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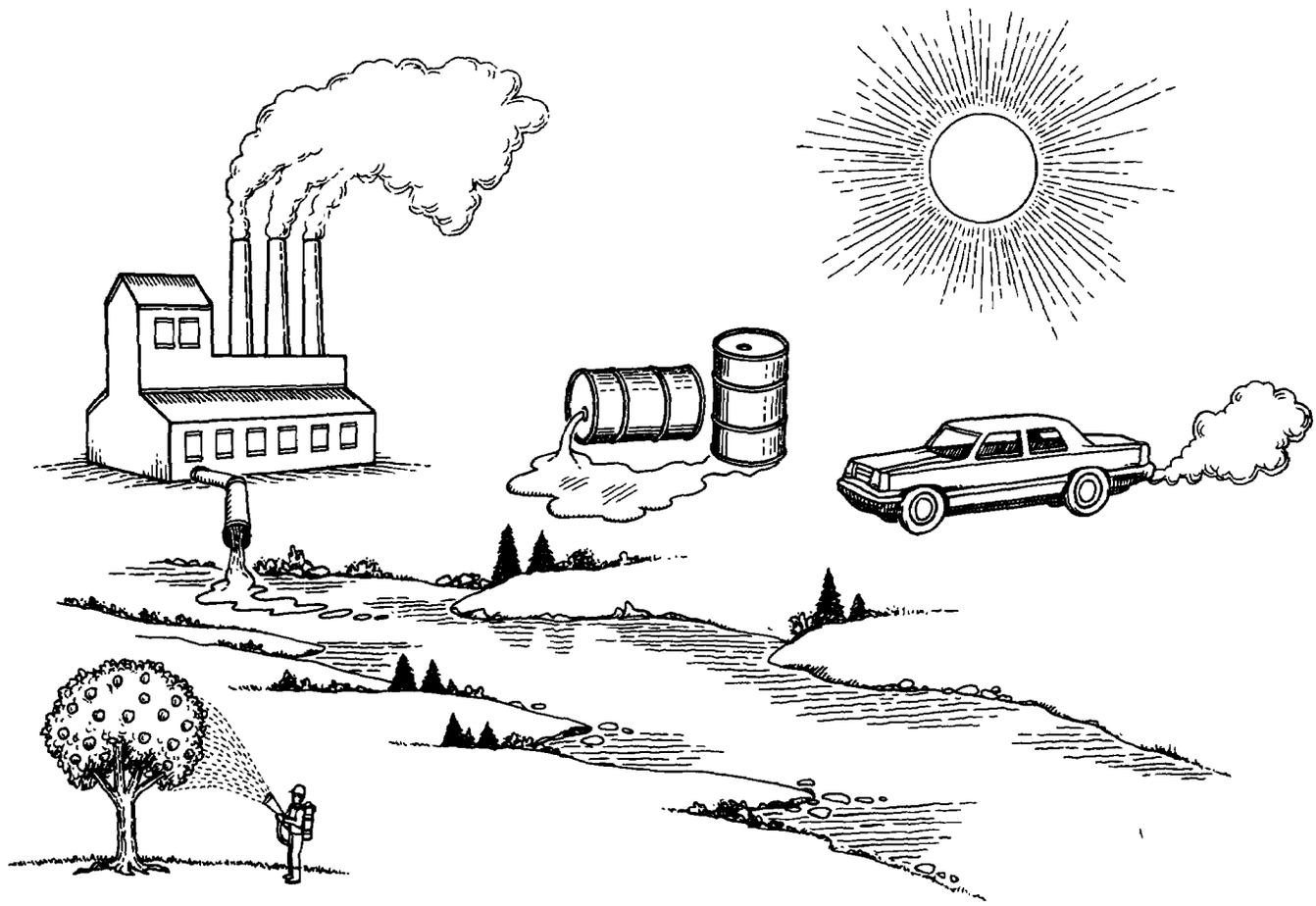
Unfinished Business: A Comparative Assessment of Environmental Problems

Appendix IV
Welfare Risk Work Group



AN ASSESSMENT OF WELFARE EFFECTS FROM ENVIRONMENTAL POLLUTION

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Comparative Risk Project

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Chapter 1

Introduction

Environmental pollution can cause diverse welfare losses, ranging from impaired visibility to reduced commercial fishing yields to losses in the property values of residences located near hazardous waste disposal sites. The definition of a welfare effect is not precise. Welfare effects from exposure to environmental pollution represent declines in the value of any commercial activity and declines in the value of other human activities. Activities related directly to human health are excluded from the welfare effects category, since these have been treated by other work groups on this project.

The Welfare Effects work group was established to rank the 31 environmental problems according to the severity of the actual and potential welfare damages they may cause. The work group was composed of senior managers from offices throughout EPA.

Ranking the 31 environmental problems was difficult, principally because of incomplete information about their effects and different levels of aggregration among the problems. Many types of welfare effects have never been assessed comprehensively. Even for welfare effects that have been analyzed extensively, only a small portion of the studies has been scientifically validated or reviewed by peers. Also, the basis for ranking some environmental problems has been a single or a few case studies. In these situations, we qualitatively weighed the evidence to assess the magnitude of effects. Because of the paucity of information, to a great degree these rankings depend on our subjective evaluations.

We also ranked environmental problems within five distinct categories of welfare losses. These are soiling and material damages (Chapter 2), recreational losses (Chapter 3), damage to natural resources (Chapter 4), damage to commercial and public property and to ground-water supplies (Chapter 5), and losses in aesthetic and nonuser values (Chapter 6). To give readers a better basis for understanding these rankings, this introduction discusses the procedures we followed in ranking the welfare effects and discusses some methodological issues associated with this effort. Chapter 7 presents a detailed rationale for our ranking and some recommendations based on the results of this effort.

PROCEDURE FOR RANKING WELFARE EFFECTS

We were asked by the Chairperson to fill out a set of fact sheets that detailed the types of welfare risks related to each of our programs. The fact sheets briefly describe each environmental problem, note the studies that have been conducted on the welfare effects the problem poses, present an estimate of the damages expected from the problem, and point out any serious methodological limitations of the studies the damage estimate is based on. To draw out relevant studies and data and to ensure the accuracy of our conclusions, we circulated the fact sheets to all of the relevant program offices for review and comment.

Because one goal of this project was to generate cross-fertilization between program offices, we grouped the fact sheets by type of welfare effect, instead of along programmatic lines. The topics we examined encompassed the full range of welfare effects: soiling and other material damages; recreation; natural resources; damages to other public and commercial property and ground-water supplies, and losses in aesthetics and nonuser values. These fact sheets formed the basis for Chapters 2 through 6 of this report.

Before ranking the environmental problems, we established the following ground rules to ensure consistency in accounting for the significance of environmental problems:

- Quantify effects as best as possible. Even when information about the extent of effects is sketchy or preliminary, weigh it so that the effects of alternative environmental problems can be projected.

- If possible, present a monetary estimate of damages. A monetary numeraire or unit provides a common basis for comparing effects across environmental settings.

- When possible, annualize monetary damages, and convert them into 1986 dollars.

- Aggregate damage estimates to a national basis whenever possible.

- Evaluate only current and future environmental effects--not effects that current EPA programs have already eliminated. This project is only concerned about ranking so-called uncaptured, or residual, effects.

- Rank future effects lower than present effects, all else being held constant.

We next ranked the 31 environmental problems. Each member first ranked the problems separately. Then, based on these individual rankings, the full work group constructed a composite ranking of the 31 environmental problems.

To facilitate the ranking and to allow for an accurate reporting of effects, we established ranges for expressing the relative severity of the damages from different environmental problems. This system presents our estimates of the national annual reductions in damages that would result from reducing pollution to levels that would exist in the absence of man-made polluting activities (background levels). When quantitative studies of damages were available, we listed their numerical values. Where information about annual damages was unavailable or incomplete, we expressed our best judgment of the severity of damages in terms of order-of-magnitude estimates. Table 1-1 shows these codes and their corresponding damage ranges.

Table 1-1

Coding System for Environmental Problems

Description of Damages	Code	Damage Range
Extremely Significant	(XS)	-- $1 billion or more per year
Significant	(S)	-- $100 million-$999 million per year
Moderate	(M)	-- $10 million-$99 million per year
Low	(L)	-- $1 million-$9 million per year
Not Applicable or Near Zero	(-)	-- $0 to several million per year
Uncertain	(?)	-- Subject to too great uncertainty for judgment

The dollar ranges associated with each code are not intended to imply a great degree of precision. Instead, they serve to systematically distinguish a small from a large effect. Although these judgments are inherently subjective, they give interested parties a sense of the basis for the final rankings of the environmental problems.

METHODOLOGICAL ISSUES

The original 31 environmental problems represent an overlapping set of sources, receptors, and pollutants. In many cases, we had difficulty classifying effects based upon the 31 problems.

For instance, many of the welfare effects from pesticides are attributed to two environmental problems: Nonpoint Source Discharges to Surface Waters (a source category) and To Estuaries, Coastal Waters, and Oceans from All Sources (a receptor category). As a result, the environmental problem Other Pesticide Risks is ranked lower than if these effects were considered as a separate source category. Thus, knowing what types of effects are included in each of the environmental problems is important for interpreting the rankings.

We also had difficulty ranking environmental problems with less severe welfare effects. Consequently, we are not confident of the relative rankings for this group of environmental problems.

Finally, it was not clear how to distinguish "welfare" effects from "health" or "ecosystem" effects. Often it is difficult to compartmentalize environmental problems into this set of categories. Partly, this is the result of the multidimensional nature of many environmental problems. Also, in many cases, the scientific literature and economic valuation techniques do not adequately distinguish effects by these separate categories.

For example, reductions in the property values of residences close to a hazardous waste disposal site may at first appear to be welfare losses. In this case, a welfare loss is defined as a loss in the commercial value of an asset or a good due to its exposure to an environmental pollutant. However, it could be argued that the reductions reflect peoples' responses to a "health" threat. Thus, the case could be made that reductions in property values indicate the amount people must be compensated to bear added cancer and noncancer risks and therefore should be evaluated in the health reports of this project.

Alternatively, suppose that risk assessments indicate that only small health effects can be documented as a consequence of the hazardous waste disposal site. This might be the case if many of the health effects were perceived but could not readily be identified. In this situation, it would be less clear as to whether to attribute the declines in property values to a "health" effect.*

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* A further complexity is introduced if health effects are misperceived. In this case, the possibility exists that the owners of residences may sell their properties at a discount to buyers who accurately appraise the health effects from the hazardous waste site. As a result, the welfare losses would actually be transfers from the original owners of the residences to the buyers.

A final complication is that property values may decline because of the unsightliness of the hazardous waste site facility, the operation of the site, the activities in the general area, or the pollution produced from the site. Declines resulting from the pollution would clearly be in the domain of environmental "welfare" losses; however, declines from the other three factors would not. Unfortunately, the literature on property value losses from hazardous waste sites has not attempted to attribute damages to different types of effects (nor is it clear that such distinctions can be made).

Similarly, problems result when attempting to distinguish "welfare" from "ecosystem" effects. In many cases, an environmental problem may fall into either type of effects. For instance, acid precipitation may reduce the diversity of forests (an ecoystem loss), thereby changing animal populations and limiting hunting opportunities (a welfare loss).

In cases of this sort, this report classifies welfare effects as those that are likely to result in losses to commercial activity or losses that can be monetized. On the other hand, ecosystem effects are effects that can be monetized in theory, but the techniques for doing so are too unreliable to be particularly useful or meaningful.

Given all the gaps in our knowledge, it was virtually impossible to sort out many of the complicated issues in evaluating welfare effects. We attempted to characterize welfare effects as accurately as possible, while explicitly recognizing the many difficulties associated with an effort of this nature. We generally included in our assessments welfare effects that are intertwined with health and ecosystem affects. Thus, double counting is likely to be present in the reports of the four work groups.

Chapter 2

Material Damages and Soiling

INTRODUCTION

Air and water pollutants can damage natural and man-made materials. For example, they corrode metals, erode paint and stone, crack paint and polymers, and discolor and soil fabrics. Materials at risk are typically buildings, bridges, pipes, cultural artifacts, machines, and clothing.

Because of the variety of materials and the complexity of the ways air and water pollutants damage them, estimating monetary damages is very difficult. In general, such estimation is based on measures of increased maintenance and repair of materials or more frequent replacement of them.

Table 2-1 lists the specific environmental problems that damage and soil materials, and ranks them according to the severity of the harm they cause. Because criteria air pollutants are such a large source of material damages, the table ranks each criteria air pollutant separately.

This chapter discusses these environmental problems, estimates the monetary damages from them, and explains how these estimates were developed and the limitations behind them.

MAJOR PROBLEMS

As Table 2-1 shows, three criteria pollutants damage materials significantly: particulate matter, acid precipitation, and sulfur dioxide.

Particulate Matter
(Part of Criteria Air Pollutants (#1))

Particulate matter is a generic term that covers various combinations of sizes and chemical constituents of particles emitted into the atmosphere. The National Ambient Air Quality Standard for particulate matter is currently based upon total suspended particulates (TSP), but may soon be changed to cover only particles smaller than 10 microns. This section assesses material damages from TSP, since most of the literature on this subject is based upon this measure of particulate matter.

Table 2-1

Ranking of Environmental Problems
That Damage and Soil Materials
(billions of 1986 $)

Rank	Environmental Problems	Damage to Manufacturing Materials	Damage to Residential Materials	Damage to Commercial Materials
	Major Problems			
	Criteria Air Pollutants			
1	Particulate Matter (1A)	3.2	15.5	--
2	Acid Precipitation (1B)	<----------2.8---------->		
3	Sulfur Dioxide (1C)	<----------1.7---------->		
	Minor Problems			
4	Drinking Water as It Arrives at the Tap	--	S	--
	Criteria Air Pollutants			
5	Ambient Ozone (1D)	?	?	M/L
6	Nitrogen Dioxide (1E)	?	?	M/S
7	Lead (1F)	--	S	--
8	Stratospheric Ozone Depletion	?	?	M/S

Key to Effects: Letter codes correspond to order-of-magnitude ranges for annual effects:

XS = Extremely Significant: damages of $1 billion or more.
S = Significant: damages of $100 million-$999 million.
M = Moderate: damages of $10 million-$99 million.
L = Low: damages of $1 million-$9 million.
-- = Not available or near 0: damages of $0 to several million dollars.
(?)= Uncertain: potentially high damages, but subject to great uncertainty.

Problem Characteristics

Particulate matter results in increased material damages and soiling to households and manufacturing firms. As a consequence, households and firms may increase their expenditures on cleaning materials and activities. In 1983, 6.9 million metric tons of TSP were emitted to the atmosphere (EPA, 1985b, pp. 3-9). The annual geometric mean of TSP that year was 48.7 micrograms/cubic meter (ug/m^3). Stationary sources, such as electric utilities, accounted for 80 percent of total 1983 emissions.

Research Approaches

Quantitative estimates of material damages and soiling have been derived from two studies: Mathtech 1982a and 1982b. The household soiling model described in Mathtech (1982a) is an econometric model that estimates the effects of TSP on the allocation of household budgets. Cross-sectional data on prices and expenditures from 24 large standard metropolitan statistical areas were analyzed for 21 aggregate goods. This analysis indicated that TSP is a significant factor in the demand for household cleaning goods and household utilities.

Mathetech (1982b) also developed a model that was designed to estimate TSP-related damages in the manufacturing sector. The hypothesis was that higher concentrations of TSP would increase costs of production due to increased expenditures for maintenance and repair of inventory or in-place capital equipment. Extrapolated estimates of reductions of TSP to background levels were developed under the assumption that the response function is approximately linear in TSP.

Estimated Damages

The Mathtech household model estimated unit damages to be $0.80 per household per microgram of change in TSP. Based upon this figure, the total damage estimate for household soiling nationally was $15.5 billion annually.

The study of manufacturing damages found that two sectors of the economy--fabricated structural metal products and metal-working machinery--incurred extra costs of about $3.2 billion annually due to TSP. Thus, total damages from TSP nationally were found to be approximately $18.7 billion annually.

Research Limitations

Because of data limitations, this research calculated TSP-induced damages for only a few manufacturing sectors, thus potentially accounting for only a portion of manufacturing losses. In addition, it did not estimate damages in other sectors.

Acid Precipitation
(Part of Criteria Air Pollutants (#1))

This section focuses on material damages resulting from acid precipitation (wet deposition). Effects related to dry deposition are evaluated in the sections that discuss gaseous sulfur dioxide and nitrogen dioxide.

Problem Characteristics

Acid precipitation deteriorates paint, accelerates the corrosion of metals, and dissolves stone and mortar. These damages can be observed on buildings; such infrastructures as bridges, transmission towers, and guard rails; and cultural artifacts. Cultural artifacts, such as statues, monuments, and buildings with carved stone surfaces, are generally composed of bronze, marble, or limestone, and are sensitive to natural weathering and elevated levels of acidic deposition.

The observed trend toward lower pH (more acidic) values in rainfall in the northeastern United States has been linked to increased emissions of sulfur dioxide from coal-fired power plants in the Midwest. However, questions have been raised as to the specific form of the relationship between the sources and receptors of acid precipitation.

Despite a consensus that emissions of sulfur dioxide and nitrogen dioxide are precursors of acidic deposition, our review foregoes joint consideration of primary sulfur dioxide (or nitrogen dioxide) and associated transformation products.

Research Approaches

In a draft report prepared for EPA, Horst et al. (1986) estimated the economic damages to buildings from current levels of acidic deposition. They measured the rate at which acidic deposition accelerates damage and leads to more frequent repair or replacement of materials.

The materials analyzed were paint (with silicate and carbonate extenders), zinc, stone, and mortar. Separate estimates of exposed areas for these materials were available for roofs, walls, chimneys, gutters and downspouts, and fencing. The estimates were derived from detailed ground surveys conducted in New Haven, Pittsburgh, Cincinnati, and Portland, Maine, by the U.S. Army Corps of Engineers (Merry and LaPotin, 1985).

In estimating economic damages to materials, Horst et al. relied on four assumptions:

- The physical stock of materials is constant over time.
- Sulfur dioxide and pH values are constant over time.
- Real maintenance costs are constant over time.
- Surface vintages are uniformly distributed over time.

With these assumptions, economic costs were computed for current and baseline levels of environmental quality.

Quantitative estimates of damage to infrastructures caused by acid precipitation are unavailable. However, studies have been completed that assess infrastructural damages due to precursor pollutants. These damages are addressed in the sections of this chapter that examine the impacts of sulfur dioxide and nitrogen dioxide.

Economic damages have been estimated for cultural artifacts as part of the National Acid Precipitation Assessment Program. The draft assessment chapter on material damages describes recent work by Rae (1984) that considered an inventory of statues, monuments, and historical buildings in the eastern United States. Damages for these items were computed on a replacement-cost basis (marble/limestone) or through an evaluation of long-term maintenance costs (bronze). The assessment was careful to note that the avoidance or replacement costs may have understated willingness to pay for certain items that are considered essentially irreplaceble.

Estimated Damages

Horst et al. estimated that if pH levels were reduced to background levels (5.6), the total annual cost savings for buildings would be $2.6 million for New Haven, $0.9 million for Portland, $18.0 million for Cincinnati, and $49.9 million for Pittsburgh.

These results are transformed into a normalized, weighted average of $16.82 per person per unit change in pH. This estimate can be used to approximate national cost savings by examining the joint relationship between population and pH in areas other than the case study cities. The derived national estimate is an annual value of $2.8 billion.

For cultural artifacts, the annualized damages are about $6.4 million. These damages are about an order of magnitude below the low estimate for common construction materials, but this estimate neglects willingness to pay for irreplaceable objects.

Research Limitations

The $2.8 billion estimate covers urban areas only and is limited to the materials identified above. The report on which this estimate is based (Horst et al., 1986) is being reviewed, so the damage estimates should be regarded as preliminary. Furthermore, the data used to develop the case study estimates are subject to considerable uncertainty. It is believed that the range of damages could span at least an order of magnitude.

Sulfur Dioxide
(Part of Criteria Air Pollutants (#1))

This section considers material damages from the dry deposition of SO_2. The previous section discussed the welfare losses from wet acid precipitation.

Problem Characteristics

Sulfur dioxide (SO_2) is produced largely by oil and coal combustion and nonferrous smelters. Electric utilities and industrial boilers are the principal emitters of SO_2. In 1982, they represented 67 percent and 11 percent, respectively, of SO_2 emissions. According to a recent SO_2 staff paper,

> sulfur dioxide has been associated with the corrosion of ferrous and nonferrous metals, [with the] degradation of zinc and other protective coatings, and with the deterioration of inorganic building materials (e.g., concrete and limestone) as well as paper, leather goods, works of historical interest, and certain textiles. (EPA, 1982c, p. 100)

In 1983, the mean annual average concentrations of SO_2 across 89 National Air Monitoring Sites and a wider set of 286 sites were 0.0115 and 0.0096, respectively (EPA, 1985b, pp. 3-13). The background level of SO_2 is less than 0.0019 part per million (ppm) annual arithmetic mean.

Research Approaches

Mathtech (1985a) analyzed the benefits of developing new source performance standards for controlling SO_2 from new industrial boilers. To calculate how much households are willing to pay for reductions in SO_2, Mathtech used the Mathtech household soiling model, which describes the relationship between SO_2 and the demand for various consumer goods.

Mathtech used a two-step procedure to estimate the national damages from sulfur dioxide. First, it developed an estimate of annual damages per ton on a per-person basis. Second, it used the normalized damages estimate to approximate the nationwide savings of reducing SO_2 to background levels. It based this estimation on 1983 county-by-county emission data provided by EPA.

Mathtech (1983) and (1985b) analyzed the effects of SO_2 on maintenance costs for a range of exterior structures, developed an inventory of materials and then estimated the costs of maintenance activities, calculated the statewide mean of SO_2 concentrations, and constructed a damage function. It used this information to calculate the benefits of reducing SO_2 to a selected low level. The maintained behavioral assumption was that repair activities occur at a fixed level of corrosion, called the "critical loss level." As SO_2 was reduced, more time elapsed before this level of corrosion was reached. Mathtech reduced annualized maintenance costs accordingly.

Estimated Damages

The research approach (Mathtech 1985a) yielded an annual estimate of the reduced material damage in the household sector if all SO_2 emissions from human activities were eliminated. The potential gains ranged from $0.32 to $3.2 billion, with a point estimate of $1.7 billion.

The Mathtech studies of exterior structures yielded a total damage estimate of $291 million per year. Damage to exterior painted surfaces accounted for $278 million (95%) of this total. Damage to other structures--including chainlink fences, galvanized wire, steet bridges, and transmission towers--in aggregate accounted for the remaining $13.8 million (5%) of the total.

Research Limitations

The Mathtech 1985a analysis provides only approximate measures of actual damages, since it does not consider adaptive behavior. The estimates have limited materials coverage.

MINOR PROBLEMS

As Table 2-1 shows, the environmental problems considered to cause minor material damages and soiling are Drinking Water As It Arrives at the Tap (#15); ambient ozone (#1D), nitrogen dioxide (#1E), and lead (#1F), which are subsets of Criteria Air Pollutants (#1); and Stratospheric Ozone Depletion (#7).

Drinking Water As It Arrives at the Tap (#15)

Problem Characteristics

Most water leaving public water treatment plants is relatively free of lead. However, corrosive water can cause the widespread leaching of lead and other corrosion by-products (e.g., copper and cadmium) into municipal water systems. While lead-containing materials can be corroded at water treatment plants, lead contamination occurs more often in water distribution systems and in household plumbing. Corrosive water can also break pipes, damage water meters and storage facilities, cause water loss, require excess repair and replacement of equipment, contaminate water due to leaks, increase pumping costs because of the reduced hydraulic efficiency of corroded or partly blocked pipes, cause a loss of service pressure, and raise the operating costs of providing water to customers.

Research Approaches

Many studies have sought to determine the extent of material damages to water distribution and household plumbing systems from corrosive water that also causes leaching of lead. Estimates of potential damages vary widely (Kennedy Engineers (1973) and (1979) and Ryder (1980)). These studies also have estimated the damages that could be avoided by controlling corrosion.

Estimated Damages

Studies have generally been divided between the economic costs incurred by (or occuring to) water utilities and private households. Estimates have been developed both for the country as a whole and for every household (the household estimate is then extrapolated to the nation). Based upon a midpoint figure of $8.50 per person, the national damages from corrosive water are roughly $537 million in avoidable costs for the 60-65 million people receiving the water (EPA 1986).

Research Limitations

Results of treatment in the field can differ from results obtained in the laboratory.

Ambient Ozone
(Part of Criteria Air Pollutants (#1))

Problem Characteristics

Unlike other criteria air pollutants, ozone (O_3) is not directly emitted by sources of pollution. Rather, ozone is

formed in the atmosphere through a series of chemical reactions involving volatile organic compounds (VOCs), nitrogen oxides (NO_x), oxygen, and sunlight. In 1983, VOC and NO_x emissions led to an average second-highest daily maximum one-hour ozone concentration of 0.146 ppm at National Air Monitoring Sites. Background levels for ozone range between 0.01 and 0.05 ppm.

The Ozone Criteria Document and Staff Paper (1985d) identify three categories of materials as being sensitive to ozone: textiles, paints, and elastomers. The impacts of ozone on textiles depend on its ambient concentration in combination with other factors, such as relative humidity, type of material, and moisture.

Estimated Damages

Ozone may damage both the dye and fiber strength of textiles. There are insufficent data to allow for a monetary estimate of damages to dyes, but according to EPA, "the limited research . . . indicates that ozone in ambient air may have minimal effects on textile fibers" (EPA, 1985d, p. 41).

Elastomers appear to be the product most vulnerable to material damage from ozone. If ozone were decreased, tire manufacturers could reduce their expenditures on antiozonants, and might see an increase in the number of used tire casings suitable for retreading. The Ozone Criteria Document estimated that the current annual cost of antiozonants for tires is $166 million. McCarthy et al. (1983) estimated a salvage value of about $3 per usable tire for retreading, and the Criteria Document reports that 17 million tires were rejected because of weather checking in 1980. This information suggests total annual damages of about $200 million.

Research Limitations

It is not clear how much expenditures for antiozonants would decrease if ozone were reduced to background levels. The change in economic costs associated with ozone-damaged casing also is difficult to predict. First, the adjustment in antiozonants is uncertain. And second, even if the changes in both ozone and antiozonants were known, the associated change in costs must be estimated.

Finally, it is unclear how many of the 17 million rejected tires were due to ozone, and how reducing ozone would affect future rejections.

Lead
(Part of Criteria Air Pollutants (#1))

Problem Characteristics

To preserve their effectiveness, pollutant control catalysts in motor vehicles require unleaded gasoline. However, because of lower prices, many people use leaded gasoline. Such misfueling can prematurely depreciate these devices.

Research Approaches

In a Supplemental Preliminary Regulatory Impact Analysis of a Ban on Lead in Gasoline (1985a), EPA attempted to determine the damages to catalytic converters from using leaded versus unleaded fuels. Using a replacement-cost methodology, EPA tried to quantify the degree to which misfueling would take place and the likely damages that would result.

Estimated Effects

Based on a projected misfueling rate of 20 percent of current levels, EPA predicts that material damages to motor vehicles from using lead in gasoline will be $148 million in 1988 (1986 dollars).

Research Limitations

It is difficult to predict the degree to which misfueling is taking place.

Stratospheric Ozone Depletion (#7)

Problem Characteristics

Chlorofluorocarbons (CFCs) are emitted into the atmosphere from a variety of human activities. These emissions mix in the lower atmosphere and eventually migrate into the stratosphere, where they are decomposed by ultraviolet radiation and release chlorine atoms. These atoms interfere with the process for forming ozone in the stratosphere, thus reducing the total amount of stratospheric ozone and shifting the ozone distribution to lower altitudes (NRC, 1976).

The two primary consequences of elevated concentrations of CFCs in the stratosphere are:

- increased levels of ultraviolet (UV-B) radiation at the earth's surface, and
- increased temperature and precipitation due to absorption and emission of infrared radiation.

The first effect harms certain materials, such as polymers. The second effect is additive to the climatic effects induced by increases in carbon dioxide concentrations from fossil fuel combustion and other human activities. We address the effects of climate change in Chapter 4 of this report. In this section, we consider only the effects associated with the increased level of UV-B radiation.

In the last several months, several EPA-sponsored conferences have focused on issues related to protecting the ozone layer. However, the papers prepared for these conferences are in draft form and are still being reviewed by peers. Thus, it is only appropriate to cite completed studies at this time. One such study is NRC (1982), which is a review and summary of available scientific data as of 1982. The remaining discussion in this section is drawn from that reference.

Computer calculations indicated that maintaining the 1977 level of releases of CFCs would result in a net decrease of total global ozone of five to nine percent, assuming no other pertubations. However, in reality, other factors may contribute positively or negatively to this depletion. For example, man-made sources of nitrogen dioxide (NO_2) appear to be increasing significantly due to agricultural practices and to solid waste disposal sites. It is estimated that a 30 percent increase in NO_2 concentrations could lead to a seven percent reduction of global ozone, all else held constant. The overall effect of joint consideration of NO_2 and CFC concentrations is believed not to be additive. However, the complexity involved in modeling atmospheric processes hinders the derivation of a single estimate of the joint effect.

Carbon dioxide emissions are thought to mitigate the adverse effects of CFCs and NO_2. Although increased carbon dioxide emissions (due to fossil fuel use) are expected to warm the troposphere, they are expected to cool the lower stratosphere. One result of this cooling is that the chemical processes involving ozone depletion are less efficient at lower temperatures. NRC (1982) reported that the reduction in ozone with CFC emissions at 1977 levels would be only four to six percent if global carbon dioxide concentrations were doubled.

Increases in UV-B radiation at the earth's surface are expected to lead to accelerated weathering effects for a variety of polymer products. The effects include yellowing, embrittlement, chalking, and decreases in tensile strength. Manufacturers of polymer products have recognized this problem and have developed pigments and stabilizers to mitigate the damaging effects.

Research Approaches

In a recent study for EPA, Horst et al. (1986) estimated the potential economic damages to selected polyvinyl chloride (PVC) products, given a time-dependent scenario for ozone depletion. They assumed that the producers of PVC products would be able to increase the amount of stabilizers to preserve the lifetime and quality of their products.

Estimates of economic damages were computed in a demand-supply framework for three PVC products: siding, profiles (including rainwater systems), and pipes and conduits. These products were selected primarily because of their exposure potential. Historical data were used to estimate an aggregate derived demand curve. Model plant data were used to identify long-run average costs. Welfare losses were computed as changes in consumers' surplus brought about by changes in production costs. A partial-equilibrium framework was assumed, with fixed input prices for stabilizers.

Estimated Damages

For moderate estimates of ozone depletion, Horst et al. estimated annual material damages from increased UV-B radiation at approximately $49 million.

Research Limitations

This estimate should be interpreted with caution. It is for the United States only, and covers only a portion of the polymers potentially susceptible to increased UV-B radiation. At a minimum, damages to all sensitive polymers in the United States are expected to be four times greater than the $49 million damage estimate.

In addition, this estimate is taken from the Andrary study (1986) which is in draft form and is still being reviewed. Finally, the long-term forecasts required to complete the analysis are subject to considerable uncertainty. A reasonable range for the point estimates identified above would span at least an order of magnitude.

Nitrogen Dioxide
(Part of Criteria Air Pollutants (#1))

Problem Characteristics

Nitrogen oxides (NO_x) are emitted primarily from the combustion of fossil fuels. Nitric oxide (NO), a colorless and odorless gas, is a major by-product of the combustion process. Available evidence does not indicate that NO in the ambient air is of direct concern for human health and welfare. However, oxidation processes in the atmosphere transform NO into one of

several other compounds, the most significant of which is nitrogen dioxide. Nitrogen dioxide is a reddish-brown gas that is corrosive and highly oxidizing.

The mean annual average nitrogen dioxide concentrations across the 14 National Air Monitoring Sites and a wide set of 177 sites were 0.031 ppm and 0.026 ppm, respectively, in 1983 (EPA, 1985a, pp. 3-29). Background levels for nitrogen dioxide range between 0.0001 ppm and 0.005 ppm. In 1983, mobile and stationary combustion of fossil fuels accounted for about 45 and 50 percent, respectively, of man-made emissions. Motor vehicles represented the largest share of mobile combustion emissions, and electric utilities made up the largest proportion of stationary combustion emissions.

Though very little quantitative information exists, nitrogen dioxide has been known to damage a variety of materials, including textiles, plastics, and metals. Nitrogen dioxide emissions significantly fade the dyes in many types of fabrics. In cellulose acetate, anthraquinone dyes (especially blue dyes) exposed to nitrogen dioxide show pronounced reddening. In cellulosics--cotton and viscose rayon--fading from exposure to nitrogen dioxide has been observed in both laboratory and field studies (at concentrations present in the atmosphere). Again, blue dyes are especially vulnerable. In nylon, acid dyes--especially certain violets and blues--can show significant fading. Polyester dyed with dispersed dyes is not affected by nitrogen dioxide exposure, though permanent-press fabrics (a blend of polyester and cotton) and textured polyester double knits fade as the dye migrates to surface coatings and residuals.

Several types of fabrics demonstrate the potential for yellowing when exposed to nitrogen dioxide: cellulose acetate and polyurethane-segmented fibers, nylon, garments containing rubberized cotton, fabrics treated with softeners, and nylon treated with a permanent antistatic agent. Fabric degradation results in reduced tensile strength and/or increased viscosity. In industrial fabrics, which comprise the end use for 18 percent of all fabrics, this effect can be costly and dangerous. A chamber study has demonstrated that nylon becomes significantly degraded when exposed to radiation at high temperatures with nitrogen dioxide, as compared to exposure without nitrogen dioxide (EPA, 1982d, pp. 13-19).

The effects of nitrogen dioxide on material strength is of primary concern for plastics and elastomers. Although most plastic materials show good chemical resistance to nitrogen dioxide, laboratory trials have found that air pollution hastens their aging.

Polymers are susceptible to sulfur dioxide, nitrogen dioxide, and ozone. Linear polymers, such as nylon and polypro-

pylene, are also known to be somewhat susceptible to nitrogen dioxide.

Nitrogen dioxide is believed to accelerate the corrosion of metals. However, most studies on metal corrosion have not examined the role of nitrogen dioxide in isolation from other causes of corrosion, such as sulfur dioxide or smog in general.

Research Approaches

Polymers were exposed to a combination of sulfur dioxide, nitrogen dioxide, and ozone. These gases are the major components of smog. The strength all of these materials decreased as a result of their exposure. Butyl rubber, an elastomer, was more affected by the sulfur and nitrogen dioxides than were the other polymers. However, ozone had the most pronounced effect on the rubber.

Estimated Damages

Based on a 1973 status report, the EPA Criteria Document for Nitrogen Dioxide estimated the cost of fading as a result of exposure to NO_x emissions to be $280 million (EPA, 1982d, pp. 13-16). Although there was little change in NO_x emissions between 1973 and 1983 (EPA 1975b, 1985b), production technology and inventory may have changed during that period.

SUMMARY

Pollution damages materials in a number ways. The major damages documented in this chapter stem from air pollution. Particulate matter is estimated to cause annual damages of $15.5 billion for households and $3.2 billion for the manufacturing sector of the economy. Acid precipitation causes $2.8 billion per year in damages, in addition to damages to cultural and other irreplaceable artifacts that cannot be readily valued. Sulfur dioxide is associated with a further $1.7 billion in material damages each year.

A number of minor categories of material damages are assessed in this chapter. Corrosive water leaches lead in municipal water systems, resulting in estimated damages of $0.5 billion annually. Ambient ozone is projected to cause moderate annual material damages, particularly to paints and elastomers. Damages from nitrogen dioxide are roughly $0.3 billion per year from the fading of fabrics, in addition to unquantified damages to other materials. Using leaded gasoline in vehicles requiring unleaded fuel results in annual damages of roughly $0.1 billion. Finally, stratospheric ozone depletion is projected to cause moderate to significant material damages annually.

Chapter 3

Reduced Recreational Opportunities

INTRODUCTION

Environmental pollution affects many types of recreational activities, such as picnicking, playing tennis, and camping. Because only limited data are available on the values of outdoor recreation and how environmental pollution changes these values, this chapter only covers the effects of water pollution on swimming, fishing, and boating, and the effects of air pollution on sportfihing and hunting and pesticide use on hunting.

Table 3-1 lists the five specific environmental problems that reduce these recreational opportunities, and ranks them according to the severity of the harm they cause. Because of the particular ranking method used, the damages to the individual recreational categories (e.g., swimming versus sport fishing) cannot be delineated.

This chapter discusses these environmental problems, estimates the monetary damages they cause, and details how these estimates were developed and the limitations behind them.

MAJOR PROBLEMS

The major environmental problems that reduce recreational opportunities are Discharges from Direct and Indirect Point Sources to Surface Waters (#9, #10); Discharges from Nonpoint Sources to Surface Waters (#11); and To Estuaries, Coastal Waters, and Oceans from All Sources (#13). Because problems #9, #10, and #11 all affect surface waters, this chapter discusses them in one section.

Discharges from Direct and Indirect Point Sources (#9, #10) and Nonpoint Sources (#11) to Surface Waters

Problem Characteristics

Discharges from industrial (direct-point) and municipal (indirect-point) sources of pollution and from the runoff of pesticides, acid mine drainage, and fertilizers from the land (nonpoint sources) can seriously limit water-oriented recreational activities. Currently, a substantial portion of the nation's lakes and streams are too degraded to support fishing, boating, and swimming. Based on state assessments of water quality, it is estimated that the quality of 1.4 million surface acres of streams and 4.3 million surface acres of lakes is substandard.

Table 3-1

Ranking of Environmental Problems
That Cause Recreational Damages
(billions of 1986 $)

Environmental Problems	Reduced Swimming Activities	Reduced Boating Activities	Reduced Fishing Activities	Reduced Hunting Activities
Major Problems				
Discharges from Nonpoint Sources to Surface Waters	<---------- 3.7 ---------->			--
Discharges from Indirect Point Sources to Surface Waters	<---------- 2.5 ---------->			--
Discharges from Direct Point Sources to Surface Waters	<---------- 0.8 ---------->			--
To Coastal Waters, Estuaries, and Oceans from All Sources	<---------- XS* ---------->			--
Minor Problems				
Criteria Air Pollutants	--	--	L/M	?
Other Pesticide Risks	--	--	--	?

* Effects to estuaries, coastal waters, and oceans are largely estimated by source categories (i.e., nonpoint source discharges).

Key to Effects: Letter codes correspond to order-of-magnitude ranges for annual effects.

XS = Extremely Significant: damages of $1 billion or more.
S = Significant: damages of $100 million-$999 million.
M = Moderate: damages of $10 million-$99 million.
L = Low: damages of $1 million-$9 million.
-- = N/A or near 0: damages of $0 to several million dollars.
? = Uncertain: potentially high damages, but subject to great uncertainty.

Research Approaches

The estimated welfare losses from these enviromental problems are based on people's willingness to pay for successive improvements in surface water quality that would make waters suitable for boating, swimming, and fishing. Here, willingness to pay includes not only the value participants of water-oriented recreation place upon these improvements, but also the value nonusers place on them for their aesthetic value, for the option of using them in the future, or for other reasons. (Nonuser values for all environmental media are also addressed in Chapter 6 of this report.)

To document these welfare values, we primarily relied on Mitchell and Carson (1984). Their study estimated welfare values attributable to successive levels of improvement to these surface waters based upon a contingent-valuation survey. The study then allocated these values to different sources of pollution.

We assumed those values would be realized from improving lakes and streams that currently do not fully support their designated uses (such as fishing or swimming). In EPA surveys, such waters are referred to either as "not supporting" or as only "partially supporting" their designated uses.

The EPA surveys also report on the proportion of stream miles and lake surface acres primarily affected by particular sources of pollution. We used these data to allocate the values from water quality improvement to the various sources.

Estimated Damages

The estimates from the Mitchell and Carson study appear in Table 3-2. It presents the user and nonuser values of surface waters for different levels of improvement in water quality. The table shows (Column 1) the value to each household for these successive improvements and (Column 2) the value to the nation as a whole. The survey and the study allow for two different interpretations about where we are now with respect to water quality and, hence, what potential benefits remain from further improvement.

One interpretation is that respondents regard "boatable" as referring to a situation where water quality is at least boatable, although the quality of many fresh water bodies is higher, and that this refers to the current level of water quality. Based upon this assumption, the potential remaining reductions in welfare losses from successive improvements in water quality to fishable and swimmable levels would be $13.0 billion per year, as shown in Column 3.

Table 3-2

Values of Various Levels of Water Quality

Upgrades in Water Quality	(1) Value Per Household ($/year)	(2) National Recreational Values (billions 1986 $/yr) Overall	(3) From Present High Est.	(4) From Present Low Est.
Increment to boatable from zero base	97	8.2		
To (99%) fishable from boatable	73	6.2	6.2	0.6
To swimmable from fishable	82	6.8	6.8	1.7
Total	252	21.2	13.0	2.3

Another interpretation is that respondents regard the water quality levels as referring to a hypothetical situation in which water quality is predominately at a boatable level, or predominately fishable, etc. Since we already are a good part of the way toward having fishable and swimmable water, a large part of the values that would come from further water quality improvements in Column 3 have already been achieved. As a result, the remaining potential values would be much less, as shown in Column 4.

Thus, in a side investigation, Mitchell and Carson estimated that the value of going from a situation in which 95 percent of the water is fishable to the practical limit of 99 percent fishable would be only eight percent of the fishable increment shown in Table 3-2, or $0.6 billion per year. Since 95 percent fishable is a good description of the current water quality situation, the latter dollar figure is an estimate of remaining potential benefits.

Reasoning similarly, the study found that 70-80 percent of the water classified as potentially swimmable is already swimmable. Assuming 75 percent of the swimmable values shown are already being enjoyed, the remaining potential values from improving water quality for swimmability were estimated to be $1.7 billion per year.

The low estimate of remaining gains from providing fishable, swimmable water is, therefore, the sum of the last two estimates or $2.3 billion per year. The high estimate is $13.0 billion, and the mid-range estimate, used in Table 3-3, is $7.7 billion.

Table 3-3 shows the results from the second step of our analysis. We allocated the potential benefits of water quality improvements among the various sources of pollution, using two sets of data. The first is an estimate of lake surface acres and stream miles not fully supporting their designated uses. The designated uses for most bodies of surface water are swimming and fishing (EPA, National Water Quality Inventory, 1985). We converted stream miles to surface acres to get a single measure for the two kinds of surface water. We estimated that 1.4 million surface acres of streams and 4.3 million surface acres of lakes do not fully support their designated uses--that is, they are substandard.

The second data set from the same source is a survey of the causes of water quality problems. For streams and lakes, we estimated the proportion of substandard water attributable to various sources (EPA, National Water Quality Inventory, 1985). From these data sets, we calculated the first column of figures in Table 3-3 and then used these figures to allocate the total benefit estimate attributable to various sources.

The greatest losses are from nonpoint sources ($3.7 billion per year), followed by municipal point sources ($2.5 billion per year), and industrial point sources ($0.8 billion per year). These estimates include both recreational and nonuser values.

The mid-range assumption regarding potential values implies that water quality improvements could increase water-related values 56 percent over what they are now. Currently, these values are roughly $13.6 billion. With successive improvements in water quality, they could rise to $21.3 billion. Based on the low and high estimates of remaining welfare values, the remaining values represent an increase over current water-related levels of from 12 to 160 percent.

In an assessment by Freeman (1982), recreational and nonuser values covered by the estimates in Table 3-3 account for 60 percent of the gains from cleaning up fresh water. The remaining gains would come from diversion uses--e.g., drinking water.

Research Limitations

Calculating welfare losses necessitates making a number of assumptions. For example, EPA surveys assessed only a portion of the total surface waters. To obtain a national estimate of the surface waters not supporting designated uses, we

Table 3-3

Proportion of Substandard Surface Waters Primarily Affected by Specific Sources*

Sources of Pollution	% of Surface Area Primarily Affected by Indicated Source	Welfare Losses (billions of 1986 $/yr)
Point Sources	42.5	3.2
Industrial Point Sources	10.3	0.8
Municipal Point Sources	32.3	2.5
Nonpoint Sources	48.8	3.7
Natural Sources	3.5	0.3
Other Sources	5.2	0.4
Total	100.0	7.7

* Numbers may not add because of rounding.

extrapolated the figures from the sampled portion of surface waters to a national figure. It is unclear whether the surface waters considered in the sample are representative of the quality of the nation's waters in terms of size and water quality. The assumption here is that the surveys assessed the larger streams and that those not assessed are meeting designated uses.

EPA generally presents water quality assessments in terms of stream miles for streams and surface acres for lakes. To assess welfare losses by specific pollution categories, we converted stream miles to surface acres. Analysis of aggregate data on fishing activity on lakes versus streams suggests that surface acres are a reasonable measure of fishable water.

A last limitation stems from the survey design of the Mitchell and Carson study itself. Based upon the set of survey questions, it is unclear as to whether respondents were asked to value hypothetical improvements assuming all fresh waters were at specific states of water quality (e.g., from

swimmable to fishable) or just improvements in that subset of fresh-water bodies that are actually at certain levels of water quality (e.g., only water bodies that are swimmable to fishable). As a result, we could construct only a broad range of welfare loss estimates.

To Estuaries, Coastal Waters, and Oceans from All Sources (#13)

Problem Characteristics

Deteriorating water quality in estuaries, coastal waters, and oceans threatens swimming, boating, and sportfishing opportunities. Pollution of near coastal waters may also affect the coastal tourist industry (including waterfront development), which has experienced rapid growth in recent years.

Research Approaches

EPA's National Estuary Program has designated seven estuarine areas for water quality improvements. These areas are the Cheaspeake Bay in Maryland, Long Island Sound, Albemarle and Pamlico Sounds in North Carolina, San Francisco Bay, Buzzards Bay in Massachusetts, and Puget Sound in Washington.

The methodological approaches for estimating the recreational losses to these waters from pollution are based on a preliminary analysis of values in the Long Island Sound (Draft EPA report, 1985). Various estimation methods were applied in this analysis. Values were measured in terms of changes in willingness to pay, and a combination of techniques was used to measure the value of recreational use (e.g., travel costs, contingent valuation, and unit-day-value).

To estimate the values that recreational users place on water quality, the Long Island Sound analysis surveyed people living near the Sound. They were asked to reveal the values they placed on being able to use the Sound for recreation. The study added the total values, divided the sum by the number of people surveyed, and then multiplied the individual value times the number of people living in the area. For the other six selected estuaries, the average individual value calculated from the Long Island Sound study was multiplied by the total populations living in their surrounding counties.

Estimated Damages

As Table 3-4 shows, water quality improvements are estimated to reduce recreational damages in the seven estuaries by anywhere from $152 million to $473 million annually. These values were the sum of estimates for each of the estuaries.

This range includes the major recreational uses of beach swimming, boating, and sportfishing.

Table 3-4

Estimates of the Recreational Values of Selected Estuaries

Estuaries	Population of Surrounding Counties (000)	Annual Values (millions of 1986 $)
Long Island Sound	5,483	56 - 174
Buzzards Bay	600	6 - 19
Narragansett Bay	947	9 - 30
Albemarle Sound	121	1 - 4
Pamlico Sound	111	1 - 3
San Francisco Bay	3,966	41 - 126
Puget Sound	2,149	23 - 69
Chesapeake Bay	1,519	15 - 48
Total	14,896	152 - 473

Research Limitations

In addition to the specific dollar estimates for estuaries, it is important to consider the recreational values associated with near coastal waters (tidal shorelines). It is difficult to estimate the incremental values that could accrue as a result of the improvement in the quality of near coastal waters, even though trends indicate that protection is increasingly important (e.g., population growth in the shoreline regions of the country and degradation is resulting from a variety of sources). A U.S. Fish and Wildlife Service survey estimated that the gains to recreational fishing from improved water quality exceeded $2 billion in 1985. That estimate did include the substantial values associated with fishing expenditures. For purposes of this chapter, the recreational estimates for estuaries and near coastal waters are limited to the seven bodies of water in the National Estuary Program.

The major limitation to the estuary estimates is that they are only simple extrapolations of Long Island Sound damages to other regions covered by the National Estuary Program. Certain assumptions of the similarity across estuaries underlie the use of the estimates presented in that study, such as:

- the economic activities that take place (fishing and recreational aspects);
- the species and distribution of shellfish and other fish;
- the amount of beach swimming area relative to the amount of shoreline;
- the level of water quality deterioration and degree of future cleanup and control;
- the manner in which economic activities are affected by changes in water quality; and
- the economic activities that could benefit from improved water quality.

EPA does not have an aggregate estimate of welfare losses to all estuaries and coastal waters. We thought that if a national figure were calculated, annual damages would fall in the extremely significant category.

MINOR PROBLEMS

We ranked only two environmental problems that affect recreational opportunities as minor: the impact of Acid Precipitation on recreational hunting activities and sportfishing, and Pesticide use on hunting.

Acid Precipitation
(Part of Criteria Air Pollutants (#1)

Problem Characteristics

Acid preciptation can lead to declines in fish populations, reducing sportfishing opportunities. In addition, it can disrupt forest ecosystems, changing the diversity of forest species, reducing animal populations, and thus limiting hunting opportunities.

Research Approaches

Quantitative estimates of damages from reduced sportfishing from acid precipitation have been calculated using travel-cost and participation models for lakes in the Adirondack region (Baker and Harvey, 1984). This region has been one of the areas in the United States most affected by acid precipitation. With the participation model, estimates of changes in fish catches were linked to changes in total fishing days, and changes in fishing days were multiplied by the value of each fishing day to determine total damages. A fishing day was valued at $30, based upon a previous study by Vaughn and Russell (1982).

With the travel-cost method, the Adirondack region was divided into 24 sites. Site-specific declines in fish populations were used to assess total damages.

Estimated Damages

Both models estimated damages at between $3 million and $6 million annually.

Research Limitations

A number of caveats accompany the sportfishing analyses. First, these damage estimates are for the Adirondack lakes only and do not include streams. Second, several of the sites were excluded from the travel-cost analysis due to data problems and third, the dose-response relationships underpinning these analyses are uncertain. No national estimate of damages was available.

The effects of acid precipitation on hunting have not yet been estimated quantitatively. A large variation in damages can be expected, depending on the hunting area and the extent of the change in the density of forest species.

Other Pesticide Risks (#27)

Problem Characteristics

A number of pesticides pose risks for avian wildlife, thereby limiting hunting activities. For example, diazinon is particularly toxic to waterfowl. Duck populations are at all-time lows, with pesticides probably contributing to their declining numbers.

Research Limitations

No estimate of damages was available. No attempt has been made to calculate losses of wildlife from exposure to pesticides.

SUMMARY

Most of the damages to recreational opportunities result from water pollution. Major problems include Discharges from Nonpoint Sources and from Indirect and Direct Point Sources to Surface Waters, and To Estuaries, Coastal Waters and Oceans from All Sources. Diminished sportfishing and hunting activities from Acid Precipitation and Pesticides are listed as minor problems.

Chapter 4

Environmental Damage to Natural Resources

INTRODUCTION

This chapter examines five types of natural resources that can suffer losses from environmental pollution. These are crops, livestock, forests, commercial fisheries, and agricultural land.

The first four resources are sources of foods or raw materials for useful products. The fifth is a productive asset. In this chapter, natural resources are valued as commercial commodities. Damage estimates are based on losses of commerical production, not on aesthetic or recreational factors (which are addressed in other chapters in this report).

An overall summary and ranking of the effects of environmental pollution on natural resources is presented in Table 4-1. It shows that natural resources are most susceptible to atmospheric ozone buildup, acid precipitation, stratospheric ozone depletion, pollution of surface water from nonpoint sources, and global warming. Significant effects on natural resources exist also in the case of potential accidents involving biotechnology. Many other environmental problems have adverse effects on natural resources at moderate to low levels.

This chapter first discusses the difficulties we ran into in ranking the environmental problems that affect natural resources. It then presents the ranking of environmental problems, explaining why those problems were selected and identified as major and minor problems. Finally, the chapter looks at each problem individually and then summarizes our findings on damages to natural resources.

DIFFICULTIES IN ASSESSING DAMAGES TO NATURAL RESOURCES

In attempting to assess the damages to natural resources from environmental pollution, our major concern was the limited amount of quantitative information available for this ranking exercise. Data from formal studies are available for only five of the 31 environmental problem areas outlined in this project (see Table 4-2). The studies have a number of methodological problems, and they vary in quality. Some of the estimates for welfare damages are for current years (the 1980s), while others, such as those for global warming, are for the distant future (a century from now).

Table 4-1

Ranking of Environmental Problems That Affect Natural Resources
(billions of 1986 $)

Rank	Environmental Problems	Damages to Crops	Damages to Livestock	Damages to Forests	Damages to Fisheries	Damages to Agric. Land
	Major Problems					
1	Criteria Air Pollutants (Atmospheric Ozone)	XS/S	--	M	--	--
2	Criteria Air Pollutants (Acid Precipitation)	M	--	S	L	--
3	Stratospheric Ozone Depl.	XS	M/S	M	S	--
4	Nonpoint Source Discharges to Surface Waters	S	--	--	--	M
5	CO_2/Global Warming	M/S	--	?	--	S
6	Biotechnology	?	?	?	--	--
	Minor Problems					
7	To Estuaries, Coastal Waters and Oceans from All Sources	--	--	--	M/S	--
8	To Wetlands from All Sources	--	--	--	M	--
9	Hazardous/Toxic Air Poll.	L/M	--	L	--	L/M
10	Direct Point-Source Discharges to Surface Waters	--	--	--	L/M	--
11	Indir. Point-Source Discharges to Surface Waters	--	--	--	L/M	--
12	Other Criteria Air Poll.	L	--	L	--	--
13	Mining Waste	--	--	L	--	--
14	Acciden. Releases of Toxics	--	--	--	L	--
15	Accidental Oil Spills	--	--	--	L	--
16	Active Haz. Waste Sites	L	--	--	--	L
17	Inactive Haz. Waste Sites	L	--	--	--	L
18	Contaminated Sludge	--	--	--	L	--
19	Other Pesticide Risks	--	L	--	--	--
20	Other Ground Water Contam.	L	--	--	--	--

Key to Effects: Letter codes correspond to order-of-magnitude ranges for annual effects.

XS = Extremely Significant: damages of $1 billion or more.
S = Significant: damages of $100 million-$999 million.
M = Moderate: damages of $10 million-$99 million.
L = Low: damages of $1 million-$9 million.
-- = N/A or near 0: damages of $0 to several million dollars.
?) = Uncertain: potentially high damages, but subject to great uncertainty.

TABLE 4-2

Summary of Quantitative Estimates
From Available Studies

Environmental Problems	Resource Affected	Estimated Annual Losses (millions of 1986$)	Comments
Atmospheric Ozone First Estimate	Crops	1,000	Losses compared with a 0.09 ppm standard (Kopp et al. 1985).
Second Estimate	Crops	800-3,000	Based on range of 10 to 40 percent ozone reduction (ERL 1984).
Acid Precipitation First Estimate	Forests	614	Based on assumption of 5 percent growth impairment (Crocker et al. 1985).
Second Estimate	Forests	348-726	Based on hypothetical radial growth decrements of 10, 15, and 20 percent (Callaway et al. 1985).
Discharges from Nonpoint Sources to Surface Waters	Crops	260 a/	Losses for Colorado River Basin (only) in year 2000, based on estimated $610,000/yr loss per one mg/l rise in salinity (1986 $).
CO_2/Global Warming	Crops	66 a/	National corn crop loss in 100 yrs.
		(4) a/	Cotton crop gain in 100 years.
	Forests	(2,720) a/	Forest yield gain in 100 years.
	Fisheries	(162) a/	Fishery yield gain in 100 years.
To Estuaries, Coastal Waters, and Oceans from All Sources	Fisheries	5.5 - 8.3	Direct commercial fishing losses. Estimates are for potential benefits of the National Estuary Program at seven major bays and sounds extrapolated from a L.I. Sound Study.
Other Criteria Air Pollutants	Crops	0.5: Oats 1.2: Wheat 2.1: Soybeans	Point estimates for effects of SO_2 on crops. Maximum estimates are equal to twice the point estimates (Mathtech 1985). National effects on corn, cotton, and other major crops not included

a/ Nondiscounted estimate. Present-value estimate would be considerably lower.

Other problems with the set of studies included:

- uncertainty or incomplete knowledge about the effects of pollutants at various concentrations upon plant and animal species under both actual and potential conditions;
- extrapolation of data to the national level, including the basis for using case study data (for particular species or localities) to represent larger aggregates; also, data samples are small;
- valuation complexities involving the effects of government subsidies; estimates of welfare losses are often based on distorted prices, rather than on the prices that would result in a free market;
- attribution of adverse effects to particular sources, when several problems are involved simultaneously; estimation of net damages when a certain problem (e.g., global warming) simultaneously inhibits the growth of some species and enhances the growth of others; and
- global warming and stratospheric ozone depletion are likely to interact to change weather patterns in the future, so these problems cannot be assessed alone.

METHOD USED TO RANK ENVIRONMENTAL PROBLEMS

Given the limited information about risks to natural resources, we collected information on the current commercial value of the five natural resources. Table 4-3 presents these values. For example, the total income to farmers from the sale of all farm crops produced in the United States averaged $70.7 billion per year from 1980 to 1984. As with the figures for the other natural resources in the table, this figure varies with yearly market prices (or support prices).

We used this information to construct plausible "upper bounds" of the welfare risks to natural resources. For instance, if we thought that a one percent decline in a natural resource's value were possible from exposure to an environmental pollutant, then we could calculate the welfare loss likely if this loss occurred. Thus, as Table 4-3 shows, for crops, livestock, commercial fishing, and forest products, a one percent decline would mean losses of $707 million, $699 million, $24 million, and $84 million, respectively.

Evaluation of welfare losses to many agricultural commodities is especially complex because most of their prices are not set in a free market. The federal government subsidizes the agricultural sector (crops and livestock products) through a large

Table 4-3

Commercial Value of Existing Natural Resources

Resource	Commercial Value (billions of 1986 $)	Value Per One Percent (millions of 1986 $)
Crops[1]	70.7	707
Livestock[2]	69.9	699
Commercial Fishing[3]	2.4	24
Forest Products[4]	8.4	84
Farm Land[5]	683.5	6,835

Note: Includes only resources in the United States.

[1] U.S. farm revenues, annual average from 1980 to 1984. In addition to the value shown, there were $4.9 billion per year of federal payments to farmers during the same period.

[2] U.S. livestock, poultry, and dairy production, annual average from 1980 to 1984.

[3] U.S. domestic commercial fish and seafood landings, annual average from 1980 to 1985.

[4] Softwood and hardwood sales valued at their average prices per board foot, annual average from 1980 to 1983.

[5] Book value of farm land, excluding buildings, average value from 1980 to 1985.

Sources: U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States 1986; U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, Fisheries of the United States, 1985.

number of programs. Major crops, such as corn, wheat, rice, cotton, and (to a lesser degree) soybeans, have support programs that typically make payments available to farmers to set aside acreage and offer floor prices for production from acreage that is participating in the government's programs. Subsidies also exist in the form of investments made in irrigation and transportation facilities and government financing of stocks of surplus commodities and distribution programs (food stamps, school lunches, etc.). Thus, it is extremely difficult to separate out the value of subsidies from farm incomes. Farm support programs have also changed every few years, in effect changing the rules that farmers follow and altering investment planning in the agriculture sector.

Federal subsidies also play a significant role in the revenues and earnings from livestock products. Feed grains, such as corn, are affected by federal support programs, and the price of milk is set under federal purchase programs.

Unlike the other types of resources, farm land is an asset, rather than a product. Its value fluctuates in part with farm profitability. This summary identifies damages to farm land only when agricultural land would be critically damaged (removed from production or downgraded in use). Since farm land is a capital asset, its value is derived from the commodities grown on it and fluctuates with the profitability of those commodities. Consequently, care has been taken to prevent double counting the value of farm land and crop or livestock values.

One final important caveat for estimating the effects of pollution on natural resources is that only U.S. resources have been valued here. In the case of global problems--particularly global warming and stratospheric ozone depletion--adverse effects could occur in other countries, increasing the losses substantially.

MAJOR PROBLEMS

The environmental problems that cause major damage to natural resources are Atmospheric Ozone, Stratospheric Ozone Depletion, Discharges from Nonpoint Sources to Surface Waters, CO_2 and Global Warming, and Biotechnology.

Atmospheric Ozone (#1)
(Part of Criteria Air Pollutants)

Problem Characteristics

Ozone (O_3) is formed by a series of chemical reactions involving volatile organic compounds (VOCs), nitrogen oxides (NO_x), atmospheric oxygen, and sunlight. Ozone decreases the photosynthetic efficiency of vegetation, which can lead to a reduction in agricultural crop and forestry yields.

The major sources of NO_x emissions are fuel combustion (50 percent of total emissions) and motor vehicles (45 percent). VOCs are emitted mainly by industrial processes (38 percent) and motor vehicles (36 percent). Atmospheric levels of ozone averaged 0.146 parts per million (ppm) at the National Air Monitoring Sites. (The second highest daily maximum one-hour ozone concentration was used to construct this average.)

Research Approaches

Both ambient oxidant and controlled chamber studies have examined the adverse effects of ozone on federal crop varieties. Crop- and region-specific models have been developed to predict damages to agricultural crops, based upon 1978 crop distributions, ozone concentrations, and crop prices.

Estimated Damages

One study reported that ozone damages crops at an estimated rate of one billion dollars per year, compared with a potential ozone standard of 0.09 ppm (Kopp et al., 1985). Another study (ERL, 1984) estimated that a ten percent reduction from current ambient ozone levels would reduce annual crop damages by $0.8 billion, while a 40 percent reduction would reduce them by $3.0 billion. This study examined corn, soybeans, wheat, cotton, sorghum, and barley, but appraised crop reductions at market prices in 1980. Ozone is also reported to cause over one million dollars in damages to forests each year, which may be a low estimate (Mathtech, 1986).

Research Limitations

The damages estimated in the Kopp et al. study are measured from a reduction in ozone from 0.12 ppm to 0.09 ppm. Since natural background levels of ozone range from 0.05 to 0.06 ppm, this estimate by Kopp et al. understated total damages to crops from exposure to ozone. Crop damages are based on sales prices, which may reflect subsidized, rather than market, prices for some major crops.

Acid Precipitation (#1)
(Part of Criteria Air Pollutants)

Problem Characteristics

The principal sources of acid precipitation are coal-fired utilities and industrial boilers. Acid precipitation gradually turns soil and lakes acidic, impairing tree, plant, and animal growth. The Northeast has been especially affected, with pH levels in many areas decreasing from 5.6 to levels of 4.0 to

4.5 (the lower the pH level, the higher the acidity). Acid precipitation may also accelerate nutrient leaching in soils.

Research Approaches

Current knowledge of the effects of acid precipitation on terrestrial systems is based in part on soil research and on studies of such species as red spruce and balsam fir in the Northeast. Models are available for estimating economic effects. One such model is the Timber Assessment Market Model (TAMM). The TAMM makes exogenous assumptions about timber supply changes and calculates the effects that will occur in lumber markets, particularly changes of lumber prices.

Estimated Damages

The TAMM estimates national damages to trees in the range of $348 million to $726 million per year, using hypothetical radial growth decrements of 10, 15, and 20 percent (Callaway et al., 1985). A study by Crocker et al. (1985) estimates timber losses at $614 million annually, based on an assumption that growth is reduced by five percent. Actual reductions in growth may be below these levels, implying an overestimation of damages.

Research Limitations

Current knowledge of the effects of acid precipitation is limited with respect to effects across a range of acidity levels, reactions of various species, and full soil reaction mechanisms. (Information on the losses of sportfish from acid precipition is addressed in Chapter 3). The assumptions about growth impairment, used in the above studies, are hypothetical or sensitivity assumptions, rather than scientifically derived estimates.

At present, there are some data on the effects of acid precipitation on individual coniferous trees. However, there are very little data on the effects of acid precipitation on stands (groups) of trees, which are believed to react differently from individual trees. Hence, the fact that growth decrements have been modeled up to the point of a 20 percent impairment is not a basis for concluding that this level of reduction will actually take place.

The TAMM is a demand- and market-oriented model that considers the price effects of exogenous changes in supply. Its accuracy is limited by the accuracy of knowledge about growth reductions caused by air pollutants.

Finally, damages outside the United States are not included, though parts of Canada and Mexico are also influenced by U.S. air emissions.

Stratospheric Ozone Depletion (#7)

Problem Characteristics

The stratospheric ozone layer shields the earth's surface from ultraviolet (UV-B) radiation. Chlorofluorocarbon (CFC) releases from stationary sources can significantly reduce the ozone layer.

In 1978, a 20 percent reduction in stratospheric ozone was projected over the next 50 years, if pre-1978 CFC emission rates were to continue. This ozone reduction would have allowed a 40 percent increase in UV-B radiation reaching the earth's surface. In response to such projections, a number of industrial countries, including the United States have moderated their use of CFCs since 1978. Consequently, this projection probably substantially overestimates likely increases in UV-B radiation.

Research Approaches

Over 200 species and varieties of crops, plants, and trees have been screened for their responsiveness to increased UV-B radiation. Plants have been exposed to UV-B light from artificial sources in plant growth chambers. Aquatic organisms have also been studied under artificial UV-B light in tanks.

Estimated Damages

Nearly two-thirds of all plants tested show some sensitivity to UV-B radiation. Pea, bean, squash, melon, and cabbage varieties are especially sensitive.

Some aquatic species currently are exposed to as much UV-B radiation as they can tolerate. In a study of anchovies, a 20 percent increase in UV-B radiation over 15 days killed all larvae within a ten-meter mixed layer in April and August. If phytoplankton move to avoid a ten percent increase in UV-B, they may also reduce by 2.5 to 5.0 percent their exposure to photosynthetically active radiation on which they depend. Hence, UV-B radiation from ozone depletion could substantially reduce the supply of fish in coastal and ocean fishing grounds.

UV-B radiation also threatens forests. Some plant varieties are particularly susceptible to higher UV-B stresses. An increase in UV-B radiation could cause ecological changes in current plant balances. While the consequences of these changes are unknown, the damages would be sizable, if harvestable tree species were at a disadvantage.

UV-B radiation may also impair animal growth. However, potential damages are not known with any degree of certainty.

Research Limitations

Relatively little is known at present about the effects of stratospheric ozone depletion. Studies are not available to comprehensively capture the damages for all categories of resources. Current information primarily comes from laboratory tests, which may be very different from natural conditions. The adaptive behavior of plants and animals also is unknown, and this exercise has assumed it to be nonexistent.

Damages outside the United States are not included, though ozone depletion has worldwide impacts. Finally, it is important to keep in mind that most of the damages forecasted from this environmental problem are likely to take place in the distant future.

Discharges from Nonpoint Sources to Surface Waters (#11)

Problem Characteristics

When water is used for irrigation, a large portion is lost through evaporation and transpiration from the soil or plants. As a result, dissolved salts and metals are concentrated in the remaining drainage water. The drainage water can also leach additional salts from the soil. In addition, heavy rainfall can erode topsoil, carrying away water-soluble pesticides and pesticides that bind to soil particles. The contaminated drainage water travels to surface waters that, when used for irrigation, damage crop production.

Research Approaches

Agricultrual damages are estimated using experimental results of the effect of salinity on crop productivity.

Estimated Damages

Damage to crops from increased salinity has been extensively studied and is a relatively certain outcome of current irrigation practices. Many of the crop damages from salinity would occur in the Colorado River Basin. The Bureau of Reclamation estimates that these damages would amount to $610,000 per year per additional milligram/liter (mg/l) of salinity above a level of 800 mg/l, measured at the end of the Colorado Basin at Imperial Dam.

In the absence of control measures, salinity has been projected to increase to 1,200 mg/l by the year 2000, implying damages of $260 million 23 years from now. (Much smaller damages have also been identified for birds at a reservoir in California, where evaporation ponds have accumulated high concentrations of selenium and other toxic pollutants.) If salinity is

severe, some agricultural lands may suffer long-term losses in their ability to produce agricultural commodities.

Research Limitations

The damages from salination of lands outside the Colorado River Basin (such as parts of California) are not included in the above estimate. Also, no attempt has been made to estimate the welfare costs to crops from pesticide runoff.

CO_2 and Global Warming (#8)

Problem Characteristics

Carbon dioxide (CO_2) in the atmosphere traps solar radiation, causing the earth's atmosphere to gradually grow warmer. Combustion of fossil fuels is increasing the rate of CO_2 formation, and tropical forests that convert CO_2 to oxygen are disappearing as a result of heavy development. Current rates of fossil fuel combustion could lead to a two degree centigrade (2°C) increase in global temperatures over the next hundred years. The long-term consequences of higher temperatures may involve the melting of polar ice, leading to a submersion of coastal lowlands, to shifts in agricultural crop-growing areas, and to decreased productivity for some harvestable plant species.

Estimated Damages

In one hundred years, a 2°C increase in temperature could reduce national corn production by $66 million annually, though cotton yields would increase by $4 million per year (in a century). Possible gains for forestry yields ($2,720 million per year in a century) and fisheries ($162 million per year in a century) could offset crop losses. The unquantified effects of the flooding of agricultural lands could result in huge reductions in agricultural commodities far into the future.

Research Limitations

No attempt has been made to separate out the welfare gains from losses as a result of global warming. This is a particularly important issue for this environmental problem, since global warming causes both increases and decreases in yields of agricultural commodities and forestry products.

The present extent of scientific understanding of this problem is limited. Quantitative estimates are not available for losses of agricultural lands from sea level rise, and effects on crops other than cotton and corn have not been studied. Finally, damages outside the United States have not been included.

Biotechnology (#29)

Problem Characteristics

Biotechnology will accelerate the introduction of genetic change. Generally, genetically engineered microorganisms are not expected to survive long in conditions other than those for which they were designed. However, there is a possibility that some of the organisms will be able to survive, reproduce, and damage commercial crops or livestock. Given the current system of monoculture, wherein U.S. farms are specialized in producing a small number of crop varieties, a biological change could rapidly cause serious damage before countermeasures could be developed. The situation is somewhat analogous to imported insects (e.g., the gypsy moth) that have escaped and, in the absence of predators in their natural habitats, have become major pests.

Estimated Damages

Potential damages are uncertain, and any estimate would be highly speculative.

Research Limitations

This is such a new area of development that knowledge of the possible effects of biotechnology is an unknown.

MINOR PROBLEMS

The environmental problems that cause only minor damage to natural resources are: To Estuaries, Coastal Waters and Oceans from All Sources (#13) and To Wetlands from All Sources (#14), Hazardous/Toxic Air Pollutants (#2), Discharges from Direct and Indirect Point Sources to Surface Waters (#9, #10), Other Criteria Air Pollutants (#1), Mining Wastes (#20), Accidental Releases of Toxics and Oil Spills (#21, #22), Active and Inactive Hazardous Waste Sites (#16, #17), Contaminated Sludge (#12), Other Pesticide Risks (#27), and Other Ground-Water Contamination (#24).

To Estuaries, Coastal Waters, and Oceans from All Sources (#13)

Problem Characteristics

Deteriorating water quality caused by industrial discharges, municipal sewage effluents, pesticide runoff, application of mosquito pesticides, tributyl tin antifouling paints on ship bottoms, and biocides used in drilling muds have reduced commercial fishing yields in estuaries and coastal waters.

Research Approaches

An analysis of reductions in commercial fishing yields for the Long Island Sound (Draft EPA report 1985) has been extrapolated on a population basis to six other major bays and sounds. Consumer and producer surpluses were considered to estimate welfare losses.

Estimated Damages

An estuary improvement program at seven major bay/sound areas would reduce commercial fishing losses by $5.5 million to $8.3 million annually. The domestic catch of oysters, clams, and blue crabs is valued at approximately $135 million annually. A sizable proportion of these landings may be at risk by accumulation of toxic chemicals in coastal waters.

Research Limitations

Estimates for reduction in losses are calculated for only the National Estuary Program and are based upon a single case study extrapolated across six bays on the basis of their populations. Population is probably a suitable measure for extrapolating recreational values to an aggregate figure, but is probably not relevant to natural resource potentials. Tin-based paints used as antifoulants on ship bottoms could accumulate to toxic levels, but dollar estimates of projected damages are not available.

To Wetlands from All Sources (#14)

Problem Characteristics

Similar to estuaries and coastal waters, wetlands face losses in commercial fishing (particularly high-value seafood, such as shellfish) from contamination by toxic chemicals, pesticides (for control of mosquitos), and disease-breeding organic matter from various point and nonpoint sources. Many states maintain regulatory programs that monitor shellfish growing conditions and prohibit harvesting of shellfish when contaminants (toxins or microorganisms) reach unsafe levels.

Estimated Damages

An estimate of the value of losses in the amount of seafood that can be harvested is not readily available for wetlands. However, it is likely to be moderate, because wetlands account for only a small portion of shellfish supplies, whose total annual value is $370 million (including all catches within three miles off shore).

Research Limitations

Wetlands refer to zones between typical high-tide water levels and permanent vegetation. There may be some overlap with estuaries or coastal regions.

Hazardous/Toxic Air Pollutants (#2)

Hazardous air pollutants can accumulate in soil and retard plant growth. Two hazardous pollutants posing the greatest threats to natural resources are cadmium and mercury. The dangers are greatest where compost containing the trace elements is repeatedly added to the same soil over many years. Quantitative estimates of overall effects are not available, but it is likely that effects range from low to moderate for crops and agricultural lands and are low for forests. Any effects would occur in the distant future and would probably be localized.

Discharges from Direct Point Sources to Surface Waters (#9)

Industrial plants contaminate rivers, lakes, and coastal areas by discharging toxic, acidic, and organic wastes in their effluents. The contaminants can render shellfish and other fish inedible, as well as reduce the populations of fish in polluted areas.

Most commercial seafood is caught in areas sufficiently distant from these discharges to be relatively unaffected. Thus, the damages these plants cause are estimated to range betweeen low and moderate levels.

Discharges from Indirect Point Sources to Surface Waters (#10)

Contamination from sewage systems representing the combined effluent of many facilities can infect fish and shellfish in rivers, lakes, and coastal areas with diseases that make them inedible and can reduce biotic activity.

Damages caused by indirect point sources are estimated to range between low and moderate levels. This is because indirect point sources are only one of several sources of contaminants that have damaged fish and other forms of sea life.

Other Criteria Air Pollutants (#1)

Other than atmospheric ozone and acid precipitation, criteria air pollutants are not substantial threats to natural resources. Lead has been a source of concern, but over 90 per-

cent of airborne lead emissions come from the use of lead in gasoline, which is being phased down markedly (Mathtech, 1985).

Aside from its role in acid precipitation, SO_2 is estimated in one study to cause likely annual losses of $0.5 million for oats, $1.2 million for wheat, and $2.1 million for soybeans. Losses could range up to twice these estimates in the maximum case (Mathtech, 1986).

Other criteria air pollutants--nitrogen dioxide and carbon monoxide--may damage crops. However, effects have not been shown for levels typical of ambient concentrations.

Mining Waste (#20)

Acid and other wastes associated with mining can leach into surrounding forests or croplands. Acid mine runoff, including acid from abandoned mines, has impaired forest growth and diminished sportfishing opportunities in coal-mining areas, such as Appalachia. Oil-field wastes are also a problem--particularly drilling muds, which contain biocides toxic to aquatic species.

In some areas where extensive strip mining of hilly slopes has taken place, damages are severe. However, these areas account for only a fraction of timberlands and are not necessarily areas that would have been harvested. Thus, forest damage from mining waste is generally minimal. The reduced sportfishing opportunities were considered under the nonpoint source category.

Accidental Releases of Toxics (#21)

Toxic chemicals occasionally spill into waterways and kill fish. While these spills occur irregularly, they can cause losses of several million dollars when they require the closedown of shellfish beds or other fishing areas. The release of kepone into the James River several years ago closed the river to all fishing for a loss of $12.0 million annually (O'Mara and Reynolds, EPA, 1976).

Accidental Oil Spills (#22)

Oil spills from offshore drilling accidents or ruptures in storage tanks or tanker vesels can damage coastal and ocean sea life. Some oil spills have been extremely difficult to control and occur in prime fishing grounds, such as the Gulf of Mexico. However, damages to commercial fishing caused by oil spills generally are low.

Active Hazardous Waste Sites (#16)

Long-term seepage of chemicals from hazardous waste disposal sites contaminates underground aquifers, reducing the supply of water for irrigation in rural areas. The loss of irrigation water may necessitate converting valuable irrigated crop acreage into less productive pasture areas. However, these damages are likely to be low, because they are localized.

Inactive Hazardous Waste Sites (#17)

As with active hazardous waste sites, inactive hazardous waste sites threaten water supplies with contamination in the long term, also reducing the supply of water for irrigation. Nearby farms may have to switch to nonirrigated crops or uses.

Nevertheless, damages for crops and agricultural land are likely to be low, because most contamination is localized, and other sources are sometimes available for irrigation water.

Contaminated Sludge (#12)

When disposed of at sea, contaminated sludge can create unhealthy conditions and reduce the number of areas that can be fished commercially. This loss is likely to be low in magnitude, however.

Other Pesticide Risks (#27)

Application of pesticides in farm areas contaminates ponds, water supplies, and feeds, and occasionally leads to deaths of cattle, farm animals, and such wild birds as geese and ducks. Use of turf insecticides and herbicides on residential lawns also contributes to the problem.

Many of the losses associated with pesticides have been considered in other problem areas, such as contamination of estuaries, and nonpoint-source runoff. Losses in this remaining category probably are low.

Other Ground-Water Contamination (#24)

Septic systems, road salt, injection wells, and other miscellaneous sources also pollute ground-water aquifers. Because they marginally impair the supply of water for irrigation, they will cause only minor crop losses.

SUMMARY

The greatest dangers to the availability of commercial supplies of natural resources are ambient ozone, acid precipitation, stratospheric ozone depletion, nonpoint-source discharges to surface waters, and CO_2 and global warming. Possible accidents involving biotechnology could also lead to substantial damages.

Agricultural commodities are the natural resources most at risk of being damaged by pollutants. The reactions of various species differ, but the growth of major crops, such as corn and soybeans, can be impaired by pollution.

When atmospheric ozone, acid precipitation, and the criteria air pollutants are aggregated back to the single environmental problem area entitled "Criteria Air Pollutants from Mobile and Stationary Sources," that area is clearly the most significant of the problem areas.

Stratospheric ozone depletion stands out as a major possible long-term danger due to the potential effects of increased UV-B radiation on a large number of plant and animal species. However, the estimates presented in this report are only informal estimates.

As a closing comment, it is probably important to point out that the estimates of damages shown in this chapter are merely rough estimates of private market losses to the identified natural resources. They do not capture all losses, since they are incomplete in terms of total geographic and/or commodity coverage. Furthermore, they have been estimated under some rather simplistic assumptions that ignore government subsidy payments for agricultural commodities. We have not used information that is sufficient enough for us to be completely comfortable that the estimates presented in this chapter represent an accurate portrayal of social losses.

Chapter 5

Damages to Commerical and Public Property and to Ground-Water Supplies

INTRODUCTION

This chapter assesses damages to property from air and water pollution that have not been addressed elsewhere and to ground-water supplies. We found only limited quantitative analysis of these types of damages, which makes it difficult to develop reliable estimates of national damages. As a result, the ranking in Table 5-1 is based primarily on our professional judgment.

MAJOR PROBLEMS

Major damages to commercial and public property and to ground-water supplies are caused by CO_2 and Global Warming (#8); Inactive Hazardous (#17), Municipal Nonhazardous (#18), Industrial Nonhazardous (#19), and Active Hazardous (#16) Waste Sites; Releases from Storage Tanks (#23); Accidental Releases of Toxics (#21); and Indoor Radon (#4).

CO_2 and Global Warming (#8)

Problem Characteristics

Atmospheric concentrations of CO_2 are projected to increase over the next century due to increased fossil fuel combustion and decreases in tropical forests from development pressures. Higher levels of CO_2 are projected to raise climatic temperatures globally by roughly two degrees centigrade (2°C), melting polar ice and raising the sea level by the year 2050. As the sea level rises, large areas could be inundated, resulting in substantial property damages to public infrastructure (such as road, bridges, and utilities) and private infrastructure (such as commercial office buildings, factories, residences, and shopping areas).

Research Approaches

Case studies of the economic effects of projected sea level rise have been undertaken for two cities--Charleston, South Carolina, and Galveston, Texas (Titus et al., 1984). Both cities are situated in low-lying coastal lands that would be significantly affected by a rise in the sea level.

Table 5-1

Rankings of Environmental Problems: Damages to Property and Ground-Water Supplies
(billions of 1986 $)

Environmental Problems	Loss in Property Value	Loss of Ground-Water Supplies
Major Problems		
CO_2/Global Warming	S/XS	--
Inactive Hazardous Waste Sites	M/S	S
Nonhazardous Municipal Waste Sites	M/S	S
Active Hazardous Waste Sites	M/S	M/S
Nonhazardous Industrial Waste Sites	M/S	M/S
Releases from Storage Tanks	M/S	M/S
Accidental Releases of Toxics	M/S	--
Indoor Radon	M/S	--
Minor Problems		
Other Pesticide Risks	?	L/M
Other Ground-Water Contamination	L	?
Radiation Other Than Radon	L	?

Key to Effects: Letter codes correspond to order-of-magnitude ranges for annual effects:

- XS = Extremely Significant: damages of $1 billion or more.
- S = Significant: damages of $100 million-$999 million.
- M = Moderate: damages of $10 million-$99 million.
- L = Low: damages of $1 million-$9 million.
- -- = N/A or near 0: damages of $0 to several million dollars.
- (?) = Uncertain: potentially high damages, but subject to great uncertainty.

Estimated Damages

For Charleston, cumulative damages from 1980 to 2075 and discounted at three percent per year have been projected to be $730 million to $1,190 million. For Galveston, cumulative damages for the same time period using the same discounting procedure have been estimated to be between $415 million and $965 million.

Research Limitations

While these estimates give some perspective on the potential extent of damages from this environmental problem, they are not particularly useful for this project. First, these damages need to be assessed in annual terms. Given that these damages occur over 95 years, annual damages would only be tens of million dollars for these two cities. Second, these case studies present damage estimates for only two cities. They do not attempt to extrapolate the estimates to a national damage figure. Third, the case studies do not attempt to assess mitigating behavior on the part of communities in response to a modest rise in sea level. It is very likely that mitigation measures will be less expensive than the option of losing infrastructure. If evaluated, the costs of the mitigating behavior would become the upper bound on welfare losses. Finally, there are great uncertainties in predicting sea level rise because of the difficulty in predicting global weather patterns in the distant future. Despite these limitations, the work group ranked this problem as significant to extremely significant.

Inactive Hazardous Waste Sites (#7)

Problem Characteristics

Currently, there are 888 hazardous waste sites on EPA's National Priority List (NPL). Contamination at these sites is significant enough to warrant inclusion in the federal Superfund program. Roughly 6,000 additional waste sites have been inspected, and a portion of these eventually will be classified as NPL sites. Another 18,000 sites have had preliminary inspections, and a smaller percentage of these sites are likely to make the NPL. About 75 percent of the NPL sites are contaminating ground water, roughly 45 percent are contaminating surface water, and 15 percent are polluting the air.

Contaminated ground water can be dealt with by removing the source of contamination and restoring the aquifer, treating contaminated ground water at the wellhead before use, or providing alternative drinking water supplies. In addition, property values of residences surrounding hazardous waste sites may be lower than comparable homes elsewhere because of factors associated

with these sites. These factors include possible exposure of the occupants of nearby residences to toxic chemicals and the attendant health problems, bothersome odors, and the aesthetic appearance of the site.

Research Approaches

Schulze et al. (1986) used statistical techniques to evaluate declines in property values of residences surrounding two hazardous waste landfills in California. The sites received both municipal and hazardous wastes and are located in highly populated suburban communities. Methane gas has migrated from the sites, creating the potential for explosions and triggering evacuations at one site. In addition, vinyl chloride (a carcinogen) and bothersome odors are present at both sites.

The Schulze et al. study related the sales prices of properties surrounding the two sites and properties distant from the sites to a variety of factors that are thought to influence property values (size of home, number of bathrooms, etc.). Regression analysis was used to estimate the extent to which the sales prices of homes were reduced by virtue of being located near the sites.

Estimated Damages

The property values of homes located within 1,000 feet of the sites were estimated to be reduced by about $10,000, on average. The sales prices of homes beyond this distance did not appear to be affected by the sites.

Research Limitations

This study examined the property values of residences close to two hazardous waste sites. Information on property values around a broad range of sites was not available. Thus, extrapolation of the case study results to the larger universe of Superfund sites was deemed inappropriate because of the widely varying characteristics of sites and land-use patterns surrounding them.

It is not clear if the reductions in the values of residences near hazardous waste sites will be permanent. These values depend in part on the public's perceptions of the risks inherent in living near the sites. If public perceptions change and affect property values, the estimates of welfare losses will change. There is uncertainty about the portion of the reductions in property values that is attributable to the pollution from these facilities, versus other undesirable characteristics, such as the visual aesthetics of the sites and unpleasant odors.

No comprehensive estimates of the costs arising from the contamination of drinking water supplies around Superfund sites was available. However, ground water is contaminated at most Superfund sites, and substantial costs will be incurred to restore contaminated aquifers and to supply alternative drinking water. Although only limited information was available concerning welfare losses at Superfund sites, we thought losses could be quite large. Thus, we ranked this environmental problem as moderate to significant.

Nonhazardous Municipal Waste Sites (#18)

Problem Characterstics

This environmental problem includes municipal landfills, municipal refuse incinerators, and municipal surface impoundments. There are about 9,100 active and 30,000 closed municipal landfills; there are about 300 sludge incinerators operating at about 195 sites; there are about 100 municipal refuse incinerators; and there are about 20,000 municipal surface impoundments. Property values may be lowered for residences near these sites because of perceived health effects, odors, methane gas migration (for landfills), and the general operation of facilities. The municipal landfills and surface water impoundments also contaminate ground water and affect private and public drinking water wells.

Research Approaches

The Schulze et al. study (1986) estimated reductions in property values for two municipal landfills that accepted both hazardous and municipal wastes. The results of that study suggest that property values may be lower for residences located near municipal landfills.

Another analysis conducted for the Office of Solid Waste (1986) estimated the costs associated with dealing with contaminated ground water at municipal landfills. A ground-water model was used to model the extent of contamination around municipal landfills for various hydrogeological and climatic settings over a 200-year period. These results, in combination with hypothetical data on wellfields surrounding municipal landfills, were used to estimate the lesser of the cost of cleaning up the contaminated portion of the aquifer or of providing alternative drinking water supplies.

Estimated Damages

The extent of contamination and the resultant resource damage varied considerably, depending on the type of hydrogeology and the distance and the number of wells surrounding the site. The average resource damage on an annual basis is roughly

$12,000 per site. Extrapolating to the universe of 39,000 open and closed landfills yielded an estimate of about $470 million per year in welfare losses.

Research Limitations

The above estimate provides only a general indication of potential damages. It is based upon preliminary analysis of a hypothetical set of landfills, rather than actual landfills. Information on the likely concentration of constituents in leachate is poor, and the potential damages from the migration of methane gas was not factored into the analysis.

No information was available to estimate property value losses associated with municipal refuse and sludge incinerators and surface impoundments or the extent of ground-water contamination associated with municipal surface impoundments.

Despite these uncertainties, we thought that the welfare effects associated with this environmental problem were significant. We based our judgment on the large number of municipal waste sites, and their potential for lowering property values and contaminating ground water.

Active Hazardous Waste Sites (#16)

Problem Characteristics

This environmental problem included RCRA landfills and surface impoundments (both open and closed), hazardous waste storage tanks, solid waste management units (SMUs), and facilities handling waste oil. There are about 1,500 facilities with RCRA landfills and surface impoundments (about 400 are planning to continue operating); about 15,000 hazardous waste storage, treatment, and accumulation tanks located at about 5,000 facilities; about 11,400 small-quantity generator facilities with hazardous waste storage tanks; and about 9,000 SMUs (these are broadly defined--they range from buried asphalt to industrial landfills contaminated with hazardous materials).

Property values may be lower for residences near these sites because of the perceived health effects, odors, and general operation of the facilities. Ground water may also be contaminated by RCRA landfills and surface impoundments, SMUs, and leaks from storage tanks. A substantial portion of RCRA landfills are located close to surface water (mostly rivers), suggesting that ground-water contamination has been restricted to small areas at many sites, and that the landfills may be a source of significant surface water contamination.

Research Limitations

The results of the Schulze et al. (1986) study suggested that the property values of residences close to RCRA landfills (and possibly surface impoundments) were likely to be reduced. However, no quantitative estimate of losses was available. No studies have been completed that assess the costs associated with dealing with ground-water contamination at these types of sites, and the extent of ground water contamination and associated welfare damages from storage tanks and SMUs was unknown.

Outside of the Schulze et al. study, little research has attempted to assess property losses to residences close to these sites. No national estimate of damages from this environmental problem could be determined. In spite of this lack of quantitative information, we ranked this problem as moderate to significant.

Nonhazardous Industrial Waste Sites (#19)

Problem Characteristics

As with other types of waste sites, nonhazardous industrial waste sites may reduce property values and may contaminate ground water. There are about 3,400 industrial landfills, 15,000 industrial surface impoundments, and 120,000 oil and gas waste impoundments throughout the country. Limited information suggests that local ground-water contamination may be severe at some facilities. As a result, we ranked this problem as moderate to significant.

Research Limitations

Because data are not available, we could not determine how extensively nonhazardous waste sites reduce property values or contaminate ground water. Thus, we used our judgment to rank this problem.

Releases from Storage Tanks (#23)

Problem Characteristics

There are about 1.3 million underground storage tanks throughout the country. Most of the tanks store gasoline and petroleum products (hazardous waste storage tanks were included in the above section on Active Hazardous Waste Sites--#16). Current estimates are that 10 to 20 percent of these tanks are leaking and may contaminate private and public drinking wells and create problems with combustible fumes in buildings.

About nine percent of documented release incidents involve combustible fumes in confined areas and eight percent of documented incidents have contaminated private wells.

Research Approaches

The Underground Storage Tank (UST) model (a Monte Carlo simulation model) has been used to simulate the frequency and extent of damages related to vapors and to ground water. The model assumes that tank owners would undertake corrective action (as evidenced in damage cases) to address the source of contamination when leaks were detected.

Estimated Damages

Damages from leaks were estimated to be about $290 million per year over the next decade. About 80 percent of the damages are associated with tanks installed before 1984 (tanks installed after 1984 have lower leak rates and lower expected releases). As the tank population is replaced, damages are estimated to decline to about $7 million per year.

Research Limitations

None of the costs of corrective action, such as removal of tanks, recovery of free products, or treatment of ground water, was included in the above damage estimates. About 80 percent of the releases were estimated to involve vapors in confined areas or damages to private drinking water. However, some of these releases could require extensive and costly corrective action. Thus, we ranked this problem as moderate to significant.

Accidental Releases of Toxics (#21)

Problem Characteristics

Accidental releases of hazardous materials occur at production facilities and during transport and many contaminate soil and surface water or damage roadways, buildings, and other types of property.

Research Limitations

Calculating the environmental and property damages attributable to accidental toxic releases is difficult. Damages reported in the Hazardous Events Data Base refer to damages to the facilities or vehicles responsible for the releases rather than to damages to nearby property or to the environment from the release and migration of toxic materials. Our consensus was that damages to property caused by accidental releases of toxic substances were on the order of moderate to significant.

Indoor Radon (#4)

Problem Characteristics

Radon is a radioactive gas produced by the disintegration of radium. It migrates through the soil into buildings, where it is trapped by dense building materials. Because the decay products of radon pose a serious health hazard, areas known to have high levels of radon may suffer marked reductions in residential property values.

Estimated Damages

Property losses due to radon have not been studied. Only recently have monitors been commerically available for measuring whether particular homesites are contaminated by radon. Once monitoring becomes widespread, it is anticipated that residences that are contaminated by radon will be discounted in the marketplace. Damages would be limited to the cost of averting behavior, which in this case would result in installing controls to limit radon accumulation. Controls may cost on the order of $1,000 to $1,500 per house affected. National damages may be equivalent to moderate levels if a large number of residences are retrofitted with controls over a number of years.

MINOR PROBLEMS

The problems we have ranked as causing only minor damage to public property and ground-water supplies are Other Pesticide Risks (#27), Other Ground-Water Contamination (#24), and Radiation Other Than Radon (#16).

Other Pesticide Risks (#27)

When pesticides seep into ground water, costs must be incurred either to remove the pesticides from the ground water or to provide alternative sources of drinking water. For example, when aldicarb was found in 1979 in drinking water in Suffolk County, Long Island, filtration systems were installed to eliminate the problem. The one-time capital and installation costs (including compensation for bottled water) were roughly $4 million, and the annual costs of monitoring, recharging filters, and inspecting the water are roughly $1 million.

While this incident gave us some indication of the nature of this problem, we could not estimate national damages, since neither the extent of pesticide contamination of ground water nor the costs that society is likely to incur to mitigate this problem were available. We ranked this problem as low to moderate.

Other Ground-Water Contamination (#24)

A variety of sources of pollution contaminate ground water. These include miscellaneous tailing, mining wastes, and injection wells. Many of these sources of pollution have been considered in other portions of this report. We ranked this problem as low for being a source of property value declines.

Radiation Other Than Radon (#16)

The presence of radioactive materials and wastes decreases the values of property near the waste. However, overall property damages are likely to be low.

SUMMARY

Little documentation is available on declines in property values and damages to ground-water supplies. As a result, we largely used our judgment in determining how extensively alternative environmental problems contribute to these losses. Major environmental problems threatening property values or ground-water supplies are CO_2 and Global Warming, Inactive and Active Hazardous Waste Sites, Nonhazardous Municipal and Industrial Waste Sites, Releases from Storage Tanks, Accidental Releases of Toxics, and Indoor Radon.

Chapter 6

Aesthetic and Nonuser Values

INTRODUCTION

This chapter addresses environmental problems that influence aesthetic and nonuser values. These values are traditionally addressed together because of their intangible contribution to welfare.

ENVIRONMENTAL PROBLEMS AFFECTING AESTHETICS

Aesthetic values are derived from the senses of hearing, smell, taste, and sight. Man-made pollution can impair the quality of these sensory experiences by causing noise and unpleasant odors, fouling the taste of drinking water, and reducing visibility.

A cursory review of the 31 environmental problems suggests that at least 27 may lead to aesthetic damages. The problems not likely to directly influence aesthetic experiences are Indoor Radon (#4), Radiation Other than Radon (#6), New Toxic Chemicals (#28), and Biotechnology (#29).

Our goal was to quantify and rank the 27 problems by the significance of the harm they cause to aesthetic experiences. However, because of a lack of data, we could only rank two major problems: Criteria Air Pollutants (#1) and Other Air Pollutants (#3). Table 6-1 presents this ranking.

Criteria Air Pollutants (#1)

Air pollution can diminish visual experiences by reducing visual range, by discoloring and layering the atmosphere, and by creating plume blight. This section focuses on the impact of air pollution on visibility, which has been studied extensively.

Problem Characteristics

Reductions in visibility are usually measured in terms of reduced visual range, which is the distance at which an object is just visible. Theoretical analyses have indicated that because of their physical characteristics and variations in pollutant concentrations, different particles in the atmosphere contribute differently to decreasing visibility.

Table 6-1

Ranking of Environmental Problems
That Hinder Aesthetic Experiences
(billions of 1986 $)

Environmental Problems	Visibility Degradation	Unpleasant Odors	Noise	Others: Unsightliness Bad Taste
Major Problems				
Criteria Air Pollutants	1.5-8.0*	--	--	?
Other Air Pollutants (noise and odors)	--	XS/S	?	--

* These figures reflect damages for 31 eastern states and parts of California.

Key to Effects: Letter codes correspond to order of magnitude ranges for annual effects:

XS = Extremely Significant: damages of $1 billion or more.
S = Significant: damages of $100 million-$999 million.
M = Moderate: damages of $10 million-$99 million.
L = Low: damages of $1 million-$9 million.
-- = Not available or near 0: damages of $0 to several million dollars.
(?) = Uncertain: potentially high damages, but subject to great uncertainty.

At many sites throughout the country, and especially in the eastern portion of the United States, sulfates (a transformation product of sulfur dioxide) are the greatest impairers of visibility. However, significant exceptions to this rule occur in the Pacific Northwest and Denver, where total carbon causes the largest reductions in visual range (EPA, 1986, p. 30). Nitrates, condensible organics, and other fine particles also degrade visibility, though to a lesser extent than do sulfates.

Research Approaches

For "nonmarket" research methodologies, two relationships are crucial to estimating damages from decreased visual range. One is the relationship between ambient concentrations of various pollutants and visible range. The other is the connection between visual range and the monetary value of observing a particular visual range. Thus, a visibility study is effectively a two-step process. In the first step, the investigator describes a change in emissions and projects the change in visual range. Then, in the second step, the investigator determines observers' assessments of the value of the change in visual range.

For households in the eastern portion of the United States, a one-mile decrement in the visual range these people typically experience implies an annual damage per household of roughly $14. This figure is based primarily on the results of a contingent-valuation study (the "Six Cities" study) conducted by Tolley et al. (1985) in six eastern cities: Washington, D.C., Atlanta, Mobile, Boston, Miami, and Cincinnati. This value is, therefore, most appropriate for these six cities and for other cities with characteristics similar to those of these six cities, especially those with visual ranges on a typical day of around ten miles.

While the Six Cities study is the most comprehensive contingent-valuation study of the value of visibility to urban residents, contingent-valuation studies for other cities (Chicago, Los Angeles, San Francisco, and Cincinnati) provide information useful for making a high-range estimate (EPA, 1985). While differences in scenarios make comparisons difficult, these additional studies found that per-mile values were somewhat higher than the Tolley et al. estimate in San Francisco, considerably higher in Cincinnati, and somewhat lower in Los Angeles. Higher per-mile values tend to be obtained for smaller changes in visibility and for preventing degradations versus obtaining improvements. Average values of $35 or more for every mile of change in visual range were obtained in several scenarios evaluated in these studies, especially--but not exclusively--in scenarios considering visual changes of five miles or less and for preventing deterioration from current conditions.

For estimating a high-range value, EPA (1985) used an annual value of about $39 for a one-mile change from the mean visual range. EPA (1985) also used one-half of the mid-range for a lower-range estimate. We interpreted it as a conservative lower bound: an annual value of about $7.30 per mile at the ten-mile mean, which is about as low as any per-mile values that have been obtained for any city (as a citywide average) in any contingent-valuation study.

Because of the distinctive features of scenic natural areas, none of the foregoing relationships represents the value of visual range at national parks. This value requires a separate treatment.

Rowe et al. (1986) have summarized the seven contingent-valuation studies that have been conducted in parks and recreational areas across the country concerning the value to visitors of protecting visibility during their visits. These studies have been conducted in Grand Canyon and Mesa Verde National Parks, Glen Canyon Recreation Area, and Great Smoky Mountains National Park. Overall, the studies estimate values of about $1 to $5 per visitor-party (average size comparable to a household) per day for a specified higher visibility level, rather than a specified lower level during a park visit.

Rowe et al. pooled the results of these studies to estimate a daily-value-per-mile function. The mid-point of the change considered in each scenario was used as the level of visual range. At the mean of the visual range in these studies (about 75 miles), the daily value per mile is about $0.08. This is based on fairly large changes in visual range (an average change of about 60 miles, minimum 20 and maximum 145) and fairly high levels of visibility (mean midpoint 75 miles, minimum 19 and maximum 143). It is less descriptive of the value for smaller changes or for areas where lower levels of visual range are typical.

Estimated Damages

Two relatively recent regional assessments--one for the eastern United States and the other for California--have calculated an aggregate estimate of damages from impaired visibility. These studies are based primarily on the methodology and data described in the preceding section.

The "Regional Haze" study examined the effect on visual range of several regional strategies for controlling emissions of SO_2 (EPA, 1985). The results of the most aggressive strategy most closely approximate the results of reducing SO_2 to background levels (to levels without man-made SO_2 pollution). This strategy would reduce annual SO_2 emissions in 31 eastern states by 12 million tons. Large (30-50 percent) reductions in SO_2

emissions in those states would substantially improve annual and summertime visibility in large portions of the East by 15 percent or more. Given these improvements, the Regional Haze study calculated reduced damages ranging from a low of $0.9 billion, to a best estimate of $1.6 billion, and to a high of $4.2 billion (see Table 6-2).

The Regional Haze study also covered values for visitors at Class I areas in the East. Class I areas usually are scenic areas where improvements in visibility will most likely result in significant welfare gains.

The predicted changes in visibility suggested that the average visual range at the Great Smoky Mountains National Park would improve by roughly 1.5 to 2.3 miles (about 14 to 21 percent). With values per mile per visitor-party of $0.8 to $0.13, the total annual gain to users would be worth $0.4 to $0.9 million. The estimated improvement in visibility at Shenandoah National Park would be about 24 percent. Because of lower annual visitation rates, the estimated total annual gain would be somewhat smaller than that for the Great Smokies. The predicted visibility change at Acadia National Park was only about 5 percent. Therefore, it was presumed to be imperceptible. Extrapolating these figures to a national figure, the authors of the Regional Haze study concluded that the annual aesthetic gains for visitors to Class I areas would be around $10.0 million.

The California study (Rowe et al., 1986) estimated the value of controlling air pollution in four California air basins containing 80 percent of the state's population and probably an even greater share of the visibility values. These basins were the Los Angeles Air Basin, the San Francisco Bay Area Air Basin, the San Diego Air Basin, and the San Joaquin Valley Air Basin.

None of the modeled scenarios reduced air pollution to background levels. Rather, the scenarios compared past and present controlled levels of air pollution to more lenient levels of control. The study estimated emissions and ambient pollutant concentrations for each scenario. Visual range (annual average) at each monitoring station was calculated using coefficients estimated from historical data for each station, and modeled ambient levels of pollutants under alternative scenarios for each station.

Based on contingent-valuation and property value studies, Rowe et al. selected a per-mile value of $35 per household for changes in urban visual range. Gains were also estimated for visitors to national and state parks and national forests.

For the purposes of this effort, the most appropriate scenario compared predicted 1987 emissions with planned controls to predicted 1987 emissions with air pollution controls set at a level of stringency characteristic of 1960. While no scenario compared existing visibility to background visibility, this scenario was comparable because it was based on the largest change in visibility and the nearest year. Total gains ranged from an upper estimate of $3.8 billion, to a best estimate of $1.4 billion, to a low estimate of $0.6 billion.

Table 6-2

Summary of Damages from Impaired Visibility
(billions of 1986 $)

Affected Areas	Low	Middle	High
31 Eastern States	0.9	1.6	4.2
Portions of California	0.6	1.4	3.8
Total Damages	1.5	3.0	8.0

Research Limitations

Any interpretation of the figures in Table 6-2 should reflect the inherent limitations of the air quality/visual range and visual range/valuation relationships that underlie these estimates. It must also recognize the limited coverage of visual aesthetic damages. The figures omit other visibility characteristics (such as discoloration, layering, and plume blight). Also, nonuser values were not considered.

Geographical coverage is incomplete. Parts of California and the 31 eastern states do not constitute a national analysis. And even within the visual range aesthetics category for parts of California and the 31 eastern states, a 100 percent reduction in manmade pollution from current levels has not been simulated. Only partial reduction of some of the pollutants impairing visibility has been reflected in the assessments to date.

Other Air Pollutants (#3): Odors

Problem Characteristics

Unpleasant odors are emitted from feedlots, industrial plants, municipal landfills, kraft pulp mills, residential leaf burning, fish kills and algae blooms caused from water pollution, chemical production and disposal processes, water with high sulfur and chlorine content, pesticide applications, and manure applied to fields.

Research Approaches

Property value (Copley International, 1973) and contingent-valuation studies (Charles River Associates, 1983) have assessed people's willingness to pay to eliminate foul odors.

Estimated Damages

Respondents to the Charles River study bid, on average, $70 annually to eliminate exposure to odors from diesel exhaust. The average respondent reported 14.5 contacts with diesel emissions from vehicles per week (754 contacts per year). By extrapolating this figure across the urban population of the United States, the study calculated annual total damages of $5.3 billon.

Research Limitations

We thought that the $5.3 billion estimate of willingness to pay to avoid diesel odors alone was implausibly high. While no alternative studies were available to estimate these welfare risks, we ranked odors as a significant to extremely significant environmental problem. The major impetus for this ranking was the fact that over half the complaints that EPA faces at the local and state levels involve odors of one type or another.

Other Air Pollutants (#3): Noise

Problem Characteristics

Noise levels of 55 decibles or higher (technically, day-night sound level, "Ldn") interfere with normal speech, relaxation, and privacy. In the list of 31 environmental problems, noise may manifest itself in a number of different ways. It is emitted from industrial activities, traffic on freeways, active hazardous and nonhazardous waste sites, aircraft, or such consumer products as lawn mowers. Although data on the frequency and duration of noise levels exceeding 55 Ldn were not available, Table 6-3 shows that 40 percent of the United States population is estimated to live or work in environments exceeding the 55 Ldn level.

Table 6-3

U.S. Population Exposed to Noise Levels Exceeding 55 Ldn, by Noise Source (in millions)

Urban Traffic	Rural Traffic	Air-craft	Rail	Agri-culture	Indus-trial	Home Appliances
102.1	4.8	50	2.4	0.1	6.3	15.0

Source: CEQ Annual Report (1979), Chapter 9 (Noise).

Estimated Damages

In spite of the paucity of data, we felt that noise pollution is a potentially serious environmental problem, often overlooked in discussions of environmental pollution.

NONUSE VALUES OF ENVIRONMENTAL RESOURCES

When we consider the goals of environmental protection, we usually think first of "use" values. We talk about how reductions in pollution will improve human health (by reducing mortality and morbidity), enhance recreational opportunities, and increase the productivity of natural resources (such as crops, forests, and fisheries). However, two additional types of value are derived from environmental protection: "option" and "existence" value. These values are sometimes referred to as intrinsic or as "nonuser" values, to distinguish them from values experienced by actual users.

Option value is the value of preserving the opportunity to use a resource in the future. (Oftentimes, option value is inappropriately used to consider the expected value of future use of a resource). As used in environmental management, option value is similar to what we would pay now to preserve our right to buy a particular parcel of land in the future--say, one that has unique value for an industrial or commercial use.

Existence value is the value of the mere knowledge that the resource exists or that the resource exists in its pristine form. Sometimes existence value is referred to as "vicarious consumption" value (such as the satisfaction derived from providing food to people affected by famine) and "bequest value" (such as the satisfaction of knowing that a clean aquifer will be available to future generations). Although there is some looseness in the terminology used to describe this class of

nonuse values, there is general agreement that popular recognition of stewardship responsibilities implies positive existence values for environmental resources.

The salient characteristics of goods with significant option or existence values are that they have no suitable substitutues, their future existence is threatened, and they would be very costly or impossible to replace if destroyed. While difficult to quantify, these intrinsic values should be factored into any assessment of the comparative risks of alternative environmental problems. These values are the residual values that are added to users' total willingness to pay for a particular improvement in environmental quality.

Surface Water

Resource To Be Valued

People who will never use a particular water body still may value its quality because they know others can enjoy its use or because they value the preservation of ecological diversity.

Research Approaches

Recent studies provide evidence that option and existence values are significant components of the total value derived from environmental protection (Table 6-4). Mitchell and Carson (1984) applied contingent-valuation surveys to estimate the values held by a representative national sample for various levels of surface water quality. (See Chapter 3 for further discussions of the Mitchell and Carson study.) Users were defined according to whether they had participated in any direct-contact (i.e., in-stream) activities within the past two years. The results were not linked to changes at a particular site, but rather to the quality of all the nation's waterways. For water of "fishable" quality, the average bid for nonusers was 47 percent of the mean total bid obtained from users. This result lends weight to the hypothesis that the intrinsic gains of improved water quality may be systematically related to recreational values.

Desvousges, Smith, and McGivney (1983) interviewed 301 households in the Pennsylvania portion of the Monongahela River watershed. Before asking the willingness-to-pay questions, the interviewer explained the concepts of use, option, and existence values. Table 6-4 reports the results of the survey.

Cronin (1982) surveyed approximately 1,530 people in the Potomac River basin in 1973. The study was designed to compare users' and nonusers' willingness to pay for water quality improvements. It suggested that intrinsic values for water quality

were 67-71 percent of use values. Using a more refined definition of nonusers, Cronin (forthcoming) has recently found intrinsic values to be 48-80 percent of use values.

Estimated Nonuse Value

These studies (and several others) indicate that excluding intrinsic values would understate the total welfare gains of water quality improvements. They support the hypothesis that intrinsic values of improved water quality are not only positive but substantial. The ratios of intrinsic-to-use values range from 0.44 to 0.80.

Since three of the studies focused on two specific water bodies, it could be argued that nonuser values may overstate intrinsic values if they decrease with distance from the recreation site. However, Mitchell and Carson (1984) asked about national water quality, rather than values for specific sites. Although there is some question about whether respondents actually related their answers to nearby sites, the Mitchell-Carson ratio of intrinsic to use values is consistent with the site-specific values.

Ground Water

Resource To Be Valued

The issue of ground-water protection is relatively new on EPA's agenda. Many difficult technical and economic issues need resolution. As with other changes in environmental quality, improvements in ground-water quality can increase user and nonuser values (Table 6-5).

A strong qualitative argument exists for the hypothesis that option and existence values for some ground-water sources are high, since many people think that some supply alternatives (e.g., bottled water) are unsuitable and that there are no substitutes. In addition, many people have expressed the desire to ensure that clean aquifers will be available to future generations. The popular recognition of stewardship responsibilities implies positive existence values for ground water.

Table 6-4

Use and Intrinsic Values from Current Studies

Study	Site	Estimation Technique	Dollar Estimates (1986/household/year) User	Nonuser	Ratio of Intrinsic Value to Use	Comments
Mitchell and Carson (1984)	U.S. National Parks	National survey of users (recreators) and nonusers of surface water resources.	299	140	.47	Values presented are for attaining "fishable" level of water quality. Use value equals the total bid of recreators (use plus intrinsic values for users). Nonusers defined as nonparticipants in in-stream activities within past two years.
Desvousges, Smith, and McGivney (1983)	Monongahela River	Residents surveyed via bidding game, direct question, and question with payment card on value of water quality.	Prevent Loss: 60 Improvement: 72	Prevent Loss: 39 Improvement: 32	.65 .44	Summary measure may mask differences among question formats. Use values may include expected use values.
Cronin (1982)	Potomac River	Residents surveyed via direct question approach for value of water quality.	Prevent Loss: 49 Improvement: 145	Prevent Loss: 35 Improvement: 97	.71 .67	Same as comment under the Desvousges study above.
Cronin (forthcoming)	Potomac River	Same as Cronin (1982).	Prevent Loss: 51 Improvement: 159	Prevent Loss: 41 Improvement: 77	.80 .48	Same as comment under the Desvousges study above. Nonusers are defined as those who would not use the Potomac even if it were as clean as they would like. Users are present users and those who would use a clean river.

Table 6-5

Values Related to Ground Water

Use Values	Nonuse (Intrinsic) Values
Direct Use	Option Value
Withdrawal for:	Value associated with the preservation of the option of using ground water
° Municipal: drinking and waste disposal (both present and future use)	
	Existence Value
° Agricultural: irrigation	Existence values for stewardship vicarious consumption (current period) and bequest
° Industrial/commercial: cooling, process treatment waste disposal, generation of steam, coal transport	
Indirect Use	
Source of water to streams and lakes to maintain flow used for recreation	

Research Approaches

No studies have attempted to measure the nonuser (intrinsic) value of ground water, nor is there any national assessment, as with surface water quality, that measures intrinsic value.

An empirical argument may exist for the importance of intrinsic value in determining the total value of a ground-water source. The apparently "irrational" response of many communities to ground-water contamination incidents could indicate that individuals receive satisfaction from knowing that a clean aquifer will be available to them and to future generations. A few cases have occurred where communities and public officials have argued heatedly for a total cleanup of contaminated aquifers that are currently not even being tapped and, therefore, provide no current value to local populations. (For example, in a situation involving underground storage tanks owned by Belmont Oil, where only irrigation water supplied by private wells had been contaminated, and no important drinking water aquifers were present, $900,000 was spent on restoring the aquifer.) In these cases, people either anticipated substantial potential future uses of the aquifer or they perceived a large unquantified value associated with its mere presence (existence value).

The only study that has attempted to determine the magnitude of intrinsic value in relationship to use value was a small pilot survey conducted in Miami, Florida, during the summer of 1984 (Rowe et al., 1985). The survey blurred the rigorous distinction between use and intrinsic values. However, the results of this survey suggested that the estimates from a traditional damage-function approach may only be capturing 30 to 45 percent of the values for users, and an even smaller share of the total values for society.

Air Quality

Resource To Be Valued

Intrinsic values are important in measuring the total value of activities regulating air quality. Prevention of the deterioration of air quality (mostly visibility impairment) is the most often cited example of a situation with high intrinsic as well as use value.

Research Approaches

Some preliminary efforts have been made to estimate nonuse values for visibility in national parks. Schulze et al. (1981) interviewed residents in Albuquerque, Denver, Chicago, and Los Angeles concerning protection of visibility at Grand Canyon National Park. Randall et al. (1981) also asked Chicago resi-

dents about their values for protecting visibility at the Grand Canyon, and Rae (1984) queried Cincinnati residents concerning the protection of visibility at Great Smoky Mountains National Park.

Estimated Nonuse Value

The quantitative results obtained to date for the relative magnitude of nonuse values for visual range in national parks are ratios of nonuse to use values, calculated as the ratio of the sum of all nonuse values held by users and nonusers to the sum of all use values held by users. This ratio was significantly higher for the Grand Canyon (200:1) than for the Great Smoky Mountains (3:1). However, since different procedures were used in the two studies, comparing them is difficult.

SUMMARY

The major welfare loss quantified in this chapter is visibility impairment. Criteria air pollutants are estimated to cause at least $1.5 to $8.0 billion in annual damages by reducing visual range. Unfortunately, little documentation was available on the extent of other types of environmental problems in relation to odors and noise. Nevertheless, we felt that these problems cause large welfare losses.

While we addressed the issue of nonuser values associated with controlling air and water pollution, we did not draw any definitive conclusions as to the extent of these values. However, in ranking the environmental problems, we did consider nonuser values.

Chapter 7

Summary, Conclusions, and Recommendations

INTRODUCTION

The ranking procedure was necessarily imperfect because the 31 environmental problems differ in:

- the degree to which they have been studied;
- the reliability of methods used to evaluate the magnitude of risks;
- the reliability and completeness of available data and knowledge of current pollution trends;
- the state of scientific understanding of a particular problem;
- uncertainty as to the timing of effects; and
- other factors, such as how the problems have been categorized (in some cases, for example, water pollution sources and receptors appear in more than one problem area, making a unique allocation of effects difficult).

The limited resources available for developing this report and ranking exercise forced us to base the rankings on the major effects associated with each problem. It is likely that many problems cause numerous small effects that in the aggregate may be quite significant. However, it was beyond the scope of the Welfare Effects work group to fully track and attempt to quantify these myriad effects. Also, effects that appear small on a national level may in fact be extremely significant to specific regions, groups, or other entities.

Finally, we could not rank eight of the environmental problems because their welfare effects were either insignificant or not sufficently documented. We assigned approximately equal weight to these eight and categorized them as "minor" problems. Table 7-1 presents the final ranking of environmental problems.

This chapter summarizes our rationales for the individual rankings and presents our recommendations on how assessments of welfare effects can be improved.

Table 7-1

Final Rankings of Welfare Effects Work Group

Rank	
	High Effects
1	Criteria Air Pollutants from Mobile and Stationary Sources (including acid precipitation)
2	Nonpoint Source Discharges to Surface Waters*
3	Indirect Point-Source Discharges (POTWs) to Surface Waters
4	To Estuaries, Coastal Waters, and Oceans from All Sources*
5	CO_2 and Global Warming
6	Stratospheric Ozone Depletion
7	Other Air Pollutants (odors and noise)
8	Direct Point-Source Discharges (industrial, etc.) to Surface Waters
	Medium Effects
9	Hazardous Waste Sites -- Inactive (Superfund)
10	Nonhazardous Waste Sites -- Municipal
11	Hazardous Waste Sites -- Active (RCRA)
12	To Wetlands from All Sources
13	Other Pesticide Risks -- leaching and runoff of pesticides and agricultural chemicals, air deposition from spraying, etc.
14	Biotechnology
	Low Effects
15	Nonhazardous Waste Sites -- Industrial
16	Releases from Storage Tanks (including product and petroleum tanks that are above, on, and underground)
17	Accidental Releases of Toxics
18	Accidental Oil Spills
19	Drinking Water as It Arrives at the Tap
20	Radon -- indoor only
21	Mining Wastes (including oil and gas extraction wastes)
22	Contaminated Sludge
23	Hazardous/Toxic Air Pollutants
	Minor Effects
	Other Ground Water Contamination
	Radiation Other Than Radon
	Indoor Air Pollutants other than Radon
	Pesticide Residuals on Foods Eaten by Humans
	Applicators of Pesticides (risks to applicators and consumers)
	New Toxic Chemicals
	Consumer Product Exposure
	Worker Exposure to Chemicals

* Includes effects from Pesticides.

SUMMARY OF RATIONALES FOR RANKINGS

The rationales for the rankings of the top 14 environmental problems are presented in this section. In addition, Table 7-2 provides comprehensive rationales for the ranking of the top 23 problems.

Criteria Air Pollutants

We chose Criteria Air Pollutants as posing the most significant welfare effects because of the large documented damages they cause in many different welfare categories. For example, they cause extensive damages to materials annually, impair visibility, and reduce agricultural, forestry, and sportfishing yields. Also, damages from criteria air pollutants are immediate, ongoing, and tangible.

Water Pollution

From the start of this project, water pollution problems were disaggregated into several distinct problems. For the purpose of this ranking exercise, this approach lead to a somewhat fragmented discussion of their effects. Ranks #2 through #4 are water pollution problems. The nonpoint and indirect-point source categories represent sources of pollution, while estuaries, coastal waters, and oceans from all sources describe major receptors of pollution. To an unspecified degree, pollution from nonpoint and indirect-point source categories contribute to the effects represented under estuaries, coastal waters, and oceans. Nonetheless, in spite of the potential double counting, we found that these categories are significant and warrant a high ranking on the list of welfare effects.

Reductions in the availability of recreational opportunities are estimated at $3.7 billion annually for water pollution from nonpoint sources and $2.5 billion per year for pollution from indirect-point sources. Most of these welfare losses are the consequence of lessened opportunities for using water resources, such as reduced swimming, sportfishing, and boating activities.

Welfare effects at estuaries, coastal waters, and oceans include reductions in swimming, sportfishing, commercial fishing, and boating. The losses from reduced recreational activities for estuaries, coastal waters, and oceans have been estimated at $150 million-$500 million annually for seven major estuaries. In addition, smaller losses to commercial fishing were demonstrated for seven estuaries. However, because we believe that the damages for the seven estuaries were only a fraction of total national damages, we ranked To Estuaries, Coastal Waters and Oceans as fourth.

Table 7-2

Summary of Ranking of Welfare Effects

Rank	Environmental Problems	Major Characteristics	Rationale for Ranking Position	
			Why Ranked High	Why Not Ranked Higher
1	Criteria Air Pollutants	Carbon monoxide, particulates, SO_x, NO_x, lead.	Multiple damage categories: material damages and soiling, reduced visibility, decreased crop and forestry yields; material damage and soiling are large.	--
2	Nonpoint-Source Discharges to Surface Water	Runoff from farms, lawns, etc.; includes pesticide and fertilizer runoff and acid mine drainage to fresh-water bodies.	Major contributor to $3.7 billion/year loss of recreational uses; decreased crop yields, downgrading of agricultural land.	Dollar values of damages not as high as those for Criteria Air Pollutants.
3	Discharges from Indirect Point Sources (POTWs) to Surface Water	Discharges via municipal sewer systems to fresh-water bodies.	Secondary contributor to $2.5 billion/year loss of recreational uses (swimming, sport fishing); reduced commercial fishing.	Damages similar to those from nonpoint sources, but a lesser contributor.
4	To Estuaries, Coastal Waters, and Oceans from All Sources	Category represents salt-water receptors of discharges to surface water.	$150 million-$500 million/year loss of recreational activities for seven estuaries; shellfish and other sea life jeopardized.	Less danger to recreational opportunities; damages reflect mostly the value of lost catches of shellfish and other fish.
5	CO_2 and Global Warming	Elevated temperatures in the future due to global accumulation of CO_2.	Submersion of low-lying coastal lands and infrastructure; property values at risk are huge.	Effects not likely until 2050-2100 time frame; uncertainty as to ultimate magnitudes; problem not well understood at present.

Table 7-2 (Continued)

Summary of Rankings of Welfare Effects

Rank	Environmental Problems	Major Characteristics	Rationale for Ranking Position	
			Why Ranked High	Why Not Ranked Higher
6	Stratospheric Ozone Depletion	Ozone depletion in the stratopshere leads to increased UV-B radiation in the future.	Value of crops, livestock, and fish species at risk is very high.	Effects are not likely in the near term; uncertainty as to ultimate magnitudes and susceptibility of species.
7	Other Air Pollutants	Unpleasant odors and noise create discomfort.	Among the greatest sources of public complaints at the local level; large populations exposed in urban areas.	Difficult to monetize, contingent-valuation studies limited.
8	Discharges from Direct Point Sources (Industrial, etc.) to Surface Waters	Industrial and other point sources of water pollution.	$800 million/year in losses to recreational water uses.	Damages similar to those of nonpoint- and indirect point-source discharges, but smaller.
9	Inactive Hazardous Waste Sites	Superfund and other inactive sites.	Depressed property values in vicinity; threats to community drinking water supplies.	Effects are usually local; most sites are located away from major urban populations and their drinking water supplies; alternative water supplies often exist.
10	Nonhazardous Municipal Waste Sites	Municipal landfills.	Depressed property values in vicinity; threats to community drinking water supplies.	Effects are usually local; most sites are located away from major urban populations and their drinking water supplies.

Table 7-2 (Continued)

Summary of Rankings of Welfare Effects

Rank	Environmental Problems	Major Characteristics	Rationale for Ranking Position	
			Why Ranked High	Why Not Ranked Higher
11	Active Hazardous Waste Sites	RCRA sites.	Depressed property values in vicinity; threats to drinking water supplies.	Damages similar to those from inactive hazardous waste sites but smaller number of sites; future wastes expected to pose less contamination problems.
12	To Wetlands from All Sources	Discharges from point and nonpoint sources of pollution.	Damage to shellfish, wildlife.	Effects similar to those for coastal areas and oceans, but commercial products of wetlands are somewhat limited; swimming impacts limited.
13	Other Pesticide Risks--Leaching and Runoff of Pesticides and Agricultural Chemicals, Air Deposition from Spraying, etc.	Runoff of pesticides into surface water; seepage of pesticides into ground water.	Endangers shellfish and certain other fish species; dangers may not become apparent until toxins accumulate; ground-water contamination.	These effects are largely accounted for in the environmental problems Discharges to Surface Waters from Nonpoint Sources and To Estuaries, Coastal Waters, and Oceans from All Sources.
14	Biotechnology	Introduction of new species of plants and microorganisms.	Potential danger to crops, livestock, trees, or marine life accompanies the introduction of new species into the environment; U.S. agriculture is highly concentrated in only a few major crops.	Likelihood of negative effects is uncertain; damages may not occur until well into the distant future.

Table 7-2 (Continued)

Summary of Rankings of Welfare Effects

Rank	Environmental Problems	Major Characteristics	Rationale for Ranking Position	
			Why Ranked High	Why Not Ranked Higher
15	Nonhazardous Industrial Waste Sites	Surface impoundments, waste piles, tailings, spent ore, etc.	Depressed property values in vicinity; threats to drinking water supplies.	Contamination probably not as severe as for hazardous waste sites.
16	Releases from Storage Tanks	Primarily underground fuel tanks.	Damages to local property and drinking water.	Contamination of ground-water supplies are less of a problem than for waste sites.
17	Accidental Releases of Toxics	Spills and other accidental releases from industrial, transportation, and storage facilities.	Damages to waterways and nearby property.	Most releases affect only nearby property; damage to property often is the result of the accident (e.g., the fire itself, rather than the toxics released).
18	Accidental Oil Spills	During production, transportation, and storage.	Loss of recreational use of water areas, danger to wildlife and some fish species.	Tangible economic damages are usually limited; most spills are small.
19	Drinking Water As It Arrives at the Tap	Corrosive water results in the leaching of lead into municipal water systems.	Documented damages to municipal water systems.	Damages less than for other environmental problems that are ranked higher.

Table 7-2 (Continued)

Summary of Rankings of Welfare Effects

Rank	Environmental Problem	Major Characterisitics	Rationale for Ranking Position	
			Why Ranked High	Why Not Ranked Higher
20	Indoor Radon	Accumulation of low-level radiation in houses in certain areas.	Could require $1,000-$1,500 in modifications per house for many houses or cause equivalent lowering in property values.	Counting dollar costs for remedies may double count the health risks by capitalizing the costs of their control.
21	Mining Wastes	Mine acid runoff, oil and gas extraction, brines and muds, uranium and asbestos tailings, chemical leachates from benefication.	Fish kills, deterioration in surface water quality.	Generally mining is not conducted near populated areas; most occurs in semi-arid areas, which mitigates runoff; most effects accounted for in Nonpoint Source Discharges to Surface Waters.
22	Contaminated Sludge	Municipal and scrubber sludges, varying degrees of contamination with toxics.	Leaching, deterioration of soil and water quality.	Disposal usually takes place in isolated areas.
23	Hazardous/Toxic Air Pollutants	Routine releases of toxic air pollutants.	Damages to agricultural crops, possible property value losses.	Limited damages are expected.

Global Warming and Stratospheric Ozone Depletion

Global warming and stratospheric ozone depletion have been the most difficult problems for us to rank. We ranked them in tandem because they have a number of similar characteristics and overall damage estimates.

Global Warming

For global warming, the projected rise in the level of the oceans poses dangers for the large investment in urban infrastructure and both urban and agricultural lands. Losses, though unquantified, are apt to be huge if sea level rises at the rate at which some experts project.

On the other hand, considerable uncertainty surrounds the projections that have been made to date. For instance, little is known about the impacts of global warming on future weather patterns. Also, with a slow sea level rise, most effects will occur far in the future in the years 2050 to 2100. Even if these projections were accurate, we debated how significant the effects would be. For example would these effects be of a catastrophic or evolutionary nature? Finally, some work group members were generally suspicious of long-range projections. In the end, the consensus of the work group was that global warming is a potentially serious but little understood environmental problem.

Stratospheric Ozone Depletion

Stratospheric ozone depletion also poses potentially significant welfare risks. Its characteristics are similar to those of global warming, such as long-term potentially large impacts in the future that are not very well understood at present. Unlike global warming, which primarily endangers property and land, stratospheric ozone depletion primarily threatens animal and plant life, as it is believed that increased levels of ultraviolet-B radiation may kill or impair some species of plant, animal, and marine life. Also, weather patterns may be influenced by changes in ultraviolet-B radiation (as well as by global warming), resulting in many effects that are difficult to foresee currently.

Other Air Pollutants (Noise and Odors)

We ranked noise and odors high because these environmental problems can significantly disrupt the daily lives of large numbers of people, particularly in urban areas. About 40 percent of Americans are exposed to elevated noise levels that result in welfare losses.

For odors, the one study cited estimated large welfare losses. While many members of the work group thought this study overvalued the welfare effects, the entire work group nevertheless remained convinced that noise and odors are serious problems. One reason for this judgment is that over half the complaints that state and local environmental agencies have received concern unwanted odors or noise.

Discharges from Direct Point Sources

This problem ranked high because it causes an estimated $800 million in national damages annually. These damages appear in the forms of foregone recreational activities--such as swimming, boating, and fishing--and reduced commercial fishing yields.

Waste Sites

Waste sites occupy the next three places in the environmental ranking. Hazardous wastes oftentimes threaten community drinking water supplies, and both hazardous and nonhazardous wastes sites can reduce property values of residences nearby. These problems were not ranked higher because most of their effects are localized, and most waste sites are located away from areas of high population density. Active hazardous waste sites were ranked lower than inactive sites because the potential number of inactive sites is greater and contamination problems are likely to be more severe.

Some members of the work group thought that the environmental problems caused by waste sites should be ranked higher because the option and existence values associated with ground water are high. Little quantitative evidence could be brought to bear on this subject, and estimates of the size of these values remained unresolved.

Wetlands

Discharges from point and nonpoint sources are the major threats to wetlands. Sizable quantities of harvestable shellfish and wildlife are jeopardized by such hazards as pesticide runoff and accumulation. The potential losses for wetlands parallel those for estuaries, coastal waters, and oceans, but are on a lesser scale in terms of their recreational and natural resource values. To some extent, damages to wetlands have been allotted to other categories of environmental problems, such as pesticides and discharges from point and nonpoint sources of pollution.

Pesticides

Other pesticide risks primarily stem from surface and ground-water contamination from pesticide use. The types of welfare risks from pesticides were largely subsumed under the environmental problems Discharges from Nonpoint Sources to Surface Waters and To Estuaries, Coastal Waters, and Oceans from All Sources. Because we were not presented with a systematic study of effects from pesticides, we based this ranking largely on our subjective judgment of what the effects are likely to be.

Biotechnology

Biotechnology occupied a somewhat controversial fourteenth place. There was considerable disagreement within the work group over the significance of potential adverse effects that may arise from biotechnological changes.

On the one hand, biotechnology's potential damages were regarded as small because of the absence of actual damages to date and the likelihood that future damage would be remote. On the other hand, it is recognized that a population of living organisms may have unforeseen effects on plants and animals, including humans, and since they can expand their population through reproduction, the effects could be very serious. For example, U.S agriculture depends on a limited number of species of crops and livestock. Rapid genetic changes introduced into the environment could have large adverse consequences, conceivably even on the scale of a major loss of an important crop, such as corn, or a blight similar to that caused by the gypsy moth.

RECOMMENDATIONS

We have developed a set of recommendations on interpreting the results of this work and on how to improve future efforts.

EPA Offices Should Intensify Their Welfare Assessment Activities

In general, we were surprised by the scarcity of information about the adverse welfare effects of many environmental problems. Given the quantifiable nature of many types of welfare effects, we expected to conduct a comprehensive assessment. However, many offices at EPA have not undertaken even a rudimentary assessment of the extent and the significance of the welfare effects their regulatory programs seek to minimize.

Rankings Should Be Viewed as Only a General Indication of the Relative Severity of Welfare Effects

One consequence of this lack of systematic study is that the information available to us varied substantially in quality and coverage. Thus, the ranking depends to a considerable extent on the collective professional judgment of the work group.

A number of work group members expressed concern that the results of this document may be applied too rigorously, particularly for the lower-ranked environmental problems, where the lack of quantitative data was more pronounced. Thus, this document should be viewed as a preliminary estimate by senior managers at EPA of the relative magnitude and extent of welfare risks from alternative environmental problems.

Research Should Continue on CO_2/Global Warming and Stratospheric Ozone Depletion

The magnitude of welfare effects from these two environmental problems is potentially enormous. However, substantial uncertainty surrounds their potential effects. For example,

- the long lead time before the impacts may occur allows for social, political, and economic adjustments, especially if the impacts are evolutionary, rather than catastrophic; and

- the potential for positive as well as negative effects suggests the potential for a distribution of wealth, rather than welfare losses.

Given these and other uncertainties, we believe that current research efforts to determine the nature of the problems should be continued.

EPA Should Evaluate the Welfare Effects of Noise Pollution

Work group members had different opinions about the relative ranking of Other Air Pollutants, which is principally composed of odor and noise pollution. Despite these differences, all the members agree that EPA should evaluate the significance of noise pollution.

Pesticide Effects Should Be Assessed Separately

We were uncomfortable with our inability to specifically delineate what we believed to be the substantial welfare impacts

of pesticide use. Separate data do not appear to exist. Information provided to us was either presented in an aggregate fashion by receptor (for example, for estuaries) or in an aggregate fashion by source category (for example, discharges from nonpoint sources). Thus, we believe that EPA should conduct research on the welfare damages stemming exclusively from pesticides.

EPA Should Conduct More Research on the Use, Option, and Existence Values of Protecting Ground Water

The environmental problems associated with ground-water contamination were ranked lower than one might expect, given EPA's attention to the problems. The assessment of these problems was influenced by the lack of research into effects, the difficulty of assessing future use values of ground-water resources, the desire of the public to maintain the option of having pristine ground water (option value), and the value the public places upon preserving pristine ground water, even if it is never used (existence value). EPA should conduct more research on the welfare effects of ground-water contamination, considering future use, option, and existence values to determine whether this report has accurately portrayed such effects.

EPA Should Improve Techniques for Assessing the Effects of Uncontrolled Biotechnology and Other Unlikely Catastrophic Events

Evaluation of the effects of uncontrolled biotechnology posed a problem somewhat different from those posed by other environmental problems. While serious welfare impacts could be postulated (e.g., permanent loss of a grain crop, such as corn) the risk of occurrence was small and unquantified. Hence, we based our judgment largely on the possibility of the release of an undesirable agent with serious impacts. EPA needs to explore more disciplined ways of collecting and evaluating whatever information is available on this subject and integrate this information into the its decision-making process.

Welfare Effects of Contaminated Drinking Water Need to Be Better Quantified

The lack of information on the welfare effects of poor quality drinking water was surprising, especially in light of such obvious areas of public concern as objectionable tastes, discoloration, or odors. This may be due to the health focus this problem has received in the past. A broader focus on effects to include welfare impacts in future research and regulatory efforts may identify substantial welfare risks not considered in this analysis.

EPA Should Reassess Its Priorities to Better Reflect the Severity of Welfare Effects

There appear to be serious discrepancies between the welfare effects documented in this report and the degree of attention that EPA currently gives particular environmental problems. Environmental problems that have significant welfare effects but have received comparatively less attention by EPA include:

- Discharges from Nonpoint Sources to Surface Waters;
- Other Air Pollutants (including noise and odors);
- Other Pesticide Risks--leaching and runoff of pesticides and agricultural chemicals, air deposition from spraying, etc.; and
- To Estuaries, Coastal Waters, and Oceans from All Sources.

Concerns about a particular environmental problem and its associated welfare effects does suggest that explicit consideration of all environmental effects can improve EPA's prioriity-setting process.

APPENDIX A

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