EWCE 431
Environment and Social Impact Assessment

Economic Evaluation of EIA

Introduction

- **Economic evaluation** of EIA involves assessing the **monetary value** of environmental impacts and integrating them into **project decision-making**.
- It helps decision-makers to compare the costs and benefits of different **project alternatives**, especially those impacts that are not easily captured by **market prices**.
- It ensures that environmental considerations are not overlooked and promotes **sustainable development**.
- **Methodological framework** that can be used to strengthen the assessment of the significance of **environmental impacts** and the effects of **mitigation measures**.
- Enhance the information content of **EIA reports**.

Introduction

- **Residual impacts** that cannot be completely mitigated need to quantify the degradation in services from the disturbance to the **natural environment**.
- Demonstrate the significant loss of the **environmental values** of the services.
- Flows of environmental services with project implementation are **real economic loss** to different stakeholders. Quantifying these losses, more informed decisions can be made.

Why it is Important?

An economic analysis and a valuation in **monetary terms** of the environmental impacts and proposals-

- Make it possible to integrate the conclusions of the EIA into the **economic and financial** analysis of the project assessment.
- Evaluate the project's **costs and benefits** and the advantages and disadvantages of different possible alternatives and scenarios.
- Find the most effective instruments to solve **environmental problems** which can arise as a result of the project.

What are Environmental Costs?

Direct Costs: explicit costs associated with environmental damage, such as:

- Cleaning up pollution (e.g., oil spills, industrial waste).
- Restoring damaged ecosystems (e.g., reforestation, wetland restoration).
- Mitigating the effects of climate change (e.g., investing in renewable energy).
- Complying with environmental regulations (e.g., purchasing permits, installing pollution control equipment).

What are Environmental Costs?

Indirect Costs: costs that arise from the broader environmental impact, even if they are not directly tied to a specific activity.

- Health problems caused by pollution.
- Loss of biodiversity and ecosystem services.
- Damage to infrastructure from extreme weather events related to climate change.
- Reduced agricultural productivity due to environmental degradation.

How can economic valuation be used?

All public and private projects have costs and benefits to society. Economic evaluation of environmental impacts and the economic assessment of the project as a whole can be used, in four main areas.

Environmental costs can:

- Enter into Cost Benefit Analysis
- Motivate and prioritise mitigation options
- Contribute to a compare significance of different impacts
- Make it easier to analyse alternative project designs, locations, mitigating measures etc.

Enter into Cost Benefit Analysis (CBA)

- Environmental costs can be included in a CBA. CBA is a comprehensive evaluation of **costs and benefits** to society in monetary terms of a proposed project.
- Main criterion for evaluation is **economic efficiency**, i.e. a given policy objective is achieved at least cost to society.
- When all impacts of the proposed project have been established and measured in monetary terms, the project should be carried out if the **net benefits** (benefits with less costs) to society are positive.

Motivate and Prioritise Mitigation Measures

- Making a **CBA** for the mitigation measures only, and not for the project as a whole.
- EIA should estimate the extra, or incremental, **environmental costs** caused by the project, both with and without mitigation measures.
- Comparing the costs and benefits of mitigation serves two purposes:
  - If the environmental benefits are higher than the costs of mitigation measures, it will motivate and make clear to decision-makers that some mitigation is justified.
  - If there is a range of possible mitigation measures, the EIA specialist can recommend the combination of measures, which yield the highest net benefit. If it is hard to find the optimal combination, individual mitigation measures can be ranked.

Compare Significance of Different Impacts

- Compare the significance of various environmental impacts.
- Introduces a **consistent method** of measuring environmental costs across different impact categories.
- All environmental costs are measured in terms of money they can be compared and their **relative significance** established.

Make It Easier to Analyse Project Alternatives

- Analysis of alternatives to the project in question (e.g. alternative project site, technology, operation).
- **EIA** process should make sure that there are no other **project alternatives** with substantially lower environmental impacts.
- As a minimum, the analysis of **alternatives** should cover the situation with and without the project.
- The **environmental costs** with and without **mitigation** for the different project alternatives can be compared and a recommendation made regarding the most **sensible** option from an environmental perspective.

Methodology

- A **critical step** in the valuation process revolves around the need to ensure **valid attribution** of impacts on environmental services to the Project.
- In order to satisfy this requirement, **physical** environmental impacts are first demonstrated.
- Establishment of a clear link between project impacts on the **physical functions** of the environment and the **alteration** of the **quality** and **quantity** of environmental goods and services.
- Guidelines of economic valuation on environmental impacts prepared by the **DoE** are adopted.

Methodology

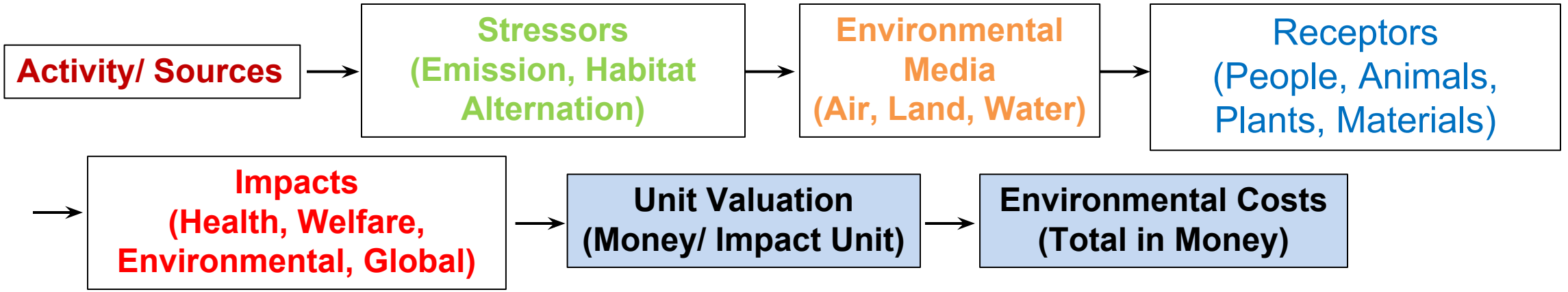
Adequate considerations have to be taken with regard to:

- Identifying the project **stakeholders**.
- Defining the "**With Project**" versus "**Without Project**" scenario.
- Describing and listing of **potential** physical impacts that can be reliably attributed to the project.
- Impacts on the environment over the duration of the project are quantified.
- The quantified impacts are valued in monetary terms using **market and non-market valuation** techniques.
- Costs and benefits of the potential impacts occur over time. To add these values, they would have to be **discounted** to the present values.

Methodology

- Determine the **aggregated net present values (NPV)** of the potential impacts of the project.
- Performing a **sensitivity analysis** on the net present values of the impacts to test for the **robustness** of the aggregated net present values estimates under **adverse economic and technical** circumstances.
- Making appropriate **recommendations** in consideration of the contributions of the various physical impacts to the aggregated net present values.
- Appropriate **mitigation measures** are recommended to improve the significant impacts.

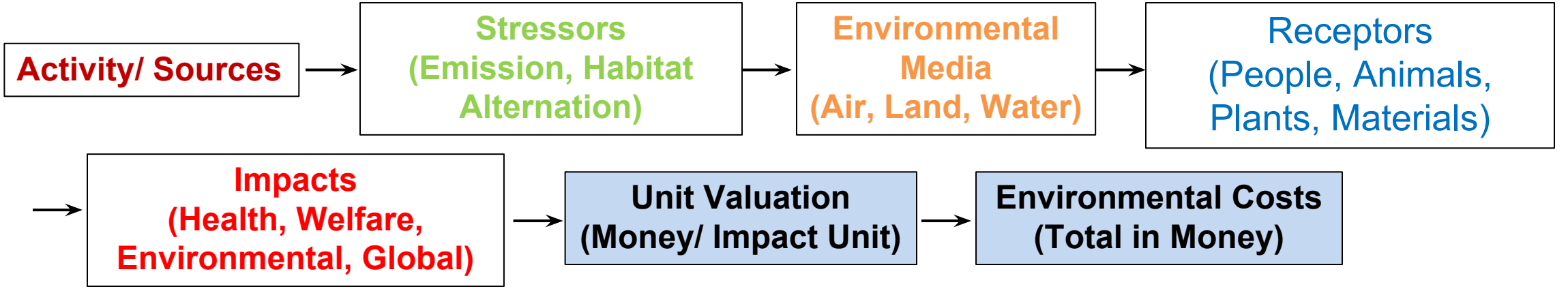
Steps in Economic Evaluation



Project activities (or sources) refer to the development project in any sector, having significant **positive or negative environmental impacts**. The impacts can occur during the **construction and/or operation phase** of the project.

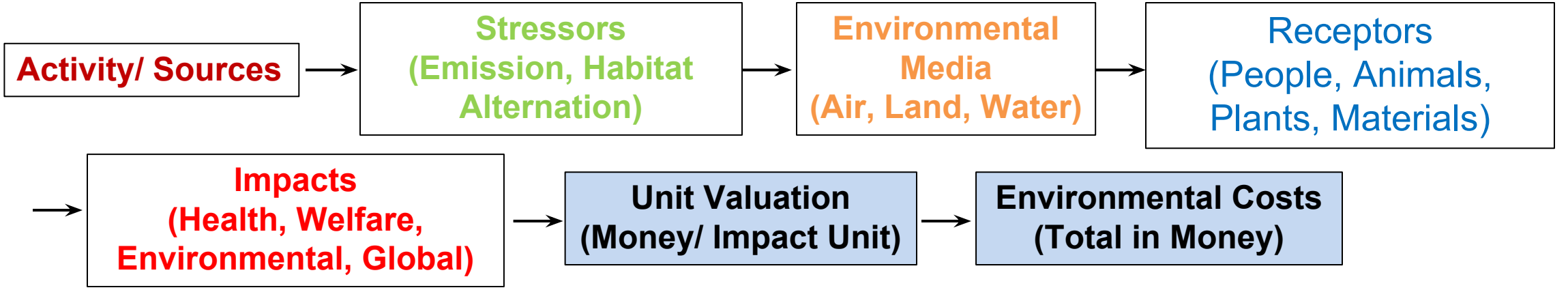
Stressor is a term used to denote the chemical and/or biological changes in the environment, e.g. **emissions or habitat alterations** associated with the project activities. A development project can have either **negative or positive effects on stressor levels**. For example, a power plant may increase physical stressors by reducing the amount of natural habitat, but at the same time replacing an older facility reducing chemical stressor levels (lower emissions than the old plant).

Steps in Economic Evaluation



- The concept of **mitigation**, which refers to avoiding or minimizing increases in environmental stressor levels, is relevant for both the **activity** and **stressor levels** of project design – for example choice of fuel type for a power plant (activity) or fitting of abatement technology, given a choice of fuel (stressor).
- The stressors affect **receptors** (people, animals, plants, materials, and ecosystems) by going through environmental media (i.e. air, land, and water). For example emissions from a stack travel through the air they are transported (dispersed) and/or chemically transformed before being deposited a considerable distance downwind.

Steps in Economic Evaluation



- The exposure of the **receptors** in time and space by different types of **stressors** determine the environmental **impacts**. These impacts refer to the good or bad **chemical** and **biophysical** consequences expected in a receptor after a change in exposure to stressors.
- Changes in impacts are typically quantified through **dose or exposure-response** relationships. The dose is the exposure to a stressor (e.g. particle emission), while the response is the physical impact (e.g. increased risk of respiratory disease).

Air Pollutant Dose

Exhibit 7. Air Inhalation Exposure Dose Equation

Exposure doses from inhalation of air can be calculated as follows:

$$D = (C \times IR \times EF) / BW$$

where,

D	=	exposure dose (mg/kg/day)
C	=	contaminant concentration (mg/m^3)
IR	=	intake rate (m^3/day)
EF	=	exposure factor (unitless)
BW	=	body weight (kg)

Default Air Intake Rates
(approximate mean)

4.5 m^3/day -	infant, less than 1 year
10 m^3/day -	child, 6–8 years
12 m^3/day -	girl, 12–14 years
15 m^3/day -	boy, 12–14 years
11.3 m^3/day -	female, 19–65+ years
15.2 m^3/day -	male, 19–65+ years

Source: EPA 1997

Inhalation exposure to contaminants from hazardous waste sites can occur as a result of direct release of gases and particles from an on-site facility, volatilization of gases from contaminated soils or water bodies, or resuspension of dust and particles from contaminated soil surfaces.

Air Pollutant Dose

Exhibit 2. Exposure Factor Equation

$$EF = (F \times ED) / AT$$

where,

F	=	frequency of exposure (days/year)
ED	=	exposure duration (years)
AT	=	averaging time (ED x 365 days/year)

For example, if a child comes into contact with contaminated soil twice a week during a 5-year period, the exposure factor would be:

EF = (F x ED) / AT

EF = ([2 days/week x 52 weeks/year] x 5 years) / (5 years x 365 days/year)

EF = 0.28

Potency Factor

- At low doses, where the dose-response curve is assumed to be linear, the slope of the dose-response curve is called the potency factor.
- Potency factors can be found in an EPA database on toxic substances called the Integrated Risk Information System (IRIS).

Chronic Daily Intake

$$\text{CDI (mg/kg-day)} = \frac{\text{Average daily dose (mg/day)}}{\text{Body weight (kg)}}$$

The Average Daily Dose is the total lifetime dose averaged over an assumed 70 year lifetime.

$$\text{CDI} = \frac{\text{Concentration (mg/m3) x Intake rate (m3/d) x Exposure (days/life)}}{\text{Body weight (kg) x 70 (yr/life) x 365 (days/yr)}}$$

$$\text{Incremental Risk} = \text{CDI} \times \text{PF}$$

Exercise

Suppose an industrial facility that emits benzene into the atmosphere is being proposed for a site near residential neighborhood. Air quality models predict that 60% of the time, prevailing winds blow benzene away from the neighborhood, but 40% of the time the benzene concentration will be 0.01 mg/m^3. Benzene has a potency factor of 2.9×10^{-2} $(mg/kg\text{-}day)^{-1}$. If the acceptable risk is 10^{-6}, should this plant be allowed to be built?

Given, Exposure Factors:

Daily intake rate = 20 m^3 (adult); 12 m^3 (child)

Exposure frequency = 350 days/yr

Exposure duration = 30 yrs

Body weight = 70 kg (adult); 15 kg (child)

We first account for the fact that exposure only happens **40% of the time**, so the effective concentration is:

$$C_{\text{eff}} = 0.4 \times 0.01 = 0.004 \text{ mg/m}^3$$

Step 1: Use the ADD formula

$ADD = \frac{C \cdot IR \cdot EF \cdot ED}{AT \cdot BW}$

For carcinogenic risk, averaging time:

$$AT = 70 \times 365 = 25550 \text{ days}$$

Adult Calculation

- $C = 0.004$, $IR = 20$, $EF = 350$, $ED = 30$, $BW = 70$

Numerator:

$$0.004 \times 20 \times 350 \times 30 = 840$$

Denominator:

$$25550 \times 70 = 1,788,500$$

$$ADD_{\text{adult}} = \frac{840}{1,788,500} \approx 4.70 \times 10^{-4}$$

Cancer Risk:

$$Risk = ADD \times SF = (4.70 \times 10^{-4})(2.9 \times 10^{-2}) \approx 1.36 \times 10^{-5}$$

Child Calculation

- $IR = 12$, $BW = 15$ (other factors same)

Numerator:

$$0.004 \times 12 \times 350 \times 30 = 504$$

Denominator:

$$25550 \times 15 = 383,250$$

$$ADD_{\text{child}} = \frac{504}{383,250} \approx 1.32 \times 10^{-3}$$

Cancer Risk:

$$Risk \approx (1.32 \times 10^{-3})(2.9 \times 10^{-2}) \approx 3.83 \times 10^{-5}$$

✅ Final Conclusion

- Adult risk ≈ 1.36×10^{-5}
- Child risk ≈ 3.83×10^{-5}
- Acceptable risk = 1×10^{-6}

👉 Both risks are **much higher than the acceptable level**.

The impacts can be categorized in terms of human health or welfare, environmental resources, or global systems.

Human health	Human welfare	Environmental Resources	Global systems
Mortality: • Increased risk of death	*Materials:* • Damage to buildings, bicycles etc	*Coastal & Marine ecosystems:* • Thermal alteration • Mangrove reduction • Fishery loss	*Direct:* • Global warming • Acid rain • Ozone depletion
Morbidity: • Increased risk of diseases such as cancer, respiratory diseases etc	*Aesthetics:* • Reduced visibility • Traffic congestion • Landscape changes • Noise/odour	*Ground water:* • Lower water table	• Change in weather patterns • Wide range hazardous chemicals • Radiation from nuclear accidents
	Resource use: • Reduced fishery, forestry & crop yields • Reduced wildlife & recreation	*Freshwater ecosystems:* • Reduced biological productivity in wetlands, watersheds, rivers/lakes	*Indirect:* • Desertification • Biodiversity loss
	Social/cultural: • Impacts on cultural/religious lands • Relocation of people	*Biodiversity/Endangered species:* • Loss of diversity of flora and fauna	
		Terrestrial ecosystems: • Reduced flora and fauna • Soil nutrient loss	

Steps in Economic Evaluation

- First the economic value (or price) for the different impacts per physical unit (for example Currency/case of respiratory illness) is estimated.
- The prices are multiplied with the extent of the physical impacts (for example number of illness cases).
- This is done to the extent possible for all impact categories to obtain the total sum of environmental costs measured in Currency.

Methods

A number of methods are used to put a value on changes in environmental quality. If the project affects resources which have a market value, it is possible, to estimate:

- changes in productivity (increase/decrease in crop harvests, fish catches etc.);
- changes in income (increase/decrease in number of sick days due to ill health, death etc.);
- costs of avoiding or reducing negative effects on the environment;
- costs of compensation for damage.

Methods

Information can also be used from related markets, with the aid of:

- **property values** (value of property inside and outside an area with environmental disorders);
- **wage differential method** (higher wages to attract manpower to areas with environmental disorders);
- **travel cost method** (value of costs of journeys to a certain nature reserve; has also been used to calculate the time required);
- **product substitution/shadow prices** (for example the value of a species of fish which is not sold is compared to the value of a similar fish which is sold on the local market).

Methods

Other methods which are often used:

- **contingent valuation method** (a method based on interviews by which estimates are made of the **willingness of people to pay** to preserve a certain environmental value, and/or what they are **willing to accept as compensation** for tolerating the loss of a certain environmental value)
- experiments in which goods are “bought“ under hypothetical conditions.

Methods

Amounts that people are **willing to pay (WTP)** for goods, including environmental and health benefits, can be estimated in three main ways:

- observing the prices that people pay for goods in various markets; (market method)
- observing individual or household expenditures of money and time to obtain goods, or to avoid their loss, and inferring WTP amounts; (market method)
- asking people about their WTP for goods. (hypothetical market situation)

Methods

- **Market methods** are either based on observations of people's behavior (so-called revealed preferences), or estimate WTP indirectly through dose response functions or damage and resource costs.
- **Hypothetical methods**, such as contingent valuation, infer WTP directly through making people to state their preferences.
- Information about environmental benefits and costs can be transferred from another primary study (benefit transfer). It uses existing data, values, or functions from studies done in one location and applies them to a different, unstudied site.

Commonly used methods for economic evaluation

Market methods		**Hypothetical markets**
Revealed Preference	Dose-Response Damage & Resource costs	Stated Preferences
Hedonic pricing & Wage-risk Travel cost	Defensive and averting expenditures Cost of illness Property damage Vegetation damage	Contingent valuation e.g. of mortality risks Contingent ranking
Benefit transfer		

Some examples of damages from pollution and how they could be priced

Receptors	End point damages	Price (remark)
Materials (air)	Shorter length of life, various materials	Prices of purchasing and installing replacement material
Plants and animals (air, water, land)	Reduced agricultural output and quality	Prices of crops, price of husbandry, price of other outputs
	Reduced output from forestry/ forests	Price of timber etc.
	Other vegetation, parks etc.	Price/cost of replacement
	Reduced fish catches and fish quality	Prices of fish
Manufacturing industry	Reduced manufacturing industry output	Prices of manufacturing industry output

Specific Evaluation Techniques

Evaluation of mortality costs

The formula to calculate death loss of respiratory system disease, cardiovascular disease, and respiratory system cancer is:

$$L = \sum VSL \times P \times \Delta c \times M \times DR$$

Of which:

VSL = value of statistical life

P = population of exposure

Δc = ambient quality (concentration) change

M = mortality

DR (ER) = Dose/Exposure-response function for mortality rate

Specific Evaluation Techniques

Evaluation of disease costs

Disease costs include costs of being hospitalised, outpatient service, work delay, and costs of having family accompanying the ill person to hospital. The calculation formulas are:

Hospital admission costs: $L = E \times T \times R \times P \times \Delta c \times ER$

E = average expenditure on outpatient service,

T = average days of hospital admission

R = hospital admission rate,

P = population of exposure

Δc = ambient quality (concentration) change

ER = Exposure-response function for hospital admission

Workday loss due to disease: $L = T \times P \times GDP \times \Delta c \times ER$

T = average workdays delayed (equal to average days of hospital admission),

P = number of hospital admission,

GDP = average GDP per capita,

Δc = ambient quality (concentration) change

ER = Exposure-response function for hospital admission