The Cost of Pollution:

A Survey of Valuation Methods and their Uses for Policy

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Executive Summary

Pollution continues to increase with the consequences affecting growing numbers of people and ultimately the global environment. The effects of pollution manifest themselves in deteriorating air and water quality around the world, resulting in increased cases of respiratory illness, water-borne disease, acid rain, and the increasing global threat of climate change. From an economic perspective, the forces behind pollution are related to the inability of markets to properly "price" the goods and services whose production and consumption processes cause pollution, as well as the ecosystems which serve to absorb the residuals of these processes. One way to address the problem of pricing is to estimate the costs that pollution imposes on society. Then, regulatory and economic instruments can be used in an attempt to alter prices as well as societal and industry behavior in order to reduce pollution.

A wide range of valuation methodologies to account for both the costs of pollution and the benefits of pollution prevention have been developed over the past twenty years. The methods discussed in this paper, as well as others, have been and continue to be utilized and experimented with in both industrialized and developing countries around the world.

Four methods for valuing the costs and benefits of environmental pollution are presented here, in addition to a fifth technique that is used primarily for identification of pollution expenditures and separating them from other expenditures included in national accounts. Market valuation demonstrates to what extent pollution has caused a decrease in the market value of the resource, or another item with market value that is impacted by environmental pollution. Maintenance cost estimates the cost of pollution prevention or environmental remediation. Dose-response provides a type of impact assessment by estimating the cost of the impact of environmental pollution on ecosystems and human health. Contingent valuation estimates

society’s ‘willingness-to-pay’ for the reduction of environmental pollution. Defensive or environmental protection expenditures are actual expenditures distinguished from other expenditures in the national accounts.

The major categories of information derived from these methods - physical emissions, sectoral pollution sources, the types of impacts pollution has on society and the environment, and ultimately the monetary cost estimates - all provide information that can be used for policy-making purposes. Physical emissions indicate the magnitude of the problem, sectoral categories of pollution identify those responsible for contributing to the pollution, the different types of pollution effects categorize and identify the variety of ways that pollution manifests itself in society and the environment. Monetary estimates provide the figures necessary to determine the costs of pollution and the benefits of pollution prevention. The results can be used to help identify, design, and evaluate policies for addressing environmental pollution.

Chapter One

Pollution and Prices

1.1 The State of Pollution

The current state of pollution in the world today is such that a large portion of the world's population lacks access to clean air and water. The World Health Organization (WHO) recommends exposure levels of less than 60 to 90 micrograms per cubic meter per day for total suspended particulates, a major threat to human health. But in the mid-1980s, about 1.3 billion people - mostly in developing countries - lived in towns or cities that did not meet these standards[1]. Data from 1989-1994 indicate that eight of the eleven cities in Asia for which data was compiled exceeded the WHO recommended exposure levels for suspended particulate matter. Annual average exposure levels ranged from a low of 169.7 micrograms (Guangzhou, China) to a high of 444.9 micrograms (Xian, China)[2]. In 1990, roughly 1.3 billion people still lacked access to safe drinking water, and 1.7 billion, predominantly in developing countries, lacked adequate sanitation[3]. The consequences of water pollution are manifest in high morbidity and mortality from waterborne diseases. Diarrhea and intestinal worm infections still account for 10 percent of the total burden of disease in developing countries[4]. The effects of air pollution are seen in increased cases of respiratory illness and lung disease.

In most rural areas in developing countries, household cooking fires, dust, and bacteria contribute to indoor air pollution and health consequences to a greater extent than previously thought. Evidence from limited and localized studies suggests that indoor health hazards can do more damage than those from outdoor pollution in the most affected urban areas. This may be explained by the consumption of traditional fuels (fuelwood, charcoal, bagasse, and animal and vegetable wastes). Consumption of such fuels accounted for 35 percent of total energy consumption in Africa, and for 21 percent in South America[5]. The burning of these traditional fuels contributes both to indoor and outdoor air pollution and cause respiratory illness and lung damage as well as increased concentrations of carbon dioxide.

1.2 Economic Forces Behind Pollution

From an economics perspective, pollution is generated because the environmental medium which is polluted (air and water), is a public resource over which no ownership exists or else is not enforced. This lack of ownership means that the use of the resource for any purpose (polluting, breathing, drinking, fishing) is “free”, in the sense that the resource is not purchased and there is no cost or charge involved with its consumption or pollution. This reflects a ‘market failure’ because the market prices of the goods and services, whose production and consumption processes cause pollution, fail to reflect the true cost to society of the resource use.

This market failure is translated into a spillover effect or externality. An externality or spillover effect is any impact on a third party’s welfare that is brought about by the action of an individual (or industry), and is neither compensated nor appropriated[6]. Externalities may be either positive or negative[7], but environmental pollution is considered a negative externality. It constitutes both misuse of an unpriced (air) or open-access (water) public resource, and has negative spillover effects or external impacts on sectors and individuals who may or may not be parties to the pollution-generating activity[8].

One example of an externality or spillover effect would be an upstream paper mill that discharges waste into a river, causing downstream pollution that damages fish stocks, reduces commercial and recreational fishing, and contaminates the water. The economic damage is an external cost borne by the commercial and recreational fishermen, and anyone who may depend on the river for their water supply. The damage is reflected in reduced profits for the commercial fishermen, and as a loss of welfare for the recreational anglers. As long as the paper mill pays no compensation or takes no action to reduce the waste discharged into the river, society suffers an overall loss of welfare.

In addition to market failure, there are also policy and institutional failures which contribute to pollution. Energy subsidies, for example, represent a policy failure as they further distort the true cost of natural resources. Lack of access to clean sources of energy, particularly in rural communities, represent an institutional failure because governments fail to provide necessary services to their people. This paper attempts to provide a basis primarily for correcting market and policy failures. Measures to correct institutional failures should be based on broader societal concerns.

1.3 Correcting Market and Policy Failures

In order to prevent or reduce pollution, the market prices of goods and services should more accurately reflect the cost pollution imposes on society. In other words, producers and consumers should pay for the right to pollute. Correcting policy failures - in the case where polluting activities are subsidized by government (e.g., energy production and consumption) - means that subsidies should be reduced or removed so that the incentive to waste energy and to produce or consume polluting energy is also removed. Correcting market failures means pricing externalities such as air and water pollution so that the costs they impose on human health and the environment are internalized into the production and consumption processes.

1.4 The Cost of Pollution

This paper will do two things. First it will give a survey (Chapter Two) of the major methods available to account for the costs of pollution. Second, it will describe potential policy uses of the different methods (Chapter Three). An annex is included which provides additional information and a summary listing of case studies that have used the different methods to account for the costs of pollution.

The purpose of this paper is to facilitate the identification and measurement of the costs of pollution so that regulatory and economic instruments can be designed to internalize the costs and reduce pollution. This paper has been prepared for government agencies that are given the mandate to use regulatory and economic instruments for pollution control. The paper will help them better assess the nature, extent, and costs of pollution. This paper has also been prepared for environmental organizations that work on pollution and consumption issues. The description of methodologies and their policy uses will better equip these organizations in their lobbying campaigns and policy development.

Chapter Two

Measuring the Costs of Pollution

2.1 Pollution

Pollution may be defined as either:

1) any discharge or residual resulting from production or consumption processes, or
2) the amount of discharge or residual from production or consumption processes that is in **excess** of an ecosystem's absorptive capacity.

Discharges or residuals may originate from any number of sources including domestic wastewater, community solid wastes, industrial waste effluents, and wastes from agricultural activities such as runoff of excess pesticides and fertilizers. Pollution may be categorized by environmental medium (air, water, and land or solid waste). Physical data compiled on emissions includes categories for different sources such as industry (manufacturing, construction, sewage, mining) households, agriculture, forestry, utilities (electricity, water, gas), and others.

Different ecosystems will have different absorptive capacities over different time periods. Thus, different countries may have different environmental standards. In terms of human health, however, the absorptive capacity tends to be more homogenous. International standards for air pollution include the World Health Organization recommendations that are based on pollution levels in excess of a geographically defined air boundary's (usually for major metropolitan areas) capacity to disperse or dilute emissions so that they do not pose a threat to human health. The absorptive capacity of global ecosystems such as oceans and the climate are less understood and would need to be agreed upon for standards to be applied at the global level.

2.2 The Costs of Pollution

The costs of pollution to society are of two kinds: the costs which arise if *no* action is taken to address pollution, and the costs which arise if action *is* taken. The costs which arise if no action is taken are generally costs resulting from the effects of pollution on human health and the environment. The costs which arise if action *is* taken are those resulting from efforts made to reduce or eliminate the pollution source. These will be discussed in greater detail in the following section.

Many of pollution's impacts on human health and the environment can be quantified and calculated, but many pollution impacts are difficult to monetize or even quantify. Certain values placed on the natural world, such as beauty or religious values are extremely difficult to include in systems of monetary accounting, as these types of values are neither bought nor sold. This paper attempts to examine those effects of pollution that can be quantified and looks at different methods of assigning monetary values to these effects, in order to determine their cost to society. Those pollution effects that are difficult to monetize are no less important, but we should rely on other systems of indicators to address these efforts.

2.3 Costs-Caused and Costs-Borne

The costs to society caused by pollution can be classified according to the two types mentioned above: those costs incurred by the polluting source when taking action to either reduce or eliminate the pollution, and those costs incurred by the individual or group of individuals effected by pollution. The previous example of the external effects of an upstream paper mill can be used to illustrate the two types of costs related to pollution. The upstream paper mill that discharges waste into a river will incur some amount of cost if it takes action to reduce the amount of waste it discharges into the river. This cost is termed *costs-caused*, as they are the costs associated with reducing or eliminating the source causing the pollution. *Costs-caused* are those costs associated with the entity (e.g., industry) that is actually causing the pollution. Costs-caused are usually accounted for by estimating the amount necessary to reduce or eliminate the pollution or to clean it up.

For households, individuals and businesses, there are economic, health and welfare ‘costs’ (damages) or environmental impact costs associated with the current level of air and water quality (e.g., from being unable to obtain clean air and water). These types of costs or impacts to human health and the environment are considered *costs-borne* since they are borne by individuals and households independent of whether they have actually or potentially caused the pollution[9]. The downstream pollution discharged by the paper mill damages fish stocks, reduces commercial and recreational fishing, and contaminates the water. The economic cost of reduced fish catches, the loss of recreational fishing ability, and the need to purify the water source, are *costs-borne* by the commercial and recreational fishermen, and anyone who may depend on the river for their water supply.

In cost-benefit terms, *costs-caused* would correspond to costs, and *costs-borne* would correspond to benefits. For example, an analysis of a proposed policy to reduce lead-emissions to a specified, non-damaging level would estimate pollution control costs (*costs*-caused) for the industries emitting the lead, and the benefits of improved human health from the reduction in lead emissions (*costs-borne* that could be avoided if action is taken by the industry). Industry is *causing* environmental pollution, and households are *bearing* the costs associated with the pollution.

2.4 Methods

During the past two decades, efforts have been made to develop and implement methods for estimating the costs of pollution. Four valuation methods have been identified from a broad range of case studies conducted around the world. This paper briefly introduces selected case studies that include calculations and analysis for pollution. Additional information on how to obtain case study texts is included in the Annex.

The case studies examined in this paper help to illustrate the different methodologies, and can provide additional insight for determining how valuation methods can be used in policy design and analysis. Four valuation techniques are discussed here, and a fifth method is also included which is not used for valuation, but for separating and highlighting environmental protection expenditures from the other items included in the United Nations System of National Accounts (SNA). (Box 2.1)

Box 2.1

United Nations System of National Accounts
The UN Systems of National Accounts provides information to identify a country's assets and liabilities at particular points in time, as well as to keep track of transactions such as purchases of goods and services, payments to wage and profit earners, import payments and export revenues for goods and services. Through its ability to measure diverse goods and services using a common system, the SNA has become the standard framework used for measuring macroeconomic performance, analyzing trends of economic growth, and providing the economic counterpart of social welfare. The core of the SNA is the calculation of the Gross Domestic Product, the market value of goods and services produced in a given period. The SNA has been criticized for its failure to include the contribution of the environment to economic activity, and one of the major goals of valuing environmental services and inputs (including those related to pollution) is to incorporate the value of the environment into the SNA along with the economic accounts.

Methods for deriving values for the costs of pollution prevention and remediation, or the costs of the impacts on the economy, ecosystems and human health.

- **Market valuation** - demonstrates to what extent pollution has caused a decrease in the market value of the resource, or another item with market value that is impacted by environmental pollution (e.g., land)
- **Maintenance cost** - estimates the cost of pollution prevention or environmental remediation
- **Dose-response or Impact Assessment** - estimates the cost of the impact of environmental pollution on ecosystems and human health
- **Contingent valuation** - estimates society's 'willingness-to-pay' for the reduction of environmental pollution

Actual expenditures

- **Defensive or environmental protection expenditures** - are distinguished from other expenditures

These valuation methods and the basic steps for their implementation are described in further detail in the following sections.

2.4.1 Market Valuation

Market valuation involves finding a market in a good or service that is influenced by the non-marketed good (pollution) and estimating the amount the market has decreased in value as the result of pollution. (See Box 2.2)

Box 2.2

Market Valuation

1. Identify a pollutant or pollutants that are known to have adverse impacts on the environment.
2. Identify a market that is negatively impacted by the identified pollutant(s).
3. Measure the amount the market value has decreased over a chosen time period.
4. Measure the amount the pollutant level(s) have increased (or decreased) over the same time period.
5. Determine to what extent the pollutant has caused a decrease in market value and by how much the value has declined.

Real estate provides a good example as property prices can be influenced by the amount of pollution in the area. Environmental quality may affect the decision to purchase a particular house, and the price of the house may be influenced in part by the environmental attributes of the property. Other types of resources such as fisheries and forests can also be affected by pollution to the extent that the market value or income earned declines. The degradation of natural and produced resources caused by pollution is reflected by market valuation only to the extent that pollution leads to a decrease in the market value of those assets. This method of valuation shows the degradation that has taken place for those resources which have a market value, and also shows to what extent the degradation has caused the market value to fall.

The changes in market prices are estimated in various ways, depending on the market. For any given pollutant (nitrogen dioxides, sulfur dioxide, carbon dioxide), a market must be identified that is in some way impacted by the pollution. The most common method is to examine the market values of properties over time to determine if the values are decreasing as a result of pollution.

In order to distinguish which changes in the value of certain resources are due to the environmental impact from the deposition of sulfur and nitrogen in Sweden, for example, values were estimated for four natural and produced resources[10]: sites by and near lakes, forest soil, nitrate in groundwater, and corrosion. The calculations of reductions in the value of lake sites and sites close to lakes are an example which is based on the assumption of *how much* pollution (acidification and overfertilization) reduces the market value of the properties. This is expressed as a percentage of the property value and is periodized over 20 years (owing to gradual deterioration of environmental quality). Specific forest areas are assumed to have a lower market value because pollution has reduced their growth rate, and in this study, the decline in market value is measured by the loss of income borne by forest owners. Nitrate in groundwater is assumed to reduce the value of properties by the cost of installing a purification system with filters connected to the well. In this valuation, the price decreases are estimated rather than observed, and no price decreases that can be directly attributed to the environmental impacts of sulfur and nitrogen deposition have been observed in actual cases.

Another example of market valuation can be drawn from a German study that estimated lost income to the fishing industry[11] resulting from pollution[12]. (Table 2.2) Estimated economic and income losses caused by environmental pollution from 1950 through 1987, amount to approximately DM 9,300 million and DM 4,697 million respectively. Losses steadily increase as depicted in 1987 prices..

Estimated Economic and Income Losses Caused by Environmental Pollution and other Anthropogenically Related Impacts in the German Fishing Industry

Table 2.2

DM	Economic Losses		Lost Income	
Year	*Actual Prices*	*1987 Prices*	*Actual Prices*	*1987 Prices*
1950	37	155	18	56
1960	57	179	28	72
1970	144	323	75	149
1980	265	355	172	211
1987	472	472	232	232

Source: Adapted from The Federal Minister for the Environment, Germany (1991).

In this case, the market affected by pollution is the German fishing industry. The market value of the fishing industry is determined in part by income in the fishing industry. The cost of pollution can be estimated by compiling earnings over time and determining whether and by how much pollution is causing a decline in market value of the fishery(ies) as reflected by lost income. Lost income estimates are also predicted for future scenarios based on current policies and additional measures concerning the fishing industry. These are discussed in Chapter Three.

2.4.2 Maintenance Cost

Maintenance costs are hypothetical costs which would be incurred to either reduce pollution to a specified level, or to restore a resource to its former (or a pre-determined) state, given the best available technology. Avoidance costs are hypothetical costs that would be incurred by specific activities undertaken in an attempt to avoid or prevent pollution, as opposed to maintenance costs, which include both the cost of prevention *and* the cost of remediation.

Maintenance costs can be categorized according to the corresponding sectors that generate pollution. For instance, air and water pollution may be primarily allocated to the oil industry, manufacturing, electricity production, transport, and household production activities, while solid wastes are assumed to be generated primarily by households in their capacity as consumers[13]. Maintenance costs do not correspond to the value of the environment (or, in the case of pollution accounting, to the value of unpolluted air and water), but rather they represent a minimum value of what it costs a particular industry or sector to either reduce its pollution levels to some pre-determined standard, or to restore the level of environmental quality to a defined level.

Calculating the Maintenance Cost

The maintenance cost approach involves estimating the costs of emissions reduction using physical accounts of emissions output and cost estimates of the amount necessary to reduce emissions. (See Box 2.3)

Box 2.3

Maintenance Cost
1. Decide on the pollutants to be considered (e.g., SO2, NOx, CO2) and estimate changes in air quality. 2. Estimate emissions by sector. Sample surveys can be carried out to measure emissions from different economic activities or pollution control boards may monitor emissions for major pollutants. Emission coefficients can also be used to estimate the amount of emissions produced per output. 3. Identify which activities are used to prevent or restore environmental pollution (e.g., reduction, substitution, prevention, restoration), and estimate the cost of emissions reduction according to the type of activity. 4. Estimate maintenance costs per sector by multiplying the unit cost estimates per emission by the amount of emissions produced per sector.

Polluting sectors may include industries, households, government, and the rest of the world (used to capture transboundary air and water pollution), but can be adapted according to the characteristics of the economy. Emissions are compiled according to the type of pollutant and the emitting sector. (Table 2.3) Emissions depend on the fuel(s) used, the technology employed, and the processes involved. Thus, they differ from sector to sector, and from country to country. Data on pollution are typically compiled from monitoring stations. They provide measures of ambient concentrations of pollutants in environmental media of air, water, land/soil as a basis for estimates of environmental quality (changes). However, for the allocation of environmental costs to those sectors that caused them - as required in the maintenance cost approach - emission rather than concentration data need to be obtained. As it is difficult to trace ambient concentrations back to their origins, emission coefficients are usually applied to production data. Emission coefficients tell the amount of pollution (unit) that is produced per amount ($) of production output. Emission coefficients are usually available from research or engineering studies, other countries with similar economic structure, or international work on typical industries and their emissions. *The Industrial Pollution Projection System*, (World Bank Policy Research WPR 1431) gives emission coefficients in terms of pounds of pollution produced per US$ million of output.

The International Standard Industrial Classification of All Economic Activities (ISIC) can assist with the identification of sectors if a more detailed breakdown is desired. However, there are no widely accepted international classifications of emissions except for waste, where UN Economic Commission for Europe has developed a Draft ECE Standard Classification of Wastes[14]. The most important pollutants and waste categories should be identified separately, since the costing of these impacts varies considerably by type of pollutant and waste. Comparison of emissions of individual pollutants by different sectors will show which sectors are emitting the most (or least) amount of a given pollutant.

Table 2.3 **Emission by Industries**

('000 tonnes)	Manufacturing	Electricity, gas and water	Government	Households	Rest of FROM	the World TO
Air						
SO2	543	455	24	233	23	50
NOx	40	2	5	70	0	0
CO2	0	100	2	17	0	0
Water						
BOD	3200	20,000	2100	4600	0	900
Land						
Wastes	34	15	60	576	13	0

Source: UN *forthcoming*

In order to assign costs to the pollutants, the activities must be identified which will either prevent or restore the environmental pollution. Five types of measures for preventing or restoring environmental degradation have been identified by the UN:

1) reduction or abstention from the polluting activity,
2) substitution of the product or modification of household consumption patterns,
3) substitution of inputs (i.e., by applying new technologies),
4) activities developed in order to prevent pollution (e.g., end-of-pipe technologies), and
5) restoration of the environment[15].

Each activity is assigned a unit cost determined by any of the following methods: cost/benefit analysis, environmental impact assessments, industrial surveys of environmental protection expenditures, and research on environmental technologies.

For example, unit cost estimates of air and water pollution in Japan are made by calculating the costs of installing end-of-pipe technologies[16] to remove discharged residuals. (See Table 2.4) Sources of air pollution are divided into fixed (factories) and mobile (automobiles) sources. For fixed sources, the cost of removal is the cost of operating air pollution prevention devices (the cost of depreciation and maintenance). For mobile sources, the cost of removal is the additional cost of placing exhaust devices in gasoline-operated vehicles. Water pollution sources included household, industrial, and livestock drainage. The cost of removal of water pollution was also calculated using the cost of operating environmental protection devices. For each source the following calculations are made:

1. the volume of removal,
2. the volume of discharge,
3. the cost of removal.

The unit cost of removal is obtained by dividing the cost of removal by the volume of removal. The maintenance cost is obtained by multiplying this by the volume of discharge. The unit cost estimates for each technology or activity provide an estimate of the cost required to reduce or eliminate a given amount of discharge. The unit costs can then be multiplied by physical accounts of emission figures to calculate the total cost by sector and by pollutant.

Table 2.4

	1985	**1990**	**Average Annual Rate of Growth (%)**
Unit Cost of Removal (m. yen/1,000 tons)	47.49	31.40	7.9
Volume of Discharge (in 1,000 tons)	5,435	6,074	2.3
Maintenance Cost (billion yen)	258.1	190.7	5.9

Source: Oda K., et. al., (1996)

When physical discharge volumes are analyzed in conjunction with unit cost and maintenance cost estimates, a more comprehensive assessment can be made of pollution costs. From Table 2.4, it is evident that maintenance costs declined despite the increased volume of discharge due to the decline in the unit cost of removal. Further analysis of environmental protection expenditures indicates that the cost of removal declined due to a decline in the value of investment in environmental protection equipment from 1978-1983[17].

Another example can be drawn from a Swedish study that assesses the costs of sulfur and nitrogen emissions to Swedish society. The study estimates avoidance costs associated with the attainment of specific environmental standards for sulfur and nitrogen emissions into the air, and for nitrogen emissions into the soil and water. Cost estimates are based on the Swedish Environmental Protection Agency's information on the costs of specific measures[18]. This study focuses on costs related to acidification, overfertilization, and nitrification from sulfur and nitrogen deposition. The avoidance costs are the costs of the measures used which achieve the national environmental standards for the substance in question at the least cost. Sulfur reduction is achieved primarily by changing the fuel used in shipping. To limit sulfur emissions to 80,000 tonnes per year costs about Skr 80 million. Nitrogen emissions into the atmosphere are reduced in the most cost-effective way by requiring that all passenger vehicles comply with environmental standards, and that specific measures relating to engines and motors are taken in ships and machinery. The greatest source of nitrogen emissions into the soil and water is agriculture, where emissions are most effectively reduced by switching over to new farming methods, better manure management and spreading, catch cropping, and the establishment of wetlands[19].

The avoidance cost estimates are complete in the sense that the selected emissions reduction measures would bring about a reduction in those emissions generated by the Swedish economy. Overfertilization and acidification would decrease if the measures were carried out. On the other hand, they would not be sufficient to eliminate the problem entirely because emissions of other substances, such as phosphorus, hydrocarbons and emissions from other countries (primarily of sulfur and nitrogen) cause pollution within Swedish boundaries. This study highlights the geographical delimitation for air pollution cost estimates which only estimate costs for the country in question. This is especially true for smaller countries. The Swedish estimates only calculate the costs of emissions reductions for Swedish businesses and households, but approximately 70 percent of the sulfur deposition in Sweden originates from foreign sources. This issue becomes more relevant when estimating the costs of reducing emissions that have global impacts such as carbon dioxide. As depicted in Box 2.2, including physical data on emissions levels received from and emitted to the rest of the world can be used to help estimate the costs of reducing emissions with global or transboundary impacts.

2.4.3 Dose-Response or Impact Assessment

The dose-response or impact assessment approach provides an estimate of the economic damage caused by the present degree of pollution. This type of assessment involves calculating the impact of pollution on human health and the environment. This can be done by tracking individual exposure levels, estimating losses of output, and/or the additional incidence of morbidity and mortality that results from environmental degradation. This may entail estimating the economic costs of sickness and death, which can create moral problems of determining a person's economic worth. While some are of the opinion that it is not possible (or morally ethical) to place monetary values on sickness or death, in many situations, governments must decide on the appropriate level of health intervention or investments to make. Putting a value (even if inevitably underestimated) on morbidity and mortality due to pollution can be a powerful tool to demonstrate the costs of *inaction*[20].

Loss of output measured as work loss days and foregone earnings is similar to the cost estimates for market valuation which calculate a decline in the market value of a resource (forests, fishery) by estimating income lost. The difference between dose-response and market valuation is in the measurement of economic damage. Dose-response measures damage as the loss of income due to pollution-related illness. Estimates for market valuation are calculated for loss of income due to the effects of pollution on the market, rather than on human health. For example, if a fishery becomes increasingly contaminated by effluents to the extent that the fish population declines and does not recover, the decline in value of the fishery resource or market is reflected in reduced earnings of the fishing industry. Dose-response could be used to estimate loss of earnings resulting from [human] illness or death caused by the same water pollution.

Calculating Dose-Response Estimates

In order to estimate the value of the damage to either human health or the environment resulting from pollution, a relationship must be determined which links changes in environmental quality to changes in human health or another object effected by pollution (buildings, ecosystems). This is called the dose-response relationship, the relationship between the pollutant concentration (dose) and the physical effect (response).

Dose-Response

1. Identify the pollution problem (e.g., air, water, land).
2. Gather appropriate medical data and data on human health and other population variables (see below).
3. Estimate the statistical relationship between the percentage increase in pollutant concentration and the physical effect on human health.
4. Determine the types of physical effects and their individual costs (e.g., medical expenditures).
5. Estimate the total monetary impact based on the cost of physical effects for the amount of pollutant concentration.

Statistical techniques are used to determine this type of relationship and can be used to analyze the relationship between air quality indicators and mortality rates. Results would determine the percentage increase in mortality rates caused by a given percentage increase in pollutant concentration (1% increase in pollutant concentration will increase the mortality rate by about 0.1%). For example, the increase in asthma cases due to a unit increase in suspended particulate matter (SPM). The type of data required for this type of estimation includes:

1) Compilation of medical data on chronological changes in human health,
2) Medical evidence linking air quality and health

The damages can be statistically estimated (number of deaths due to a rise in SPM concentration), and then human health can be assigned an economic value based on various medical expenditures. Values may range from a doctors fee for occasional breathlessness due to an abnormal increase in atmospheric SPM to incremental deaths reported in a major metropolitan area due to sustained high levels of SPM. For estimating economic values of human health, the following data is needed[21]:

1) Costs of various medical facilities in the country,
2) Data on general health, longevity, cause of deaths, age distribution,
3) Per capita income and other household variable such as living conditions, consumption patterns, expenditure on health maintenance, etc.

These calculations will give estimates for the values of each type of health impact measured. The statistical data that determines the numbers of each health impact per pollutant increase can be multiplied by the values of each health impact to arrive at a health cost estimate based on unit increases in pollution.

One example of the physical (health) damage that air pollution imposes on society is the exacerbation of respiratory illness or morbidity. Illnesses impose costs on the individual and society in many ways. Individuals incur medical expenditures, society loses productivity, and government spends more resources cleaning up pollution and curing disease caused by pollution. The cost of morbidity is manifest in doctors fees, medicine, hospitalization, and work days lost. Each of these costs can be estimated and calculated for different afflictions to arrive at the total economic value of an increase in respiratory illness caused by an increase in air pollutant concentrations.

The economic costs of air pollution in the Philippines were estimated for people suffering from respiratory illness, hypertension and premature deaths caused by pollution[22]. The economic damages that air pollution causes to human health can be calculated by estimating the amount people spend on medical attention to treat the illness. The Philippines Environment and Natural Resources Accounting Project (ENRAP) estimated pollution costs through the limited application of dose-response relationships. Dose-response relationships were used to measure the effects of air and water pollution on health, ecosystems and economic productivity.

Table 2.5

Health Damages from Air and Water Pollution - 1988 & 1992

	1988 **Million Pesos**	**1992** **Million Pesos, 1988 prices**
Air Pollution	1297	1942
Effect of Particulate Matter and Lead Emissions, Metro Manila		
Work Loss Days from Morbidity	48	38
Medication	658	1194
Foregone Earnings due to Premature	590	710

Death		
Water Pollution	596	615
Increased Incidence of Water-Borne Disease		
Work Loss Days from Morbidity	43	131
Medication	91	138
Foregone Earnings due to Premature Death	462	346
TOTAL HEALTH DAMAGES	**1,893**	**2,557**

Source: de Los Angeles and Peskin (1996).

Health damages from air and water pollution were calculated for work loss days from morbidity, medication, and foregone earnings due to premature death. Health damages from air pollution consist of foregone earnings and medication expenses from worsened respiratory illnesses from particulate matter and lead exposure, increased hypertension from lead, and premature deaths caused by both pollutants[23]. Total health damages from water and air pollution increased approximately 35 percent from 1988 to 1992, but damages from water pollution increased only 3 percent, while those from air pollution increased approximately 50 percent. (See Table 2.5) From this data, it is evident that air pollution is a greater threat to the population of Manila than water pollution, and government policy could be prioritized accordingly.

Dose-response estimates can be considered "benefits" in a cost-benefit analysis, where the costs of reducing pollution are compared to physical benefits realized in terms of reduced illness or environmental damage. Dose-response estimates can provide the counterpart to the maintenance cost estimate in a cost-benefit analysis at the macro level. This concept is discussed in greater detail in Chapter Three.

2.4.4 Contingent Valuation

Contingent valuation or willingness-to-pay, measures how much households are willing to pay in order to preserve or restore the natural environment. Willingness-to-pay can translate into a certain amount of consumption or expenditure that a household will reduce or abstain from, in order to prevent environmental degradation. This type of valuation can be carried out in the form of surveys, where individual households are asked to respond to questions regarding their willingness to reduce consumption. Questionnaires may ask for the maximum reduction in level of consumption that people would be willing to accept if all types of economic impacts on the environment could be avoided. Then the respondents would indicate how much of their forgone consumption to allocate for specific environmental issues (UN 1993).

Contingent Valuation

1. Identify the pollution problem(s) to be addressed.
2. Decide on the population to use in a survey.
3. Develop a survey that asks respondents for the maximum reduction in level of consumption they would be willing to accept, or for the maximum amount they would be willing to pay (per month, year) in order to preserve air or water quality, or to support a price increase based on market instruments (e.g., tax or user fee).
4. Include population characteristics in the survey such as income level, use of environmental service, age, education level, social class, in order to minimize biases.

Contingent valuation (CV) approaches may be used to estimate the value of non-marketable goods (the presence of a natural environmental and recreational opportunities) that are degraded due to environmental pollution through the use of surveys. Surveys are designed to ask people a hypothetical question(s) related to how much they would be willing to pay to maintain the quality of a certain resource. For example, a Dutch study aimed at estimating the welfare loss for the Dutch population due to severe acid rain damage to forests and heather used CV surveys to assess the value of the potential damage to the non-marketed goods provided by the forests and heather (a natural environment and recreational opportunities)[24]. The forests and heather also provide marketable goods in the form of timber, but damage to the timber was measured separately as a productivity loss in the timber market. The CV study included a random sample of households who were asked to state their willingness to pay for the preservation the present condition of the forests and heather as compared to the expected future condition in the absence of any additional [protective] policy[25]. The actual willingness to pay was found to be dependent on the characteristics of the population itself.

Willingness to Pay for Forest Preservation from Acid Rain

Box 2.3

Amount willing to pay		Income Level	Number of Forest Visits	Perceived Gravity of the Acid Rain Problem	Age	Education Level	Social Class

Per Month	Per Year	D*f*l.		Scale 1-10			

Survey results indicated that on average, respondents were prepared to pay D*f*l. 22.83 per household per month (1985). This amounts to D*f*l. 1.45 billion per year for the Dutch society as a whole. Damage to timber production would amount to D*f*l. 13.1 million per year estimated from the difference in growth between the two conditions. Before this study was conducted, the only available estimate of the damage of air pollution to forests was an estimate of productivity losses in forestry, which amounted to an annual damage of D*f*l. 30-50 million. This estimate is marginal compared to the willingness to pay estimated in the study. Even if the method and consequently the exact magnitude of the estimated value remain controversial, the results lend support to increased environmental protection.

Contingent valuation can be used to estimate the value of a statistical life (VOSL) for determining the costs of pollution on human health. CV estimates the willingness of individuals to pay to obtain a reduction in the probability of mortality[26]. If a person is willing to pay US$1,000 to secure a reduction in the risk of dying by 1/1000, the VOSL is US$1 million, or the willingness to pay multiplied by the change in risk[27]. CV can also be used to estimate a population's willingness to pay for improved air or water quality in the form of taxes or automobile related costs. The results of this type of estimate can be included as 'benefits' in cost-benefit analyses of proposed or existing environmental regulations (See Chapter Three for more detail).

Monetary accounts using studies of willingness-to-pay show the loss of welfare, measured as the quantity of consumption people would be willing to forgo and which are caused by the current environmental pollution. One problem with contingent valuation is the fact that willingness-to-pay partly depends on the income situation of the persons questioned. Willingness-to-pay is determined largely by ability to pay, which depends on the individual's income level. This means that interpreting aggregates of individual potential expenses across different income groups becomes questionable. Nevertheless, surveys can be designed that take into account varying levels of income (See Box 2.3), as well as other variations that are characteristic of large populations (e.g., social class, education). This can help take into account differences in income, class, and education so that the study will produce more accurate estimates.

2.4.5 Defensive Expenditure

Defensive or environmental protection expenditures are the actual expenses associated with restoring the resource to a pre-determined qualitative or quantitative standard or with preventing deterioration of the resource from occurring in the first place. Qualitative standards may relate to the emission by activity, the concentration of chemical and other agents, the composition of products, and the consumption of raw materials and energy. Standards can also be related to environmental function. In the case of pollution, standards may dictate the pollutant concentration allowable for the environment to maintain the identified function (e.g., climate regulation, water supply, carbon dioxide absorption). The expenditures for each measure that is required to comply with regulatory standards then tells us in monetary terms how far a country has drifted away from (or moved toward) its target of environmental quality[28].

These expenditures are already included in the SNA, but are usually not identified separately as environmental protection expenditures. They include the costs involved in preventing or neutralizing a decrease in environmental quality, as well as the actual expenditures that are necessary to compensate for or repair the negative impacts of a degraded environment (UN 1993). Defensive expenditures differ from maintenance costs in that they are expenditures that have already been spent. Maintenance costs are only hypothetical, “predicted” expenditures that would be spent to either prevent or clean-up a given level of pollution.

Environmental protection expenditures are included as subsets within the traditional national accounts according to expenditures for goods and services, output by industry, stocks of equipment, and capital formation and consumption. For more comprehensive assessment, activities such as environmental clean-up, and the production of environmental protection goods and services (e.g., waste/pollution treatment facilities, filters, cleaning materials) can also be separately identified by commodity classification.

A Draft Classification of Environmental Protection Activities (CEPA) has been developed by the UN which may be used for the purposes of compiling expenditures by sector.

Environmental Protection Expenditures

Table 2.6

Environmental Protection Expenditure	**Sector**			
	Manufacturing	Construction	Sewage & Sanitation	Transport
1. Protection of ambient air and climate 2. Protection of ambient water (excluding groundwater) 3. Prevention, collection, transport, treatment and disposal of waste 4. Recycling of wastes and other residuals 5. Protection of soil and groundwater 6. Noise abatement 7. Protection of nature and landscape 8. Other environmental protection measures 9. Research and development				

Source: UN (1993)

Sectors may vary depending on the structure of the economy and the types of expenditures. Defensive or "environmental" expenditures compiled for the United Kingdom include:

1) pollution abatement,
2) environmental conservation,
3) research and development,
4) education and training, and
5) general administration[29].

Estimates were calculated for each expenditure according to four different spending groups.

Summary of Estimates of Environmental Expenditure by Activity and Spending Group for the United Kingdom 1990-91

Spending Group

Main Modules	Government	Enterprises	Households	Nonprofit	Total
Pollution Abatement	2200	5900	680		8800
Env. Conservation	290			160	450
R & D	250				250
Education & Training	90	60			150
General Administration	100				100
Peripheral Modules					
Natural Resource Mgmt.	630	2800			3400
Amenities Improvement	1200				1200
	4800	8700	680	160	14000

Source: Bryant and Cook (1992).

Environmental expenditure in 1990 represented approximately 3% of GDP. Pollution abatement represents over half the total expenditure on the environment, and spending by enterprises represents over half the total expenditure as well. Expenditure estimates were also broken down by environmental medium (waste, air, water, noise, land, and other).

Expenditures here are not estimated, but rather identified and separated from the traditional expenditures as those which relate to environmental protection. Those industries that are particularly relevant for environmental analysis (e.g., manufacturing, construction, sewage) and which account for most of a country's environmental impacts, are used to categorize the expenditures by sector. Estimates of the size of defensive expenditures in the United Kingdom (UK) have been taken from the Department of Energy's "The UK Environment". Environmental expenditure is defined as capital and operating expenditure which has been incurred because of, and can be attributed directly to, the pursuit of an environmental objective[30]. However, counting only those expenditures incurred in response to an environmental objective, omits a portion of the defensive expenditure, as manufacturers often introduce new technologies that jointly increase productivity and decrease pollution.

Chapter Three

Internalizing the Costs

Accounting for pollution can provide an analytical basis for regulatory and economic instruments that internalize costs and reduce pollution. The accounting methods covered in this paper are also used to value other types of natural resource degradation such as soil erosion, and various resource uses (consumption). The methods described in the previous chapter are discussed here only in relation to their use for environmental and economic policies which address pollution. A country can derive the following types of information from the different valuation methods:

- how much each sector is currently spending to prevent or reduce air pollution (environmental protection expenditures),
- any decrease in property or other resource values due to the effects of air pollution,
- how much each sector *would need* to spend to achieve a [pre-determined] air quality standard ,
- how much society is willing to pay or give up to prevent air pollution,
- the costs of air pollution to society in terms of health effects and impacts on ecosystems.

These types of monetary estimates can be used to assess the costs and benefits of pollution reduction in order to compare policy alternatives, and to provide information for the design of sectoral and national policies aimed at the reduction or elimination of environmental pollution.

3.1 Market Valuation

Identifies the loss in market value of impacted assets

Market valuation studies generate three types of information: the market or markets effected by pollution, the nature of the pollution effects on the market, and the monetary amount by which pollution has caused the market to decline. Information describing the particular markets that are declining in value shows which specific industries, sectors, geographical areas, or resources are being impacted by pollution. This information may be used to help target policy interventions for those areas most affected by pollution. Market valuation studies also describe how pollution is actually affecting the market. This can be used to design policies that incorporate the different relationships between a single pollution source and the multiple impacts it may have on the market. The monetary amounts that are recorded over time show if and by how much value is decreasing. These estimates provide values of the damage caused by pollution and can be used in cost-benefit analysis to estimate the economic benefits of a pollution prevention program or more stringent environmental regulations. Cost-benefit evaluations are usually conducted to assess the costs and benefits associated with a particular regulatory standard or economic instrument such as a tax or user fee.

To illustrate, market valuation studies of sulfur and nitrogen deposition in Sweden identified four distinct markets which were impacted by acidification and overfertilization due to SO_2 and NO_x. The four markets included: the housing market for sites by and near lakes, the housing market for properties affected by nitrate in groundwater, the forest industry market, and properties or buildings damaged by corrosion. The results of the study demonstrate that SO_2 and NO_x cause the most damage to properties and buildings in the form of corrosion (Table 3.1).

Table 3.1

Sites by and near Lakes	160
Acidification (SO_2)	3
Acidification Risk	17
Overfertilization of lakes	40
(NO_x)	100
Overfertilization of the sea	320
Forest Soil	110
Nitrate in Groundwater	969
Corrosion	
Total *millions of kronor (lost)*	1559

Source: Skånberg and Ahlroth 1997

This information can be used to prioritize policy interventions for addressing acid rain and NO_x emissions. If pollution-related corrosion is causing the most [economic] damage in a given geographical area, then policy measures which specifically address corrosion can be given priority over those that are targeted toward lakes, which suffer the least amount of economic damage in the form of price decreases.

Market valuation studies illustrate how one pollutant can impact multiple markets, and also describe the type of effect. From the Swedish study it is evident that sulfur deposition affects lakeside property, forest soil, and also causes corrosion. This gives an indication of the broad range of impacts that sulfur deposition has on Swedish society.

Information on the types of impacts a pollutant has on a market can be incorporated into regulatory or restorative policies. From the German study on income lost in fisheries mentioned in the previous chapter, the pollutants are not identified, but the specific nature of their impacts on the fisheries were listed as disease, stock fluctuation, ingestion of harmful substances, etc. Data on fish populations and health could be used for restoration policies such as aquaculture management or restocking programs.

Monetary cost estimates can be used in cost-benefit analysis to estimate the economic benefits that would result from a pollution prevention program, more stringent environmental regulations, or restorative policies, in comparison with their costs. If the benefits are assessed as outweighing the costs, the conclusion of the analysis would be that the proposed measure will, with a reasonable degree of certainty, be profitable for society. If the sources of pollution can be identified, as sulfur and nitrogen were in the Swedish study, government policy can directly target the sources of sulfur and nitrogen pollution. If the pollution sources cannot, or have not been identified, as in the case of the German fishing industry, then it is difficult to address the source of the problem, and additional research may be required.

Studies can also be used to estimate future costs based on different policy scenarios. Future lost-income scenarios were developed for the German fishing industry: one for status-quo scenario based on current national and international environmental and fishing policies as well as on the anticipated success of these measures, and one for a “ trend scenario” which includes measures to improve the general conditions in the fishing industry. (Table 3.2)

Table 3.2 **Lost Income in the German Fishing Industry: Forecast from 1990 to 2010**

Sectors	**Status Quo**		**Trend**	
	Worst case	*Best case*	*Worst case*	*Best case*
Inland Fishing	128	123	122	116
	116	112	110	105
	105	101	99	95
	94	90	89	85
Sea Fishing	207	171	117	61
	187	154	105	55
	168	139	95	49
	151	125	85	44

Source: Federal Minister for the Environment, Germany (1991)

These forecasts give lost income estimates under both the current and improved environmental and fishing policies. If estimates are found to be considerably lower under an improved policy scenario, then government may consider implementing the policies or management programs used in the future scenario in order to reduce the amount of income lost.

The market valuation method provides estimates of price decreases in markets that are affected by pollution. However, the total economic damage caused by any given pollutant may not be fully accounted for by market valuation. To more completely assess the damage caused by a particular pollutant, additional valuations should be conducted which covers the impacts that are not market-related (e.g., health). Market valuations may not always identify the source of pollution, and in these cases, complementary studies may also be carried out which specifically identify pollution sources so that policies can be directly targeted toward these sources.

3.2 Maintenance Cost

The process of estimating the maintenance costs of environmental pollution also produces three types of information: the physical data that indicates which pollutants are emitted in the greatest and lowest quantities, sectoral sources of pollution, and the monetary cost estimates.

The physical data produced from the compilation of emissions indicates the magnitude of pollution problems. Numerical data on emissions can be used to set up and evaluate emission standards. If data is collected annually, emission standards can be evaluated for their progress in emissions reductions, providing a basis for regulation or modifications in regulations. Environmental regulations that mandate the reduction or maintenance of emissions to specified levels can be evaluated for their effects on future emission levels and on sector-specific costs of emissions reduction.

Both maintenance and avoidance cost estimates can provide the quantitative information necessary to determine the sectoral economic impacts of environmental regulations that mandate compliance with specific standards. Based on the level of economic impact estimated, a standard can be adjusted in order to reflect the cost involved with compliance. In other words, if the estimated costs of compliance prove to be too costly by industrial or political opinion, than a lower standard could be adopted, and vice versa.

Sector-Specific Policies

Classification of industries provides information on emissions by sources. Emissions sources are classified by sector, and specific sectoral information can be used to help target policy interventions so that they address the sources of pollution. Sectoral breakdowns of pollution sources in a Philippine study indicate the sectors of the economy that contribute the most to air and water pollution. Data generated from Philippine Environmental and Natural Resources Accounting Project[31] indicate that exclusive focus on industries as the target for pollution reduction (as is primarily the case in industrialized countries), would not achieve considerable impact on improving the quality of air and water resources. This is due to the fact that households contribute 44% of all BOD effluents, while the agriculture, fishery and forestry sectors contribute 91% of all suspended solids. The percentage contribution of each sector toward air emissions also varies by pollutant. Households contribute 63% of particulate matter, 90% of CO_2, and 90% of volatile organic compounds. Manufacturing, however, is responsible for the majority of NO_x emissions (40%), and 32% of SO_x. Electricity, gas and water also contribute significantly (53%) to SO_x emissions. Sectoral breakdowns of pollution sources provide information for targeting pollution prevention or reduction policies. In the case of the Philippines, major reductions in water discharges could be achieved through public investments for improving sewerage facilities and sanitary services in the short-term and for reducing soil erosion. Air emissions would be more effectively addressed by targeting individual pollutants based on their sectoral sources. Pollutants can be prioritized using the physical accounts of emissions that indicate which pollutants are emitted in the greatest quantities. If particulate matter is emitted in the greatest quantities, then households would be the primary target of a pollution reduction policy. If CO_2, NO_x, and SO_x are emitted in the greatest quantities, then households, manufacturing and electricity, water and gas would be the primary targets of government policy. Sectoral breakdowns of emission sources not only indicate which sectors are responsible for generating different types of pollution, but can also be used to prioritize policy goals when used in conjunction with physical emissions accounts.

Figure 3.1 and 3.2

Cost Estimates

Monetary estimates indicate the cost required to meet a standard or regulation. They are useful for identifying cost-effective measures when a specific standard is required by policy or law, so that extensive costs are not incurred to obtain a small additional reduction in pollution. Internalizing pollution costs may be described as the required cost of maintaining the quantity and quality of the environment at a certain level, such that the external effects or impacts [on the environment and human health] are reduced in accordance with some predetermined standard.

Cost estimates, used in conjunction with the physical emission data can be used to estimate the impact (on output and profits) of existing and prospective regulations, taxes, and economic instruments of environmental policy such as: user fees, effluent charges, emissions taxes and tradable pollution permits. Regulations, taxes, and fees can be adjusted according to the cost estimated for achieving the desired impact on emissions, output, and profits.

For example, a country's physical accounts indicate that CO_2 emissions are 60,000 tons and the government would like to reduce emissions to 40,000 tons. A sectoral breakdown of air emissions by source shows that the manufacturing industry contributes approximately 65% or 39,000 tons of CO_2 emissions. Achieving this goal would require that the manufacturing industry reduce its emissions to approximately 26,000 tons. The government decides to target the manufacturing industry and proposes a policy which includes a capital investment tax credit for modern energy-efficient and environmentally clean plant technology to be funded with a CO_2 tax levied on energy consumed by industries[32].

The size of a CO_2 tax can be estimated by calculating the amount of energy consumed by industries, the maintenance cost of adopting clean technologies, and by estimating the size of a tax credit needed to encourage adoption of clean technologies (a percentage or the entirety of the maintenance cost). A tax credit that is too small, would result in low adoption rates, while an extremely large tax credit would be difficult to fund. The size of the tax credit can be calculated based on the maintenance cost of adopting clean technologies that bring emissions down to the desired level while maintaining current levels of production and consumption. A tax credit would ideally encourage industry to adopt new technologies that are less polluting, even if they are more expensive.

Estimates of air and water pollution maintenance costs in Japan provide an example of estimating the cost of operating (adopting) pollution prevention technologies. Costs were estimated according to the cost of removing the discharged residuals at the end-of-pipe while maintaining the current level of economic activities (production and consumption)[33]. The cost of removal is set equal to the cost of operating air and water pollution prevention technologies. For SO_x, estimates were made for the volume of removal by desulfurization devices. For NO_x, estimates were made for the volume of removal by exhaust denitration devices. These estimates provide technology-specific cost estimates necessary to reduce emission levels of a given pollutant. The estimates can be used to determine the economic impact of existing and proposed environmental policies that require the reduction of emissions to a specific standard, according to the best-available-technology.

Cost estimates can be combined with physical accounts to provide a breakdown by emission source and by the type of natural asset impacted. In Japan, for example, the total estimated environmental cost for 1990 was 8.4 trillion yen, and the ratio to NDP was 2.3%. 75.7% of air and water pollution was attributed to the production activities of industries and 24.4% was attributed to the consumption activities of households. 79.0% of maintenance costs were attributed to air pollution, and 2.3% to water pollution. These figures indicate that air pollution is a greater problem in Japan than water pollution, and that industry is the greatest contributor to both air and water pollution. This information can be used to design policies that target industry for the air pollution problem in Japan.

Figure 3.4

If data is collected over time, increases and decreases can be observed in sectoral costs and environmental impact. While the total cost increased from 8 trillion yen in 1985 to 8.4 trillion in 1990 (1.2% rate of increase), the cost attributable to the consumption activities of households increased by 4.3%, and the cost attributable to the production activities of industries increased at 0.3%[34]. These estimates can also be used to indicate sectoral economic investment opportunities for environmental protection or target areas for government programs. In Japan, the data would indicate that households were increasingly contributing to environmental pollution and to most effectively reduce pollution levels, households should be the primary focus of government policy. Analysis would show which areas of pollution (air, water, land) that households were contributing to, and this would provide additional information for policy design purposes.

Maintenance cost estimates for specific "pollution prevention" technologies that breakdown financial requirements by sector can be used to estimate the economic costs of an environmental policy or program. Maintenance cost estimates can also be compared to environmental expenditure accounts to arrive at the difference between the amounts currently being spent on pollution prevention measures, and those that would be required in the future, given the implementation of an air or water quality standard. Maintenance costs for Korea are estimated for wastewater treatment technologies that include the capital and operating costs of a sludge treatment plant(s) and land-fill(s)[35]. These costs can be estimated for the level of treatment necessary to meet a predefined emission standard or criteria that form part of an environmental law or regulation.

Table 3.3 **Combined Physical and Monetary Accounts**

Year		**BOD Discharge**		**Costs**	(million Won)	
	Domestic	Industrial	Livestock	Domestic	Industrial	Livestock
1991	1,481	79.24	397	667,163	27,318	1,235,524
1992	1,434	84.0	422	709,740	32,344	1,386,142
1993	1,319	85.71	471	648,296	36,192	1,567,187

Source: KETRI 1995

Physical accounts of emissions can be used with monetary accounts to identify priorities for policy decisions. In Table 3.3, the amount of BOD emitted by domestic wastewater is 2.8 times that of livestock wastewater in 1993, but the cost of livestock wastewater treatment is about 2.4 times that of domestic wastewater treatment. While the contribution of livestock wastewater to total BOD discharge into water bodies is not as high as that of domestic wastewater, the maintenance cost of BOD discharged from livestock wastewater is very high compared to domestic wastewater. This is mainly due to the treatment cost increase by the higher concentration of water pollutants in livestock wastewater. This indicates that the [Korean] government should put a higher priority on developing more cost-effective methods for livestock wastewater treatment to improve the water quality of in-land waterways.

3.3 Dose-Response

Estimates the damage to human health as a function of emissions

Dose-response estimates provide information on the relationship between pollutant concentrations and their effect(s) on human health. For example, a certain percentage increase in pollutant concentration will increase the morbidity or mortality by a certain percentage. Estimates also include how economic damage is incurred, and the amount of the damage as a result of pollution related health problems. Information from pollutant concentrations and their effects on human health also indicate the magnitude of a pollution problem, but from the perspective of the impact on human health. Percentage increases for different pollutants (e.g., 1 percent increase in particulate matter increases mortality rates by 0.1 percent), give an idea of which pollutants have the greatest impact, and also provide an estimate of the magnitude of the impact. This can be used to target policy interventions. This information can also be used to set up emission standards based on concentration levels according to their affect on human health.

Dose-response estimates also include how damage is borne or incurred, usually in the form of medical expenditures and work days lost. This data can be used to assess how pollution is affecting human health, and whether its effects are causing the most damage in the form of increased illness or death. This would give an idea of how society loses productivity that is related to environmental pollution, and can be used to address those pollution sources that are causing the most losses in productivity and damage to human health, as well as assess the progress of pollution prevention or regulation. Monetary estimates of the damage caused can be used in cost-benefit analysis to determine the economic gains (or costs that can be avoided) of regulatory standards and pollution prevention programs.

Dose-response estimates are particularly useful for major urban centers in developing countries that are increasingly suffering from the effects of air pollution (CO_2, SO_2, NO_x, as well as particulate matter) due to rapid industrialization, urbanization and automobile usage. The damage of urban and rural air and water pollution in India is estimated according to its impact on human health (morbidity or mortality). The results give an idea of the general impact that [air] pollution has on selected populations in India in terms of medical and hospital fees, work days lost, and death rates. (Table 3.4) Dose-response assessments can be used to determine if the impact on human health is increasing over time beyond levels that are considered acceptable to society[36].

Bronchitis/Asthma Patient Medical Attention

1. Mild attacks - no doctor visits, one work day loss
2. Moderate attacks - two doctor visits per attack, three work days lost

3. Severe attacks - 5 days in the hospital, 10 work days lost

Morbidity Expenditures (*example*)

1. Medical Consultation
   - Doctors fee
   - Diagnostic tests
   - Medicines
2. Hospitalization

Total Economic Value of Increased Respiratory Illness (Dyspnea)

Table 3.4

Severity of Attack	**Number of People**	**Loss Suffered**	**Rupees (‘000s)**	**Total Rupees (‘000)**
Mild Attack	434,276 (50%)	One Workday Lost	36,045	36,045
Moderate Attack	173,710 (40%)	Consultation (80*R* x 2) Diagnosis (100*R*) Medicine (50*R* x 5) Transport (40*R* x 2) Workdays Lost (3 x 51)	26,309 16,443 41,107 13,154 25,157	129,011
Severe Attack	21,701 (5%)	5 Days in Hospital Diagnostic Tests Consultation Food Transport Workday Loss (Patient) Workday Loss (Assist.) Medicine	51,385 20,550 20,550 15,412 10,277 52,402 10,280 20,550	162,877
Total Impact				**223,809**

Source: IGIDR (1996)

This example details how pollution impacts human health in the form of respiratory illness. Economic losses are incurred through various medical expenditures and work days lost. The data also provides information on the extent of the impact as broken down by the number of people suffering from varying degrees of illness (mild, moderate, severe). 50% of the affected population suffers from mild attack, while 5% suffers from severe attacks. This data compiled over time, can be used to assess the progress of any measures taken to reduce air pollution, as reflected in the numbers and percentages of people suffering from respiratory illness. The total cost to society (223,809 Rupees), can be weighed against the cost of implementing regulatory standards that aim at reducing pollution levels, to assess the benefit to society of environmental regulation.

If this type of data is compiled over time, along with the physical accounts of pollution output (See Table 2.3) then it is possible to determine whether medical expenditures and the incidence of illness are increasing, as well as the *rate* at which they are increasing. If morbidity rates and subsequent medical expenditures are steadily or rapidly increasing, along with pollution flows, then this would signal to policy-makers that the particular type of pollution problem should be addressed. If estimates are calculated by region or locale, then this would indicate which areas are impacted the greatest by pollution, and policies could be designed accordingly. For instance, if a large metropolitan area has the highest morbidity rates and the highest levels of pollution, then more money could be allocated to the local or provincial government to implement pollution control programs.

When valued at market prices, does-response estimates can also provide the counterpart to the maintenance cost estimate in a cost-benefit analysis at the macro level. Results from these two estimates can be compared to determine whether the costs of environmental protection are proportionate to the benefits. (This is covered in more detail at the end of this chapter) Using maintenance cost together with dose-response estimates of pollution for a macro cost-benefit analysis may provide the most comprehensive method of estimating the costs and benefits to society of pollution abatement for policy-making purposes. Estimating human health benefits from reduced environmental pollution is associated with the necessity to value the costs and benefits of proposed environmental regulations. Converting air pollution-related health and environmental damages[37] into monetary values, an analysis of U.S. data has shown that that effects on health contribute approximately 90% of total damages[38]. The Clean Air Act and its amendments mandate the U.S. Environmental Protection Agency to establish primary standards to protect human health, with special emphasis on the health of particularly sensitive population groups. Executive Order #12291 requires Regulatory Impact Assessments of major federal rules and regulations, making cost-benefit analysis of health oriented standards a norm[39].

3.4 Contingent Valuation

Estimates how much households are 'willing-to-pay' for environmental protection

These studies give an idea of public opinion or the level of public support for an environmental problem and can be used to guide priorities in political decisions. Willingness to pay estimates the effects on an individuals' own intangible welfare. A chronological series of valuations made in the same way would give some indication about changes in public attitudes over time, and in how the state of the environment is perceived. If willingness to pay studies demonstrated increasing amounts over time, then it could be expected that the general public may be more supportive of environmental protection measures. This may be useful for decisions about implementing or designing economic instruments which involve user charges on emissions or products.

Charges that are levied formally on emissions of polluting sources such as households, include charges for water consumption (sewerage and sewage treatment), waste water effluent, municipal waste charges levied at flat rates with each household paying a fixed sum that is unconnected to the quantity of waste actually generated, and waste disposal taxes. Revenues from user charges can be used for waste collection and disposal, while revenue from taxes is generally used for an overall budget, or is earmarked for a broad range of environmental expenditures such as subsidies on waste treatment and recycling. Charges on products may include 'tax differentiations' for the areas of automobile transport and fossil fuels. Automobile transport charges consist of an individual car sales and an annual vehicle tax differential between cars with high and low emissions. Charges on fossil fuels include carbon taxes and charges based on the sulfur content of fuels.

Willingness to pay studies can help determine how much a country or some representative sample of the population would be willing to pay for user charges or taxes that would be used to lower emission levels. If the results of a study indicate that the population is not willing to pay for environmental protection, or is only willing to pay for certain aspects (e.g., wouldn't support a gasoline tax), then this would indicate that other policy alternatives should be investigated that would command a greater level of public support. Willingness to pay studies may also be useful at the local or municipal level to help determine user charges for wastewater treatment. Throughout the developing world, municipal sewage treatment and disposal are inadequate due to water subsidies which encourage excessive use and waste[40]. Municipal user charges are necessary to balance revenues and expenditures, and they also provide incentives to households (and industry) for conserving water and reducing waste. User charges incorporate the 'polluter pays' principle, by signaling to households and industries that those who generate more waste, pay more [for treatment] than those that generate less.

Example

Willingness to Pay (US$)	*Gasoline Tax*	*Waste User Charges (e.g., household)*	*Water User Charge (e.g., municipal)*	*Carbon Tax*
Municipal	450	132	432	32
Metropolitan Area	2300	342	654	132
National	4700	5432	3453	234

Willingness-to-pay studies, however, may not provide sufficient information by themselves to set user charges for resources such as electricity and water, but they would give a general estimate of a municipal (or other) population's willingness to pay (even an estimate of 'ability to pay' in developing countries would be useful for setting user charges or fees) for unsubsidized or less-subsidized utilities.

3.5 Defensive or Environmental Protection Expenditures

Measurement of the total economic costs of environmental protection

Measurement of sectoral costs

Measurement of unit abatement costs

Distinguishing defensive or environmental protection expenditures (EPEs) from other expenditures in the national accounts is useful for identifying environmental costs according to the sectors or groups incurring the costs, identifying the amount spent on each type of expenditure, and identifying the amount spent on each environmental medium (air, water, land). Environmental expenditure data classified in this way provides information for developing specific environmental policies. The information indicates current environmental priorities, cost-sharing between government, industry, households, and non-profits, and the demand for environmental goods and services.

Figure 3.5

For the UK, the majority of environmental expenditures are incurred by industry and government[41]. Over 80% of total expenditures is on waste, air and water. Information on sectoral expenditures indicates the potential for business opportunities in environmental pollution prevention and clean-up. For example, in the UK, the largest percentage of expenditures is incurred by industry and is spent on pollution abatement. This indicates that there may be a growing need for the development of pollution abatement technologies within the industrial sector. Expenditure amounts from these estimates can also be compared with maintenance cost estimates to determine how much additional expenditures would be spent to restore environmental quality or to meet a government specified standard.

Information on EPEs can also be linked to environmental indicators to evaluate the effects of environmental policy. The UN Draft Classification of Environmental Expenditures includes categories that are similar to the types of "responses" (to environmental issues) under the Environmental Indicators Matrix developed by the World Bank. The categories under Pressure in this matrix can be linked to physical accounts that measure emission levels of gases and other pollutants. The State (of the Environment) category is for recording pollutant concentrations in the air and water, as well as solid and toxic waste on land. This information can be used to set up and evaluate standards for ambient air and water quality. The Response category is composed of various types of policy, regulatory, and management options targeted toward the identified issue with the goal of reducing the amount of pollution in the environment. EPEs based on these categories can estimate the costs of moving toward established environmental targets and standards, and estimate the effectiveness of environmental expenditures over time.

Figure 3.6

Sectoral costs that are linked to environmental targets can be used to evaluate the effectiveness and efficiency of policy over time. Expenditure amounts can be compared to the rate(s) at which targets are being met, in order to assess whether the amounts spent are achieving justifiable progress. This information can be used to encourage the application of those technologies which provide the greatest amount of pollution reduction at the least-cost. EPEs can be used to evaluate the effects of environmental policies on the competitiveness of an economy. The expenditures represent economic costs incurred by society in order to address environmentally damaging techniques of production and levels and patterns of consumption. The greater the level of pollution, the higher the amount of EPEs required, resulting in greater costs to society and a less competitive economy.

The ratio of the amount spent on environmental protection expenditures compared to the Gross Domestic Product of a country shows the portion of the economy that is devoted to environmental protection and clean-up.

Table 3.5 **A Summary of Pollution Abatement Expenditure in the European Community - 1990**

Country	GDP (billion Sterling)	Pollution Abatement Expenditure	Pollution Abatement as % of GDP
Belgium/Luxembourg	113.1	0.7	0.7
Denmark	73.7	0.8	1.1
Germany	836.9	13.2	1.6
Greece	37.1	0.2	0.5
Spain	276.6	1.7	0.6
France	669.9	6.6	1.0
Ireland	23.9	0.2	0.9
Italy	613.4	4.4	0.7
Netherlands	157	1.9	1.2
Portugal	33.6	0.3	0.9
United Kingdom	549.5	6.5	1.2

Source: Ecotec Research and Consulting Ltd. (1993)

Compilation of pollution abatement expenditures for different countries can provide a basis for international comparisons of expenditure levels. Table 3.5 provides a comparison of abatement expenditure levels in the European Community. The data indicate that, for 1990, expenditure levels for the UK, France, Denmark, and the Netherlands were comparable, but well below those of Germany, in terms of the percentage of GDP spent on pollution abatement. Greece has the lowest level of expenditure, and Germany, the highest.

3.6 Combining and Comparing Results of Valuation Methodologies

Although many countries face constraints related to data gathering and modeling, in places where it is possible to perform additional valuation studies, or perhaps as research topics, performing different valuation methods in one or various combinations may assist in forming more comprehensive assessments of environmental pollution problems, their sectoral origins, and their impact on human life and the environment. The following are two examples of how combining valuation methods can be used to more comprehensively assess the monetary impact pollution has on society.

3.6.1 Maintenance Cost and Dose-Response

Comparing maintenance cost estimates with the monetary impacts to human health and ecosystems in the form of dose-response valuations provides a type of cost-benefit analysis at the macro level. Results from these two estimates can be compared to determine whether the costs of environmental protection are proportionate to the benefits (e.g., impact on human health that could be avoided). In order to compare the maintenance costs with the benefits, for example, air pollution maintenance costs could be compared with the damage air pollution causes to human health. For example, if the damage to human health from particulate matter equals US$10,000, and the maintenance cost estimate of how much it would cost to prevent or reduce particulate emissions to some acceptable level, is less than $10,000, than the benefits to human health of pollution prevention for particulate matter, outweigh the costs. The Philippine Environment and Natural Resource Project estimates the costs and benefits under two lead reduction targets (Table 3.6).

Table 3.6

Policy Option	Reduced Pb (g/l)	Benefit (P million)	Cost (P million)	Net Benefit (P million)
Mandatory Use of Unleaded Gasoline for all Equipped Vehicles	0.073	335.6	233 - 378	122 - (22)

World Health Organization Ambient Standard Compliance	0.1216	122.4	73.6 - 130	49 - (7)

Source: de Los Angeles and Peskin 1996.

Estimated maintenance costs are those costs that would be necessary to phase out lead in gasoline and to refit and manufacture vehicles that only use unleaded gasoline. The benefits to society are the reduction in health damages from cleaner air. In Metro Manila, health damages from air pollution total P2,557 million, which is greater than the approximate cost of air pollution reduction of at least P1,530 million[42].

3.6.2 Contingent Valuation and Dose-Response (Impact Assessment)

One problem with studies of willingness-to-pay is that they often may only be measuring 'ability-to-pay', due to differences in income levels. Poorer segments of society may indicate that they are willing to pay less than higher income groups, but in reality, they are not capable of paying the same amount. If a comparison is made between the results of a contingent valuation study and an impact assessment, the results will provide a more complete description of the impact of pollution and the amount people are willing to pay to prevent it. If a contingent valuation study indicates a low level of public support for environmental protection, but the impact assessment demonstrates that pollution is causing a high level of impact, this would signal to policy makers that the cost of emissions reductions may be beyond the capability of households' willingness-to-pay. For instance, if air pollution in a major metropolitan area in a developing country results in increased respiratory illness in the urban population, and yet a contingent valuation study indicates that there is a low level of public support for the reduction of air pollution emissions, then this could be an indication that the population is unable to demonstrate financial support for environmental protection, but still suffers from the effects of pollution. This prevents the assumption from being made that low levels of public support derived from contingent valuation studies indicate that the environmental problem is not or should not be a priority for government policy. In developing countries or in low-income areas, alternative management programs could be implemented which direct assistance to poorer segments of the population, rather than encouraging user charges or similar fees which may not be effective at reducing pollution generated by rural or poor urban populations. Instead taxes or fees could be levied on business or subsidies could be reduced and the revenue could be used for government or non-profit assistance programs.

These are examples of how valuation studies may be combined in order to better determine priorities for environmental pollution policies. If one or more methods are combined, a more complete picture can be obtained of the nature, and impact of pollution on society, and also of how much support the public is willing or able to provide for environmental protection.

Chapter Four

Conclusions and Recommendations

Steadily increasing levels of pollution on a global scale are posing greater threats than ever before to human health, the environment, and the economy itself. With the numbers of people suffering from poor air and water quality continuously increasing, and environmental quality steadily decreasing, the consequences require that action be taken to reduce pollution. How can we address pollution most effectively? Environmental regulation and economic instruments are examples of policy alternatives that can be used to help reduce environmental pollution by internalizing the costs imposed on society and the environment. Calculating the costs and benefits of pollution reduction to society can help identify those regulatory standards and economic instruments that are the most cost-effective, economically feasible, environmentally efficient, and that command the highest degree of public support.

Pollution is primarily the result of incorrect or below-cost pricing. Distorted prices result from the inability of economic markets to incorporate environmental services such as air and water into the traditional exchange system of goods and services (e.g., buy/sell). Price distortion also results from the failure of government policies to internalize the costs pollution imposes on society and the environment.

To address pollution, the prices of those goods and services whose production and consumption processes cause pollution should more accurately reflect pollution’s true cost. Prices that internalize the cost of pollution can be adjusted through environmental regulation and economic instruments. To design regulations and market-based economic instruments, basic information is required which is used to define the magnitude of pollution, its sources, and its costs to society. Pollution accounting methodologies provide this type of information.

One of the greatest uses of valuing the costs of pollution is the possibility to consistently and directly compare both the environmental and economic costs and benefits of policy measures to address pollution. The capability to estimate both the costs and benefits of environmental policy and its economic instruments provides a way for government to evaluate the feasibility of policy and regulatory proposals and their impact on the various sectors of society. Environmental costs should be used for priority setting (e.g., budgeting and policy priorities), as they reflect the technological and economic feasibility of environmental protection.

Sectoral environmental cost assessment is also one of the most important results of pollution accounting. It provides the initial cost measurement required for setting the level of cost internalization tools such as taxes, user fees, effluent charges and tradable pollution permits. Physical emissions accounts can be used in conjunction with sectoral cost assessments, as they provide sectoral breakdowns of pollution by source. Physical accounts can also be used to determine the magnitude of pollution impact on the global environment through transboundary flows (emissions) in terms of contribution from countries. The contribution to pollution from foreign sources can also be assessed using the physical accounts that measure the quantity of emissions received from the rest of the world.

For those who work on pollution at the national, regional or municipal level, a number of steps can be, or may already have been taken. These steps include:

- *Identification of data sources or data collection agencies*.

Data collection may pose a problem for developing countries that may not have an extensive institutional structure set up for data collection. Some types of data are available from published studies. *The Industrial Pollution Projection System* (World Bank Policy Research WPR 1431) gives emission coefficients in terms of pounds of pollution produced per US$ million of output. The International Standard Classification of All Economic Activities (UN 1990) provides a classification system for goods and services. Average [pollution] abatement costs by sector are listed in a World Bank study, *The Cost of Air Pollution Abatement* (Hartman *et. al.,* 1994). A model for air emission inventories also is provided by the World Health Organization in *Assessment of Sources of Air, Water and*

Land Pollution. Part one: Rapid Inventory Techniques in Environmental Pollution (Economopoulos 1993).

- *Identify key pollution problems from physical accounts of emissions*.

The physical accounts will show which emissions are produced in the greatest quantities. This information can be used to prioritize environmental policy in order to address pollution and pollutant problems according to their magnitude. Emissions accounts compiled over time can also be used to monitor the effectiveness of policies whose objectives are the reduction of emissions.

- *Apply valuation methods to derive numerical cost figures*.

The selection of which method to use depends on the situation in which the decision-making takes place, and on the policy objectives. It may be best to apply more than one method and to view each estimate as a piece of evidence in a larger scenario. For example, in a study analyzing the costs and benefits of U.S. air and water pollution control programs, cost estimates were made using five different valuation methods[43] to value pollution control costs and benefits to society. Ultimately, valuation approaches can be chosen to fit the specific needs, budget, and data limitations of the country.

- *Set priorities for policy and budgeting*.

Data from the physical emissions accounts can be used with the cost estimates in order to prioritize policy options and their budgetary requirements. Valuation methods help provide the cost analysis necessary to estimate the economic cost/impact of policy proposals, can be used to assess their economic feasibility in terms of available technology as well as their effectiveness in terms of pollution prevention, reduction or remediation.

- *Design regulatory policy and economic instruments*.

The numerical cost figures produced from the valuation methods can then be used in the policy design process. Cost analysis can help determine the economic feasibility of compliance with a desired air quality or water quality standard. The analysis can also be carried out for individual sectors of the economy to determine which sector(s) will bear the largest economic cost or burden of a regulatory policy. Similarly, cost analysis can provide data to help set the most feasible levels for economic instruments such as taxes, effluent charges, tradable pollution permits, and user fees. Sectoral analysis can be used to design sector-specific policies that target the individual sources of pollution.

- *Monitor progress, compile data and indicators regularly*.

  Where data gathering and monitoring stations do not exist, it may be advantageous for a country to establish or coordinate a program for this purpose. Without consistent and reliable data, the physical emissions accounts - which form the basis on which priorities are set and cost estimates are made - cannot be compiled. Data and indicators are also critical for monitoring the progress of pollution policies, and can indicate if pollution levels are increasing or decreasing over time.

[1] World Bank (*1996*).
[2] World Resources Institute (1996).
[3] ibid.
[4] ibid.
[5] ibid.
[6] Pearce and Warford (1993).
[7] A positive externality is the benefit that upstream forest owners provide to downstream farmers in the form of a steady water supply made possible by a forested watershed.
[8] Panayotou (1993).
[9] Grambsch and Michaels (1994).
[10] ibid.
[11] German deep-sea fishing, German coastal fishing in the North and Baltic Seas, river fishing, lake fishing, and pond management (aquaculture).
[12] The Federal Minister of the Environment, Germany (1991).
[13] van Tongeren J. in Lutz ed. (1993).
[14] UN/ECE (1989).
[15] UN (1993).
[16] Oda K., et. al. (1996).
[17] Factors that caused the unit cost of removal to fall included the fall in the price of environmental protection equipment owing to its wider availabilitiy, improvement in its capacity, and the economy of scale associated with the large fixed cost inherent in the sewage industry.
[18] Skånberg and Ahlroth (1997).
[19] Ibid.
[20] The World Bank (1993).
[21] Indira Gandhi Institute of Development Research (1996).
[22] de los Angeles and Peskin (1996).
[23] Ibid.
[24] Barde and Pearce (1991).
[25] Present condition in which the damage is still somewhat limited. Expected condition of forests in 2010 in the absence of any additional policy (80% of forests severely damaged).
[26] Hamilton and Atkinson (1996).
[27] VOSL can also be estimated using wage-risk studies and avertive behaviour.
[28] Leipert (1989).
[29] Bryant and Cook (1992).
[30] Ibid.
[31] de los Angeles and Peskin (1996).
[32] Bernow S. *et. al*., (1997).
[33] Oda K. *et. al*., (1996).
[34] Ibid.
[35] KETRI (1996).
[36] Although there currently are no defined levels of normal or acceptable morbidity and mortality rates, current or predicted rates can be compared with past rates to judge if they are increasing rapidly (e.g., significantly more rapidly than in recent years) over time, and with concurrent increases in levels of pollution.
[37] Mortality, morbidity, agricultural productivity, damage due to corrosion, and aesthetic damage (reduced visibility).
[38] Freeman (1982).
[39] Ibid.
[40] Pearce and Warford (1993).
[41] Bryant and Cook (1992).
[42] de los Angeles and Peskin (1996).
[43] Hoehn and Walker (1993).