CHAPTER IV
DESIGN OF THE STUDY

Studies on pollution and consequent environmental degradation are difficult because the required data are difficult to get. The problem gets more complex when, as in the present study, the objective is to study the economics of pollution including the impact of pollution on social welfare. Externalities associated with pollution make the exercise more difficult. Not only the problem of inadequate and often inaccurate data must be tackled, but also the problems of conceptualization, quantification and measurement of variables. Therefore, the methodology adopted for the present study involved use of both secondary and primary data and the latter had to be collected with care to avoid exaggeration of damages and their costs, by the respondents. In this chapter, the methodology of collection, processing and analysis of data, a brief description of theoretical underpinning and the model used to estimate cost elasticity of environmental management are presented.
4.1 Data Collection

4.1a Choice of the Study Area

Tiruchirapalli district constituted the universe for the study. Its selection was purposive for several reasons:

(i) Firstly, it was easily accessible for the researcher, as the area was the home district of the researcher and each of these centres could be reached within four hours by public transport.

(ii) Secondly, and the most important reason was that the problem of cement pollution was very severe in the district 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.

(iii) Thirdly, the Departments of Agriculture, Animal Husbandry and Public Health and their officials working in the district offered to cooperate with the researcher in the collection required data, besides supplying the information available with themselves. All the Government Departments in the district were contacted to collect the secondary data.

4.1b Sampling Procedure

The Departments of Agriculture, Animal Husbandry, Social Science, Pollution Control, Health, Industries and Social Welfare were the major sources of secondary data, besides the District Statistical Officer. The Managements of the cement factories were another important source of secondary data.
In the District, there were three major cement factories and all the three were selected. The areas surrounding each factory was treated as a unit. Thus, there were three units: Unit I, Unit II and Unit III. Of them, one was a Government Factory, and the other two were private companies. Selected cement factories were personally visited and the area damaged by cement pollution was personally examined. The general conclusion was that the degree of pollution and the intensity of damage caused by it, decreased as the distance from the factory increased; and it was found that pollution was below the safe level (as measured by the density of pollutant particulates in the atmosphere) at a distance of 2 km and beyond. Therefore, the area surrounding the sample factories was divided into three zones. First Zone comprised the area upto one km radius around the factory. Second zone included areas in the radial distance of one to two km and the area beyond 2 km was included in the third zone. The Third Zone served, therefore, as a control to measure spatial difference in pollution and damage caused by it. However, there was an exception: Around the Zone 3 there were quarries that supplied raw materials to the cement factories and they were the sources of another type of pollution caused by the cement producing units. Therefore, quarries and their proximities were treated as Zone 4. These four zones were marked for each of three factories.

Considering the resource constraints of an individual researcher, who had to work part time and who had to personally
FIG II DEMARKATION OF STUDY ZONES

ZONE: 1
ZONE: 2
ZONE: 3
ZONE: 4
QUARRIES
FACTORY CAMPUS
enquire the sample 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 100 households for each factory and 10 for each quarry. Therefore, the ultimate sample consisted of 330 households. This sample was distributed among the zones as 40, 30, 30 and 10 for zones 1 through 4 respectively for each factory. Required number of households in each zone was selected by simple random sampling method, with the help of voters' list for listing all households zone-wise. This random selection allowed representation of all sections of the population. Therefore, around seventy per cent of the sample households were farm households and the rest included artisans, unskilled labourers, traders and other professionals. The location of the factories and demarkation of zones are shown in Fig. 2.

4.1c Period of Study

A good time series would require data for over 10 years. But due to the resource and other constraints and also on account of non-availability of data, the researcher had to be contended with data for a two-year period only. Primary data were collected by personal survey method. Data related to two years viz., 1985-86 and 1986-87 were collected within a period of six months ending in December 1987.
4.1d Collection of Data

Specifically designed, pre-tested and comprehensive questionnaires were utilised to collect the requisite data from the sample households by personal interview method. The following information was obtained from the heads of the sample households.

i) Size and composition of the family

ii) Years of continuous living in the area and property particulars

iii) Educational and employment status of members of the family

iv) Number of days working per month

v) Monthly income and expenditure particulars

vi) Diseases, deaths, medical expenditure and aids particulars

vii) Agricultural yields, lands' quality and their values

viii) Number, yield, disease, death and treatment particulars of livestock

ix) Awareness of pollution and its impact on their properties

x) Willingness to join anti-pollution movement and to bear the cost of pollution control and other grievances

The data were collected through questionnaires prepared for the purpose.

The three cement factories were contacted to furnish information on the following aspects:
i) Investment and employment particulars

ii) Annual production, income and expenditure

iii) Specific investment on pollution prevention equipments, their maintenance costs and depreciation

iv) Expenditure on labour and social welfare aspects

Though the results of the study relied mainly on the primary data collected on the above aspects from the sample respondents and cement units, secondary data relating to human and animal healths and agricultural yields, unit-wise were collected from Primary Health Centres, Animal Husbandry Units and Agricultural Department Offices.

At the district level, the district Environmental Engineer of the Tamil Nadu Pollution Control Board, Madras, was requested to furnish information on the cement particulate emissions and air quality in the vicinity of the areas of study, specified standards, measures taken and investments made by cement factories on pollution prevention and other aspects.

The office of the Regional Joint Director of Agriculture, the District Statistical, Health and Animal Husbandry offices and the District Industries Centre were also contacted to gather information on crop yields and other related particulars of the study.
4.2 Method of Analysis

4.2a Conventional Analysis

Collected data were analysed with respect to each of the objectives. In measuring the degree of pollution and intensity of damage, an inter-zone comparative analysis was useful, especially by treating Zone 3 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 hypotheses and anticipating a few cases of inconclusive results, mainly for want of adequate data.

An aggregate analysis by pooling the data from all the factories was done to determine equilibrium levels of investment (expenditure) in countering—such as curing diseases or 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 costs of environmental management. These concepts, their theoretical support and the empirical model specified and estimated for the purpose are described in the next section.

4.2b The Model

Pollution. Practically all human economic activities do effect considerable changes in their environment; but many of these changes
are of a disrupting nature. The continuing economic progress, as well as the technological innovations involved in it, have increasingly led to considerable environmental deterioration. This is the negative effect of the rise in material welfare and needs to be recognised and checked. Therefore, environmental quality analysis is now becoming a necessity.

From an economic point of view, man's environment can be defined as the totality of external, natural, physical and residential conditions which affect man directly and indirectly, and which are in turn influenced by economic decisions and technological developments.¹

The environment has a large but finite capacity to provide natural resources for human activities and to absorb waste materials. Each production or consumption activity constitutes a chain in the spatial dispersion of material products and hence of waste residuals. When these residuals exceed the waste assimilative capacity of the environment, it is a source of potential damage to the environment-pollution.

Pollution is generally considered an undesirable change in the physical, chemical or biological characteristics of air, land and water and it may harmfully affect human life or that of desirable species of organisms, living and working conditions or cultural assets. This description is too broad to allow objective assessment of pollution and its impacts at a reasonable cost any way.

¹Freeman et al., Economics of Environmental Policy.
**Externality.** Clearly residuals can be named pollutants on the basis of a certain ideal or reference structure of ecosystems. Generally, pollution is considered to be relevant only if it has consequences for human welfare. Therefore, the problems of evaluating environmental degradation and externalities arises, when residuals assume the proportion of being pollutants. Given, the environmental impacts of certain activities, the crucial question is, How to evaluate these effects? First, it is necessary to recognise that all these effects cannot be measured in monetary units, but some can be measured. Therefore, methods must be devised to evaluate both monetary and non-monetary impacts.

Impact on commodities which have market value, houses for instance, can be measured by the difference in the market value of the commodities affected, and comparable units of those commodities not affected. Some traditional methods in this field are cost-benefit analysis and cost-effectiveness analysis. But in both methods, the problem of externalities has a bearing on defining the costs. According to Scitovzky, there are two types of externalities. First type is called technological external economies and the second type is called pecuniary external effects due to interdependence among producers through the market mechanism. But many more environmental factors are observed in the modern problems of assessing environmental effects. Collectively that may be called Environmental External Effects (EEE). They are

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non-market effects which result as side effects of economic activities of producers and consumers, and which also affect the welfare or profit conditions of other households through spillovers via man's surroundings. Some examples of such externalities are water pollution from a factory discharging its waste into a nearby stream; tannery effluents affecting fertility of cultivable land, air pollution from chemical plants and pollution from cement factories—all of which affect air, soil, water, crops, livestock and human beings. This brings to focus the problem and concern with the possibilities of solving or internalizing them. It has already found wide acceptance among Economists that the concept of externalities is a meaningful expedient to come to grips with environmental problems. However, a basic problem is the frequent lack of operationality of the externality approach.

**Internalising externalities.** Operationality of the concept of internalising the externality requires first estimation of the costs of environmental damage and of 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 costs) and the environmental management costs (or pollution control costs). The former is the cost of a decline in environmental quality incurred by not preventing wastes from causing damages to the environment, while the latter refers to the expenses incurred by the factory, and the public bodies to
prevent some of the damaging or noxious effects of wastes (like filters of smoke fitted to chimneys).

If the overall objective of the society is to minimise total environmental protection cost, given the amount of pollution, a correct balance between expenditure on preventing pollution (expenditure to avoid damage by pollution) and of suffering due to the welfare damage of pollution can be attained by the use of a simple model based on Nijkamp. ³

Damage costs. If the environmental quality is denoted by Z and the amount of environmental damage costs by $C_D$, the following cost function may be assumed.

\[ C_D = f(Z) \text{ with } \frac{\partial C_D}{\partial Z} < 0, \quad \frac{\partial^2 C_D}{\partial Z^2} > 0, \]

so that optimizing conditions may be satisfied.

Management costs. Similarly, the environmental management costs $C_M$ can be related to environmental quality as

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

implying a positive relationship between $C_M$ and Z. If the overall objective is to minimize total cost $C$:

\[ C = C_D + C_M \]

Then the optimal level of environmental quality can be calculated by the first order derivative:

\[ \frac{\partial C}{\partial Z} = \frac{\partial C_D}{\partial Z} + \frac{\partial C_M}{\partial Z} = 0 , \]

which implies that at the optimum level, marginal environmental damage costs equal marginal environmental management costs.

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 those effects is the use of environmental impact analysis, which has two phases viz.,

(i) the purely technical-physical effects and
(ii) the economic evaluation of these effects.

To elaborate, the pollution vector \( P \) associated with a certain production vector \( q \) can be represented by means of the following impact function:

\[ P = f(q) . \]
These data may be available with cement factories, because they have a mandate to check pollution within a 'safe limit'. Given the location of the factory and the direction and velocity of wind in the locality, there is a difference in the spatial concentration of pollution; closer to the factory higher being the concentration. This spatial concentration might be represented by a dispersion function:

\[ d = h(P). \]

The vector of physical environmental effects 'e', accruing from the pollution level 'P' will vary by the distance of the location from the factory. It can be represented by an effect function 'g' which relates the intensity of pollution (at different localities) to the physical effect (damage) caused by it. Then,

\[ e = g(d). \]

Now substituting (5) and (6) into (7), it can be written that

\[ e = g |h \{f(q)\}|, \]

which is essentially a stimulus-effect representation of a set of consequences (damages to be specified) to various environmental objects, accruing from pollution of a cement factory.
Monetary weights. The above relationships are purely of a technical nature; they have to be studied for their economic implications. It is the second and important step of economic evaluation. It raises the question: how to gauge the environmental impacts of pollution in economic terms? In other words, what monetary weights $r$ have to be assigned to the effect vector $e'$? The answer to this question would imply that the total economic value $m$ of environmental impacts would be equal to:

\[(9) \quad m = re = rg|h(f(q))|\]

Obviously $m$ is the aggregated unidimensional value of multi-dimensional physical effects of environmental goods. Equation (9) implies that all different physical consequences of environmental pollution measured in different dimensions were brought into relation with the measuring rod of money. Therefore, Eq. (9) could be used to estimate the total costs of environmental deterioration. Details of estimation of monetary values of each of the components of the environmental impact value $m$ are presented below.

The damage costs of environmental pollution might relate to various objects affected, and which constituted the vector $q$.

For the study area, the following elements are included in the environmental damage costs ($C_D$):
i) damage to residential properties
ii) damage to agricultural production
iii) damage to quality of land and water
iv) damage to animal production
v) damage to human health
vi) damage to socio-psychological wellbeing.

Components of environmental management costs ($C_m$) are:

i) Depreciation cost of pollution control devices, their maintenance cost including an interest on the working capital for the maintenance;

ii) expenses for welfare contributions, i.e., social security obligations;

iii) cost of amelioration of damaged (cultivable) land;

iv) medical care expenses on animals; and

v) health care expenses of households.

Pollution from cement factory is the fall out from cement production process, which contributed income, employment and other benefits to the area of its location. The major benefits were the following: (a) net income generation, (b) net monetary value of employment generated, and (c) other benefits. The above elements are discussed in some detail.

Residential properties. Damage costs of residential properties included both additional maintenance costs and/or relative decline in the value of these properties. Damage to residential
properties by depositions of cement factory pollutants caused faster wear and tear and so people discounted the value by a larger rate than in other places. By checking the value of properties within and outside the area of pollution, the discount rate was estimated for a sample of 20 properties and the same rate was used to all the properties of the sample households. Houses and buildings damaged by cement pollution required higher costs for maintenance. This additional cost was assessed and directly attributed to the effect of pollution. An interest rate on the cost of maintenance was added to the cost, because the money invested in repair and maintenance had an opportunity cost. Total of these three costs was taken to be the measure of damage cost of environmental pollution from cement factories (C.I).

Agricultural products. Cement pollution exerted a negative effect on agricultural production both qualitatively and quantitatively. This loss in agricultural production could in principle be gauged by comparing yield in the affected area with normal yield of the year in the district. Agricultural production included annual crops, perennial crops and livestock; and pollution affected soil and water also. Therefore, the following three items were included in the cost of environmental pollution on agriculture: (i) cost of amelioration of pollution affected soil and water; (ii) loss of yield of crops and livestock vis-à-vis the normal yield; and (iii) additional cost of health care of animals for treating pollution related diseases. Aggregated for all crops and livestock and
for the soil and water affected, this constituted the cost incurred per farm by the damage to agricultural production due to cement pollution (C.2).

**Human health.** Damage costs to health of human beings included (i) a decreased productivity; (ii) cost of health care; and (iii) increased mortality (or more precisely the reduction in life expectation). With some simplifying assumptions, loss in productivity was assessed by the product of labour days lost (in rest and treatment for illness), and the average money wage for the work normally performed by the workers in the family. Cost on health care included the expenses on medical fees paid, cost of medicine actually used, and the incidental costs in visiting the hospital/clinic, for both the individuals/workers and their dependents in the family, but only for the pollution-related diseases. Painstakingly, these were assessed and aggregated. Reduction in life span was measured as the difference between average age at the time of death separately for men, women and children in areas not polluted, and that in the sample families. This difference in years multiplied by the average annual income at the time of actual death for the persons who actually died in the year of observation provided an approximate cost of mortality due to cement pollution. The sum of these three components was the total cost of damage to human health caused by cement pollution (C.3).
**Socio-psychological well-being.** Estimation of monetary value of the decline in socio-psychological well-being can be made only by adopting the Kaldor-Hicks compensation principle: how much money has to be paid, if a person has to be compensated for the decline in his socio-economic well-being. This utility-based approach is very difficult to operate. However, the present study used a simple approach. The sample households were asked explicitly to express their willingness to join anti-pollution drive and to pay additional tax for pollution abatement measures in five point graded scale; strongly willing/willing/undecided/not willing/strongly not willing—with scores for each at 2,1,0,-1,-2 respectively. The score multiplied by the amount the respondent was willing to pay for financing the drive and measures was taken as the cost of the damage in the form of decline in socio-psychological well-being. This amount was taken as zero for those with a score of 0, -1 or -2 for their willingness to join the drive and pay the tax. This cost was denoted (C.4).

Then the cost of damage due to cement pollution was the sum of C.1, C.2, C.3 and C.4. Some heroic assumptions involved in this process were unavoidable. This cost might understate the real cost of damage due to cement pollution, because damage to natural environments such as parks and grazing lands and damage to industrial and business units arising from corrosion to plants and properties and consequent increase in their maintenance costs, though recognized, were not taken into account, largely because
of the formidable problems in estimating such damages and their money values.

Environmental management costs. As earlier shown, in addition to environmental damage costs, one has to distinguish the environmental management costs \( C_M \). Given the large scale degradation of environmental quality in areas surrounding cement factories; 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" principle is generally accepted as a cornerstone of environmental management in many countries. This implied that the polluter has to bear the costs associated with pollution. In this context, two administrative systems of environmental management are possible, viz, (i) a system of prevention and physical regulation, and (ii) a system of levies or 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, environment management is based on a compromise of those policies. Estimates of costs of environmental management are difficult not only due to the problems in conceptualisation and valuation, but also due to the unwillingness and distinct non-cooperation of the cement factories to provide necessary data.
With much persuasion and efforts, the costs of environmental management were assessed. It was simply defined as the value of all efforts and investments put in to prevent or to minimise 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 contribution for welfare measures; (iii) cost of land reclamation; (iv) cost of medical care for animals and (v) cost of health care for human beings. While (i) and (ii) were assessed from the factories, 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 factories.

Benefits. But there were some benefits also from the factories to the area covered by its pollution. These benefits came in the form of employment and income provided to the local people from cement production, and also other fringe benefits accruing from cement production. They included parks, good roads, transport and communications, marketing, educational and recreational facilities. These benefits were assessed net of the costs incurred in maintaining them. Aggregates of these benefits had to be subtracted from the aggregate environmental management costs discussed above to get net social cost (NSC) of environmental management. The problems in conceptualisation and valuation of these benefits have persisted in the process.
Thus, there were six 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 costs ($C_D$).

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 costs and 5 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 increasingly lost as the degree of pollution increased, while larger the pollution higher would be the 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 $\frac{1}{P} = Z$ was the measure of environmental quality for the study.

As production increased pollution also increased, bringing with it increasing cost of pollution control (management costs $C_M$). 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 cement production, i.e., $C_M = f(q)$. Secondly, pollution was related to $q$ as $P = g(q)$. To derive elasticities log-log functions were specified and estimated.

4.2c Functional Analysis

It was possible to assess different levels of environmental pollution
for spatially distributed observational points and the costs \( C_D \) and \( C_M \) associated with them. Then application of (4) to find the equilibrium condition required specification of functional forms for (1) and (2). The scatter diagram for \( C_D \) and \( C_M \) with \( Z \) suggested a double log linear function. More specifically, the functional forms specified for the two functions, i.e. (1) and (2) were the following:

\[ (10) \quad C_D = \alpha Z^{-\beta} \]

and

\[ (11) \quad C_M = \gamma Z^\varepsilon \]

Clearly \( \beta \) and \( \varepsilon \) are the cost elasticities of \( C_D \) and \( C_M \) with respect to \( Z \). Then the marginality rule of (4) implies:

\[ (12) \quad -\beta \alpha Z^{-\beta-1} + \varepsilon \gamma Z^{\varepsilon-1} = 0 \]

or

\[ (13) \quad \beta \frac{C_D}{Z} = \varepsilon \frac{C_M}{Z} \]

or

\[ (14) \quad \frac{C_D}{C_M} = \frac{\varepsilon}{\beta} \]
Thus, the optimum ratio 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.

4.2d The Equilibrium

Several ways exist to arrive at the equilibrium point. One is the regulation of pollution to reduce discharges below a certain standard level. An alternative is to levy a pollution charge equal to the marginal waste disposal costs. This internalisation uses the traditional price mechanism, but its 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.