs).

Unfortunately the present treatment system is insufficient for reducing the total dissolved solids (TDS), particularly the chlorides and sulphates. The average TDS concentration in the treated effluents is more than 6000 mg/l in both IETPs and CETPs, which is far higher than the standard of 2100 mg/l. The same is true of chloride, which averages 3290 mg/l in IETPs and 3127 mg/l in CETPs whereas the standard is 1000 mg/l.

Formulation of Expert and Monitoring Committees

In response to the writ petition failed by the Noyyal River Ayacutars Protection Association on 2003, the Madras High Court constituted an Expert Committee on 5.5.2005 to go into the question formulated by the court. The major task for the six member committee is to suggest the action plan for remediation of Noyyal river and Orathapalayam reservoir and to inspect the Tiruppur industrial cluster

and suggest ways and means for preventing the discharge of polluted trade effluent directly or indirectly to the Noyyal river. At present industries have been instructed by the Expert Committee to install reverse osmosis (RO) plants for achieving zero discharge for protecting the ecosystem [10]. Since RO is difficult in IETPs, most of them are planning to connect to new CETPs. The first installment (token advance) towards installation of RO plant has provided by units to the concerned authority. Subsequently, the Madras High Court also formed a monitoring committee on 1.8.2005 basically to evaluate the progress in installation of RO plants by Tiruppur units and its efficiency in achieving zero discharge.

Loss of Ecology Authority

The Supreme Court of India in a landmark judgement in the Vellore Citizens Forum case held that the "Precautionary Principle" and the "Polluter Pays Principle" are part of the environmental law of the country. The court ordered the creation of a new agency, the Loss of Ecology (Prevention and Payments of Compensation) Authority for the State of Tamil Nadu to provide compensation to those affected by pollution from tanneries. The court upheld the Total Dissolved Solids (TDS) standard and ordered all industries the tanneries to comply with the standard. Subsequently, the court expanded the jurisdiction of the LEA to cover all industries.

The Loss of Ecology Authority (LEA) which is headed by a retired Judge of the Madras High Court has four members. The basic tasks of the LEA include:

- Estimating the monetary value of the ecological damage caused by industrial pollution (including reversing the damage/ restoration);
- Identifying the industries which have to pay compensation and fixing the amount for each industry;
- Identifying the farmers and the amount that they will receive as compensation.

In the case of the Noyyal River Basin, the LEA sought the assistance of the Centre for Environmental Studies, Anna University to assess the loss of ecosystem services in the areas affected by the industries in Tiruppur. The University carried out water quality studies and identified the list of villages affected by the effluents. Each of the villages was classified based upon a weighted average of electrical conductivity in the sample wells in the village. The University also calculated the monetary loss of agricultural productivity loss based on type of crop, average yield, and procurement price. The compensation to the farmer was calculated on the basis of the cropping pattern as well as the average level of pollution in that village. In the case of villages which had access to canal water from other irrigation projects, the compensation was fixed at a lower level.

The amount to be paid by each industry was calculated based on its product, production level and the level of pollution control. The industries were ordered to pay the compensation amount in instalments to the District Collector. The Collectors of the respective districts would distribute the compensation to the farmers as per the schedule provided by the LEA. The LEA awarded compensation of Rs.248 million for the period 2002-2004 to a total of 28,596 farmers located in 68 villages in

seven taluks in the Noyyal River Basin. The industries have challenged the award on various grounds, and the case is currently being heard in the Madras High Court.

The industries were asked by the Court to reverse the damaged ecology, namely the restoration of the Orathapalayam Dam. The Tiruppur Dyers Association have offered to pay for the desilting of the dam. The Public Works Department has estimated that the cleaning of the dam would cost Rs.100 million. The LEA has not required any additional compensation from the industries for reversing the damaged ecology, since the industries have made the commitment to the Court and have begun to make the payments for cleaning the dam. The Expert Committee and Monitoring Committee appointed by the Court are supervising the cleaning of the Orathapalayam Dam as well as ensuring that the industries to do not discharge any more effluents into the Noyyal.

EMERGING TRENDS

With rapid urbanization and industrialization, the disposal of liquid and solid wastes is a growing problem. Reuse of domestic wastewater for agriculture is possible if it is not contaminated by industrial waste and if other precautions are taken. However, when industrial effluents are discharged on land or water they not only pollute the environment but also affect the ecosystem services such as irrigation, drinking water and fisheries. These ecosystem services are related to rural livelihoods, particularly of the poor. Hence when the ecosystem services are affected by pollution, it would be equitable to compensate the losers.

The Supreme Court in its landmark judgement in the Vellore Citizens Forum case took the view that the tanneries must compensate the farmers whose livelihoods have been affected. A new agency, the Loss of Ecology Authority was constituted to decide on the amount to be paid as compensation. The same principle was adopted by the Authority in the textile case since the Court ruled that the Authority has jurisdiction over all industries in Tamil Nadu. The precedent set by the tannery case is likely to be followed by the judiciary in all States in India. Thus, payment of compensation for the loss of ecosystem services due to industrial pollution has become part of the settled environmental law of India. In fact, the judgement goes beyond compensation and requires the industry to restore the ecosystem to its earlier state. Clearly, these are serious disincentives and industries will be forced to be more careful about indiscriminately discharging effluents into land and water.

A major problem is the methodology for computing compensation. Industries have continuously challenged the awards made by the Loss of Ecology Authority on various technical and legal grounds. The cases drag on in the courts for several years before the compensation is actually paid. The legal experts have to work out a system that is fair and transparent and ensures that justice is provided speedily, particularly to the poor. The present system compensates only land owners, but not landless agricultural labourers who may lose their livelihood, unless they take up other occupations.

Another issue is the technology of pollution control. Given the problems with total dissolved solids, the Tamil Nadu Pollution Control Board has taken the position that industries like tanneries and textiles

will have to achieve zero discharge. Zero discharge will require expensive control technology like reverse osmosis and evaporator or nano-filtration. The advantage is that the water can be recycled. Hence, the economics of zero discharge may have to be worked out. The cost of control may become prohibitive and result in the closure of units that cannot afford the cost. It may be necessary for the Government to finance part of the costs of control particularly in the case of small industries. In India, common effluent treatment plants (which have a subsidy component) have been mooted as an option. But, CETPs have been plagued by management problems and very few of them are functioning efficiently in India.

Thus, the Noyyal case study provides a good example of the conflicts that arise when there is a loss of ecosystem services due to industrial pollution. These cases are becoming more common in India and possibly in other developing countries which are predominantly agricultural.

INADEQUACIES / AREAS FOR FURTHER RESEARCH

Damage assessment is a relatively new area of research in environmental / ecological economics. Different valuation methods may yield varying results, particularly with regard to “non-use values”. In this particular case study, some of the issues encountered were as follows:

- Could the level of TDS in the ground water be attributed to industrial pollution alone / or to natural causes?
- If farmers, use various coping mechanisms such as salt tolerant crops, is their livelihood affected? Farmers may also have other irrigation sources which are less polluted.

- The implementation of drinking water schemes may be unrelated to industrial pollution. The Water Supply Board may have used other criteria for their schemes.
- If farmers or agricultural labourers have given up agriculture and taken up work in the industrial sector where the wages are high, is their livelihood affected?
- Are there any health impacts due to contamination of drinking water and fish?

Some of these issues were raised with regard to our research results and some that the Loss of Ecology Authority had to wrestle with in awarding compensation. All these issues need to be considered in future research exercises on compensation for pollution damage. The methodology needs continuous refinement, since there are many gaps and uncertainties. This is particularly important when actual compensation has to be paid.

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END NOTES

1. Productivity loss refers to the monetary loss due to a reduction in agricultural productivity due to pollution of the irrigation source.

2. Replacement cost is the cost of providing an alternative source of drinking water since the local water source is affected by pollution.

3. Tanks are natural or excavated depressions where water collects during the monsoon season. Surplus from one tank often flows to the next tank in the chain. Water is released from the tank at the appropriate time for irrigation.

4. Ground Water Pollution studies carried out by Government Departments include Central Ground Water Board 1983, 1993, and 1999, Tamil Nadu Water Supply and Drainage Board 1999, 2001, and 1995-2001 and the Public Works Department 2002-03. Jayakumar *et al* 1978, Jacob 1998, Rajaguru and Subburam 2000, Senthilnathan and Azeez 1999, CES 1996, Azeez 2001, Ramasamy and Rajaguru 1991, Jacks *et al.* 1995, Furn 2004, and Berglund and Nina 2004 are studies by researchers and academic institutions.

5. Surface Water Pollution studies done by Government Departments include Public Works Department - Environmental Cell - 2001, Tamil Nadu Pollution Control Board 1997-99, Hydrology Research Station – Fisheries Department - 1995, Soil Testing Laboratory 2000-01, Central Water Commission 2000-01. Palanivel and Rajaguru 1999, Jacob 1998 are studies by researchers.

6. Electrical conductivity is a measure of the the Total Dissolved Solids (TDS). EC values in mmhos/cm can be converted to the TDS in mg/litre by multiplying by 640.

7. Following our study a government agency the Loss of Ecology Authority commissioned another study on the productivity loss in agriculture. Details are given in the next section.

8. In India, the administrative hierarchy consists of State, district, taluks, block, and village. In Table 4 Tiruppur taluk lies in Coimbatore, while Perundurai and Kangeyam are in Erode district (Map 3).

9. System tanks are irrigation tanks fed by the river (see Map 2) the effluent flows down the river into the tanks and pollutes the tanks causing damage to both agriculture and fisheries.

10. Reverse Osmosis is a membrane filtration system which is effective in removing the total dissolved solids. The main advantage of RO is that the final effluent is clean water which can be recycled. The rejects from the RO have to be put through an evaporator if zero discharge is to be achieved.