Chapter III

DESIGN OF THE STUDY

The methodology followed for the study is briefly described in this chapter. First the concepts used in the study are defined. It is followed by detail on sources of data, method of collection and tools of analysis.

CONCEPTS

Tannery

Tannery is an institution which processes the putrescible hides or skins into imputrescible leather. For understanding the functioning of tannery, it is essential to know the various states of tanning process.

Tanning process

The process of tanning usually takes nearly 40 to 45 days. However with mechanization the process is completed in about 20 to 25 days. Soaking, liming, dehairing, fleshing, deliming, scudding, tanning, myrobing, oiling and dressing are the important stages of tanning process.

Soaking

Green and wet salted hides or skins are washed in water to remove dirt and adhering salt. Dry salted and dry hides are soaked in water for a day or more until they become soft, before they are washed and cleaned.

Liming

The soaked hides are put in lime liquor for eight days. Daily they are hauled up and put back after stirring up the liquor. Some tanners use sodium Sulphide along with shell lime. Country lime is also used.
Dehairing

After eight days the hides are unhaired or dewooled. The hides are put over a sloping beam, and the workers use a sharp long handled knife to scrap off the hair with a firm downward stroke. Then the hides are soaked in lime water. These lime vats are called SALLAKUZHI. For two or three days the hides in these pits are turned every day till the lime water swells the pelt and makes it plump.

Fleshing

The fleshing is done on a similar beam with a shorter and heavy knife. After the fleshing is scrapped off, the hides are put in water for washing.

Deliming

The hides are dipped several times in water with a small amount of Sulphuric acid to remove lime. Swelling is reduced and scud, i.e., hair stumps loosened.

Scudding

This is a process to remove any trace of lime still sticking on in the pelt and to open out its pores to receive freely the tan liquor. The quality of skin will be spoilt, if some lime is allowed to remain in the skin.

Control drying

If the stock is dried in a controlled manner by maintaining optimum temperature and relative humidity, it may become an alternative method for salt curing. The first operation in leather processing in the tannery is soaking. The hides and skins are soaked in three changes of water in order to rehydrate it and to free it from dirt, dung and salt. Usually, the stock is used in the conventional system by using 30 - 40 per cent of common salt based on its weight. If the salted stock is taken directly for soaking, the waste water will contain nearly 80 - 90 per cent salt, which will create environmental problems
due to high salinity. On account of this, the chloride level in the soak liquor is of the order of 60,000 - 65,000 mg/litre. In order to reduce the pollution load in soak liquors, partial removal of salt prior to soaking is essential, and this is known as the desalting process.

**Desalting**

Conventionally, desalting is nothing but the removal of salt from the salted stock by gently beating the hide on a specially constructed masonry pillar of two feet height, with a curved surface on top to prevent mechanical damages. This conventional system is a labour oriented and time consuming process. Now the system has been mechanized by the Central Leather Research Institute (CLRI), which has designed a perforated drum to remove salt mechanically from the hides/skins. By drumming the salted goods in the specially designed drum, it is possible to remove up to 30 per cent of the total salt used. Mechanical desalting has long-term implications in preventing environmental degradation of groundwater and soil.

**Soaking after desalting**

Normally for soaking in the conventional system, three changes of water are given at 300 per cent per soak, causing large consumption of water. To reduce this counter current soaking system can be followed. By this method, the spent liquors of the second and third soak can be used for the initial soaking of the next batch of raw stock. Through this, it is possible to reduce 60 - 65 per cent water consumption in soaking operation. It is also found by adopting this system, there is no deterioration in the physical or functional properties of the resultant leather.

Another important step in clean technology is green fleshing. Green fleshing helps reduce the consumption of chemicals because it reduces the weight of the stock by 10 per cent. Apart from reduction in the consumption
of chemicals, green fleshing facilitates better penetration of chemicals in subsequent operations. Thus, by green fleshing, the consumption of chemicals gets reduced and thereby the load on the effluent also gets reduced.

**Liming**

Liming is done after soaking in the sequence of operations. In the conventional system, it is done by the hair destructive method, using sodium Sulphide and lime. The hair destructive method not only increases BOD/COD levels in the effluent but also interferes with the bacterial oxidation process. So, it is very important to adopt the hair saving process to reduce BOD/COD level in the effluent. Hair saving method can be followed by employing the dehairing enzyme alone or a combination of dehairing enzyme and sulphide or with sulphide and lime.

**Deliming**

Deliming is the process of treatment of the limed and fleshed goods with acid salts to remove the lime from the pelt. This is normally done by using either ammonium sulphate or ammonium chloride in the drum with sufficient quantity of water. Deliming with ammonium salts results in pollution problems because of the oxidation of ammonium contaminated waste-water into nitrates and nitrates through the activity of aerobic micro-organisms referred to as nitrifying bacteria.

In the ammonium form, it may be directly toxic to aquatic life. Nitrogen can seep through ground and contaminate the drinking water. Excessive concentration of nitrates in drinking water has been associated with public health problems. Nitrogen can exist in several forms in the aquatic environment. Transformation can occur from one form to another and since such transformations are biochemical in nature, the occurrence and the speed...
with which they occur are affected by a vast array of factors. All this makes the nitrogen cycle a complex one.

To avoid such problems, carbon dioxide deliming has been developed as a cleaner technology. It can be seen from Table 15.4 that there is a significant reduction of nitrogen compound in the effluent with carbon dioxide deliming.

**Tanning**

Avaram tree bark, Konam tree bark, wattle extract and wattle bark are used for tanning. The hides are laid up putting a thin layer of bark on each hide into the tan pits. The hides will remain for five of six days in tan pits and later they are again put in the tan pits. This is called second bark. The hides will remain in the pits for five or six days. In all these days, the hides are handled every day, laying back and sprinkling some bark on each side.

**Myrobing**

This is a process to prevent the reddening of the hides when dried out. The Myroblam are crushed and put into water. For two or three days, the hides are kept immersed in the pits. Again they are put in the Myroblam pits for two or three days. This is called second myrobing.

**Oiling**

The hides taken out of the Myroblam liquor are washed, and pungam oil is applied on the grain side. Later the oiled hides are hung up.

**Dressing**

This is a process to remove the wrinkles on the grain side. The dressed hides are again hung up for drying and then trimmed. The hides are tanned and are ready for marketing.
Techniques

Two techniques are used for tanning. They are (1) vegetable tanning and (2) chemical tanning.

Vegetable tanning

The most commonly use vegetable tans are bark. Quabracho wood, mangrove bark, pine bark, Myroblam and chestnut. Tanning process which uses the above tans for converting hides or skins into leather is called vegetable tanning. This is a primitive, vegetable based and labour intensive process, but is relatively less polluting.

Chemical tanning

Chemicals like chromium, aluminium, arsenic, cadmium, sodium chloride, sodium bicarbonate, sulphuric acid, fat liquor and dyes are used for tanning hides or skins, it is called chemical tanning or modern mechanical and chemical tanning process. Since chromium is used as the most important tanning agent by tanneries, chemical tanning is called as ‘chromium’ chrome tanning also. The chemicals causes pollution when discharges with effluent.

Effluent

Waste water discharged by the tanneries into the environment along with removed salt, chemicals, wattle extract, fat liquor and dye, and hair refers to effluent in the study. This causes pollution.

Pollution

Pollution meant introduction by man, directly or indirectly any hazardous waste into the environment as a result of which there arises many hazards to human health, plant or animal life, harm to living resources or ecosystems, damage to amenities or interference with other legitimate uses of the environment.
Water pollution

When chloride content of the water exceeds 200 mg/litre, the hardness of water exceeds the tolerance limit and it becomes unfit for drinking, domestic use and irrigation. This is described as water pollution in this study.

Soil pollution

The concentration of salt, chromium and other chemical above the permissible limit makes the soil unfit for cultivation by reducing the fertility of the soil and this is considered as pollution of soil.

Externality

The effluent discharged into the environment by tanneries imposes certain cost on the people living in and around the tannery concentrated area. These costs are considered as externality in this study.

Pollution damage cost

Pollution damage cost refers to the expenses incurred by inhabitants and employees of tanneries to overcome the problems caused by pollution impact of tanneries on water, soil, other properties and themselves.

Damage cost on drinking water

Cost on drinking water includes the pollution damage cost relating to cost incurred by inhabitants and tannery employees. It includes the extra amount spent by them to acquire water for domestic use from far off places as the locally available water is unfit for use. This cost has to be incurred by them, as the wells hitherto supplying domestic water have been polluted by tannery effluent discharge.
**Damage cost on agriculture**

The other cost incurred by inhabitants is the amount of income they have lost due to pollution of soil and irrigable water due to discharge of effluent into open lands. This affects the fertility of the soil and reduces land productivity. Fertile lands became barren. They have to spend a lot of money to rejuvenate the soil and to get irrigable water. This cost is too high for the farmers to bear or uneconomical. So they sell the lands to tannery owner and migrate to other places seeking employment. As it is difficult to assess the loss of income to the farmers, this type of cost is estimated in terms of reduction of land under cultivation and disappearance of crops produced. In both cases the value of land sold to tannery and the value of crops lost are taken into account.

**Damage cost on property and Material goods**

Polluted soil water and air in the surroundings of the tanneries cause damage to the walls and roof of the residential and other buildings. The value of this damage is a cost of pollution. It is difficult to estimate directly. However it is possible to estimate this cost indirectly, at least approximately, by the amount spent by the inhabitants in maintenance and upkeep of the property over what is considered normal (in unpolluted area).

**Damage cost on health**

Living in polluted land and using polluted water causes health hazards to the inhabitants. In the case of employees in tanneries this is very high because they handle chemicals by their bare hands. The health hazards are the diseases that affected them. Dysentery, headache, stomach disorder, fever, skin diseases and deformation are some of the diseases which affect them. They have to spend on medical treatment. The health damage cost is thus estimated by taking into account the cost incurred by them for their medical treatment of pollution related diseases. This includes the bus fare from home
to hospital and back-home, the consultation fees, operation fees, the cost of medicine and the cost of taking X-ray, scan etc. It further includes the loss of earnings due to man-days of work lost, evaluated at the average wage per day of normal work. The man-days of work lost are the result of health hazards caused by tanneries. This cost is equated to the daily wage earned by the person affected by a disease and compensation if any paid by the employer for this health damage that amount is deducted from the total health damage cost.

**Pollution control**

In this study pollution control refers to the measures undertaken to control pollution by tanneries Government and affected people in tannery concentrated area. Tannery has to treat the effluent before discharging it into open land. Solar pond system is to be adopted to store the effluent water in tannery site itself. This may be leading to ground water pollution. So each tannery has to install an effluent treatment plant. Over production must be controlled in order to keep the level of effluent standard fixed by the government. Less number of chemicals is to be used in reducing the toxicity of effluent. First air facility is another measure by which the affected worker could be given immediate treatment to reduce the intensity of health hazard. ESI hospital is functioning in Sempettu to help the affected people. Gloves and boots are to be provided to tannery workers to control skin diseases. These are the measures to be taken by tanneries to control pollution.

Treatment of tannery wastewaters is always required. Some streams, such as soaking liquor (which has high salinity), sulphide-rich lime, liquor, and chrome wastewaters should be segregated. Spent pickle liquors from the pickling process can be recycled into the pickling process or reused in the tanning process in order to reduce the amount of salt and effluent discharged
to sewers. Another technique to reduce the amount of salt and effluent is the use of a short pickle float. Some processes use an average pickling float of about 100 per cent; this can be reduced to 50-60 per cent, which means that the use of 0.5 - 0.6 m³ of water per tonne of fleshed pelt is achievable.

It is common practice to keep sulphide containing effluent from the beam house separate and at a high pH until the sulphide is treated, because at a pH lower than 9.0 the formation of toxic hydrogen sulphide gas can occur. The sulphide in the deliming and pickle liquors can easily be oxidized in the drum by adding hydrogen peroxide, sodium metabisulphite, or sodium bisulphate. The associated emission level after treatment of sulphide is 2 mg/L in a random sample in the separate effluent. Where segregation of sulphide bearing liquors is not possible, the sulphide are generally removed by means of precipitation with iron (II) salt aeration. A disadvantage of this precipitation is the generation of high volumes of sludge. Usually, the first treatment of the raw effluent is the mechanical treatment that includes screening to remove coarse material. Preliminary screening of wastewaters is required because of the large quantities of solids present. Recovery of hair from the dehairing and liming process reduces the BOD of the process effluent. Up to 30 - 40 per cent of gross suspended solids in the raw waste stream can be removed by properly designed screens. Mechanical treatment may also include skimming of fats, grease, oils, and gravity settling. After mechanical treatment, physico-chemical treatment is usually carried out, which involves the chrome precipitation and sulphide treatment described above. Coagulation and flocculation are also part of this treatment to remove a substantial percentage of the COD and suspended solids. Physical-chemical treatment precipitates metals and removes a large potion of solids, BOD, and COD. Biological treatment is usually required to reduce the remaining organic loads to
acceptable levels (0.3 kg BOD, 2 kg COD, and 0.004 kg chromium per metric ton of raw hide).

Post-purification sedimentation and sludge handling are the last steps in wastewater treatment. With sedimentation, the sludge in the wastewater treatment plant is separated from the water phase by gravity settlement. After dewatering this sludge by means of filter presses, a sludge cake with up to 40 per cent dry solids can be achieved, whereas belt presses produce a sludge cake with up to 20 - 25 per cent dry solids. Centrifuges achieve up to 25 - 45 per cent dry solids and thermal treatment, up to 90 per cent dry solids.\textsuperscript{106}

**STUDY AREA**

Tiruchirappalli City Corporation in Tamilnadu constituted the universe for the study. Selection was purposive for several reasons.

The most important reason was that the problem of tannery pollution was very severe in the Sempet area and there was a felt need among the public to study the extent of damage to men, animals, crops and the natural resources and to find remedial measures.

Secondly, next to tanneries are concentrated in Sempet, Tiruchirappalli city corporation of Tamilnadu and pollution by tannery was severe. Moreover, it was nearer to the researcher and it could be easily reached within four hours by public transport.

Thirdly, the department of agriculture, animal husbandry and public health and their officials working in the Tiruchirappalli city corporation - Tamilnadu offered to cooperate with the researcher in the collection of

required data, besides supplying the information available with themselves. All the government departments in the Tiruchirappalli city corporation were contacted to collect the secondary data.

**Sampling procedure**

The department of agriculture, animal husbandry, soil science, pollution control, health, tanneries, tanner’s association in Sempet and social welfare were the major source of secondary data, besides the city corporation of Tiruchirappalli and statistical office.

Since tanneries are less in number, total number of tanneries are considered in Sempet as per report of 2005 and 2006, total number of tanneries are 14. Formerly there were 18 tanneries in 2001-2002. 4 tanneries have been closed due to want of effluent treatment plant. So at present only 14 tanneries are functioning in Sempet. So, 14 tanneries are taken into account for this analysis Among them 6 tanneries are found in eastern side of Pudukkottai road and 8 are found in western side of Pudukkottai road. Therefore western side of tanneries in Pudukkottai road is group I tanneries and eastern side tanneries in Pudukkottai road is group II tanneries based on place of concentration.

All tanneries were personally visited and the area damaged by tannery pollution was personally evaluated. The general observation was that the degree of pollution and the intensity of damage caused by it decreased as the distance from the tannery increased. It was measured by the toxicity of pollutants in tannery effluent discharged into the environment. To study the differences in the level of toxicity the area surrounding the tannery group unit was divided into three zones. First zone comprised the area within 2 km radius around the factory. Second zone included areas in the radial distance from 2 km to 4 km and the area beyond 4 km was included in the third zone. The
third zone, therefore, served as a control to measure spatial differences in pollution and damage caused by it. So there were three zones to measure the extent and types of pollution.

Considering the resource constraints of an individual researcher, who had to work unemployed full-time and who had to personally enquire the sample workers and households respondents because of the nature of questions to be asked and the cross-checks necessary to minimize bias in reporting, the sample size was fixed as 184 households for group I and 138 household for group II tanneries. Therefore the ultimate sample consisted of 322 households. The sample was distributed among the zones as 64, 60 and 60 for zones 1 through 3 respectively. Group II tanneries at the rate of 58, 40 and 40 zone 1, zone 2 and zone 3 respectively. Required numbers of households in each zone were selected by simple random sampling method. The random selection allowed representation of all section of population. Therefore, around eighty per cent of the sample households were farm households and the rest included artisans, unskilled labourers, traders and other professionals.

Out of the 548 unskilled (permanent and temporary) workers of the Tanneries 140 workers were also selected from two groups of units of tannery based on simple random sampling method in order to analyse occupation related diseases of the tannery worker.

**Period of study**

Primary data were collected in the second half of 2006 for the two years: 2005-2006. Secondary data were available only for five years 2000-2001 to 2005-2006. Available data were collected.
Collection of data

Specifically designed pretested and comprehensive questionnaires were utilized to collect the requisite data from the sample households by personal interview method the following information were obtained from the head of the sample households.

Size and composition of the family. Years of continuous living in the area and property particulars. Educational and employment status of members of the family. Number of days working per month. Monthly income and expenditure particulars. Diseases, deaths, and medical expenditure particulars. Agricultural yields, lands, quality and their values. Number, yields, diseases, death and treatment particulars of livestock. Awareness of pollution and its impact on their properties. Willingness to join anti-pollution movement and to bear the cost of pollution control and their grievances.

To collect data from tanneries another questionnaire was used. The information collected from all the tanneries included year of establishment of tanneries, years of working. Number of persons employed. Capital structure and financial status of tanneries. Items of leather and amount of leather produced. Quantity of effluent discharged and method and mode of discharge and pollution control methods adopted and its cost.

Though the results of the study related mainly on the primary data collected on the above aspects from the sample respondent and groups of tannery units. Secondary data relating to human and animal health and unit-wise agricultural yields were collected from primary health centers, animal husbandry units and agricultural department offices respectively.
At the city corporation level, the district environmental engineer of the Tamil Nadu pollution control board, Madras, was furnished information on tannery effluent pollution and the quality of the environment (water, land and soil) in the vicinity of the areas of study, specified standards, measures taken and investment made by tanneries on pollution prevention and other aspects.

The office of the joint director of agriculture, the city corporation statistical, health and animal husbandry offices and the district industries centres were also contacted for information on crop yields and other related particulars of the study.

**Analysis**

Collected data were analysed with respect to each of the objectives in measuring the degree of pollution and intensity of damage, a inter-zone comparative analysis was useful, especially by treating zone-III as control.

For this purpose extensive tabular analysis and a few simple correlation analyses were sufficient the focus of the analysis was to relate primary data to the information supplied by the secondary sources and to draw specific inferences, either rejecting or accepting the hypothesis and interpreting a few case of inconclusive results, mainly for want of adequate data.

An aggregative analysis by pooling the data from all the tanneries was done to determine equilibrium levels of investment (expenditure) in countering such as curing diseases of reducing damages caused by pollution and in preventing/reducing the level of pollution. The two types of investments were called costs due to environmental damage and cost of environmental management.
Internalizing externalities

Operationally of the concept of internalizing the externality requires first estimation of the costs of environmental damage and the environmental management and then their inclusion in the production and consumption decisions. For the purpose the environmental costs incurred by a society due to pollution are the total of the environmental damage costs (or pollution cost) and the environmental management costs (or pollution control cost). The former is a cost of decline in environmental quality incurred by not preventing wastes from causing damages to the environment. While the letter refers to the expenses incurred by the tannery and the public bodies to prevent some of the damaging or noxious effects of wastes (like treating the effluent).

If the overall objectives of the society are to minimize total environmental protection cost given the amount of pollution, a correct balance between expenditure on preventing pollution (expenditure to avoid damage by pollution) and are suffering due to the welfare damage of pollution can be attained by the use of a simple model based on Nijkamp.\(^{107}\)

**Damage cost**

If the environmental quality is denoted by \( z \) and the amount of environmental damage costs by \( C_D \). The following cost functions may be assumed. So that optimizing conditions may be satisfied.

**Management cost**

Similarly, the environmental management \( C_M \) can be raised to environmental quality as

\[
1. \quad C_D = f(z) \quad \text{with} \quad \frac{\partial CD}{\partial Z} < 0 \quad \frac{\partial^2 C}{\partial^2 Z} \geq 0
\]

2. \[ C_M = f(Z) \quad \frac{\partial CM}{\partial Z} > 0, \quad \frac{2}{\partial Z^2} > : \]

Implying a positive relationship between \( C_M \) and \( Z \). If the overall objective is to minimize total cost \( C \).

3. \[ C = C_D + C_M \]

Then the optimal level of environmental quality can be calculated by the first order derivatives.

4. \[ \frac{\partial C}{\partial Z} = \frac{\partial C_D}{\partial Z} + \frac{M \partial C}{\partial Z} 0 \]

Which implies that at the optimum level, marginal environmental damage cost equal marginal environmental management cost.

Empirical application of this model involves two steps. First identifying the cost components of the total environmental costs in terms of more disaggregated variables and the quantification and measurement of the costs and second, the specification of functional form for (3). An estimation of environmental damage costs requires a detailed insight into the various effects of environmental deterioration. A manageable and systematic way of assessing and quantifying all these effects is the use of environmental impact analysis which has two phases like, (i) assess the purely technical-physical effects and (ii) the economic evaluation of these effects.

For the study area the following elements are included in the environmental damage cost.

i. Damage to residential property

ii. Damage to agricultural production
iii. Damage to quality of land and water
iv. Damage to animal production
v. Damage to human health

Components of environmental management cost ($C_M$) are

i. Depreciation cost of pollution control devices, their maintenance costs including an interest on the working capital for the maintenance.
ii. Expenses for welfare contribution, that is social security obligation.
iii. Cost of amelioration of damaged (cultivable) land.
iv. Medical care expenses on animals and
v. Health care expenses of Households.

Pollution from tannery is the fallout from leather production which contributed income, employment and other benefits to the area of its location. The main benefits are following (a) Net income generation (b) Net monetary value of employment generation and (c) other benefits.

**Environmental management cost**

In addition to environmental damage costs, one has to distinguish the environmental management cost ($m$) given large scale degradation of environmental quality in areas surrounding tanneries and the large scale depreciation of environmental capital. It is reasonable to see that environmental management was assuming political importance. Environmental management associated with pollution was oriented to pollution abatement and pollution prevention. The “Polluter pays” principal is generally accepted as a cornerstone of environmental management in many countries. This implied that the polluter has to bear the cost associated with pollution. In this context the administrative system of environmental
management are possible, viz. (i) system of prevention and physical regulation and (ii) a system of levies and charges in terms of social costs. A system of levies was considered to be more efficient, whereas a system of physical regulation was considered to be more effective in terms of environmental quality. In practice environmental management is based on a compromise of these policies. An estimate of costs of environmental management is based on a compromise of these policies. Estimates of costs of environmental management are difficult not only due to the problems in conceptualization and valuation, but also due to the unwillingness and non-co-operation of the tanneries to provide necessary data.

With much persuasion and efforts, the cost of environmental management was assessed. It was simply defined as the value of all efforts and investments put into prevent or to minimize pollution. It included (i) the cost of depreciation of equipments and structures (constructions) installed and used for pollution control and their annual maintenance cost including interest on working capital for maintenance (ii) social security payments and expenses by ways of construction for welfare measures (iii) cost of land reclamation (iv) costs of medical care for animals and (v) cost of health care for human beings. While (i) and (ii) were assessed from the tanneries, and the other costs were assessed from the primary data collected from sample respondents. Sample average costs were used to estimate aggregate costs for the area covered by the polluting tanneries.

**Benefits**

But there were some benefits also from the tanneries to the area covered by pollution. These benefits came in the form of employment and income provided to the local people from leather production. They included good road, transport and communication, marketing and recreational facilities.
These benefits were assessed net of the costs incurred maintaining them. Aggregates of these benefits had to be subtracted from the aggregate environmental management costs discussed above to get Net Social Costs (NSC) of environmental management. The problems in conceptualization and valuation of the benefits have persisted in the process.

Thus there were five elements in damage costs and they had to be set off against three elements of benefits (a, b, c) to arrive at net value of damage cost ($C_D$).

On the other hand, there were five elements in environmental management costs ($C_M$). After estimating monetary values of all the 14 elements (6+3) in net damage cost and five in environmental management costs. Next step was to relate this to the degree of pollution and in turn to the environmental quality. The environmental quality would be entirely lost as the degree of pollution increased; while larger the pollution higher would be cost of damage. Thus the reciprocal of the degree of pollution would be a measure of environmental quality, from the point of view of pollution related damages. Thus $1/p$ was the measure of environmental quality for the study.

As production increased pollution also increased bringing with it increasing cost of pollution control (Management cost $C_M$). Therefore $C_M$ and degree of pollution would be negatively related, while $C_M$ and $Z$ would be positively related. This relationship was studied in two stages. First, $C_M$ was related to the level of tannery pollution i.e., $C_M = f(q)$ secondly log-log function were specified and estimated.

**Functional analysis**

It was possible to assess different levels of environmental pollution for spatially distributed observations points and the costs ($C_D$ and $C_M$) associated with them. The application of (4) to find the equilibrium conditions required
specification of functional forms for (1) and (2). The scatter diagram for $C_D$ and $C_M$ with $z$ suggested a double log liner function more specifically the functional form specified for two function, i.e., (1) and (2) were the following.

5) $C_D = \alpha Z^\beta$

And

6) $C_M = r Z^\Sigma$

Clearly $B$ and $\Sigma$ are the cost elasticities of $C_D$ and $C_M$ with respect to $z$. Thus the marginality rule of (4) implies.

7) $-\beta \alpha Z^{\beta-1} + \sum rZ^{\Sigma-1} = 0$

8) $\beta \frac{C_D}{Z} = \sum \frac{MC_i}{i}$

9) $\frac{C_D}{C} = \frac{\Sigma}{B}$

Thus the equilibrium level of $C_D$ and $C_M$ equals the inverse ratio of their respective cost elasticities. It implies that at equilibrium point, a rise (fall) in environmental damage costs is precisely compensated by a fall (rise) in environmental management costs.

**The Equilibrium**

The several ways exist to arrive at equilibrium point. One is the regulation of pollution to reduce discharge below a certain standard level. An alternative is to levy a pollution charge equal to the marginal waste disposal costs. The internalization uses the traditional mechanism, but the effectiveness is limited. A subsidization policy with regard to abatement investments is another option but it has no stimuli to polluters to reduce their waste discharges. A combination of all of them might be useful.