CHAPTER 5

AN OVERVIEW OF THE MAJOR ENVIRONMENTAL PROBLEMS OF TODAY

5.1. APPLICATION OF PRINCIPLES TO ENVIRONMENTAL PROBLEMS.

In chapters 2, 3 and 4 we outlined some of the principles applicable to environmental problems, and used examples to illustrate how these principles can be applied. Throughout we have concentrated on creating an understanding of the problem, rather than determining all the different environmental problems of today. Environmental problems change with time. What is crucial today might be solved during the next decade, during which time new problems will have appeared.

The principles we might employ to solve these problems will also change with time, but at a much slower rate, so we can probably use the same principles to solve the different and novel problems of the next decade. This chapter is devoted to a brief discussion of those environmental problems of major concern to man today.

To understand the basis of an environmental problem a long list of questions and problems, has to be answered. This may not always be possible because of lack of data. However, when the data are available the principles explained in chapters 2, 3 and 4 can be applied to formulate and answer the relevant questions. Which questions to ask is sometimes difficult to decide upon, but an attempt can be made as follows:

1. What is the source of pollution?
2. What is the distribution pattern of the pollutant in time and space in the ecosphere and in the ecosystem?
3. Is the pollutant harmful to plants and animals? What is its toxic effect? What is its level of toxicity?
4. Does the pollutant take part in chemicobiological processes in the environment? Will such pollution affect the ecological balance?
5. Will there be any chance of biomagnification? What is the ecological buffer capacity related to the pollution?
6. Will the pollutant accumulate in organs?
7. Will the pollutant accumulate somewhere in the ecosystem? (as for example heavy metals and nutrients accumulate in sediments)
8. What is the overall effect on man, bearing in mind all the pathways from the source to man?

Fully quantitative answers to such a list of questions often require the application of ecological models, as many interacting processes are involved and the system is very complex. However, without sufficient data it is impossible to solve any environmental problem, and an ecological model cannot give the answer, as it is only a tool to cope with complicated systems *provided that sufficient data are available.* But some data at least are available for environmental problems and in these cases it is possible partially to understand the core of the problem. Let us consider the DDT problem as an example of how far we can deal with most problems today. We know that the source of DDT is the application and the production of a particular pesticide. The problem is related to the toxicity, the low biodegradability and the biomagnification effects of this compound. Data focusing on these aspects of DDT are available and by applying the relevant principles (see sections 1-2.3) it can be concluded that only minor use of this pesticide can be accepted, and that a better solution would be to introduce alternative (biological) methods or compounds with better biodegradability and less chance of biomagnification. These conclusions can be made without the use of ecological models; on the other hand, a quantitative relationship between a given application of DDT and its final concentration in top carnivores in an ecosystem would require the use of an ecological model.

Many environmental problems cannot be solved easily, but require *the imposition of legislative measures* to remove the source of pollution. This has been the case with DDT, which is banned in many countries. Other problems such as the use of nutrients cannot be solved in that way, but will require prudent planning of their use with ecological aspects taken into consideration. But in both cases it is crucial to understand the problem fully if the right decisions are to be made.

The following paragraphs list the major environmental problems of today. References to a more comprehensive and detailed treatment of these problems can be found in the reference list. The problems have been divided into the following categories:

1. Air pollution. Pollution problems mainly related to the atmosphere.
2. Pesticides and other toxic organic compounds which affect the hydrosphere, lithosphere and atmosphere.
3. Heavy metal pollution, which like (2) affects all three spheres.
4. Water pollution problems, mainly related to the hydrosphere.
5. Noise pollution.
6. Pollution from solid wastes.
7. Food additives.
8. Energy alternatives.

5.2. AIR POLLUTION.

Air pollution problems are concerned either with global effects on the climate or local (regional) effects due to toxicity of air pollutants.

There are several ways in which man's activities may affect global climatic patterns in the future. One of these has been mentioned in sections 2.5 and 3.5, i.e. the increasing carbon dioxide concentration in the atmosphere produced by the combustion of fossil fuel. Decreasing atmospheric transparency by the injection of particulate matter (dust, sulphates, liquid droplets) into the atmosphere from industry, vehicles, space heating, agriculture and land clearing activities might, however, have the reverse effect on the climate by increasing the reflection of solar radiation (Watt, 1972). Man is also changing the albedo (i.e. the percentage of incoming solar radiation that is directly reflected back into space) of the earth's surface through irrigation, urbanization, deforestation and agriculture. Furthermore, the rate of thermal energy transfer between the oceans and the atmosphere is altered by oil pollution in the hydrosphere (see also 5.5) and finally there is the problem of the direct emission of heat to the atmosphere by the burning of fossil and nuclear fuels.

Regionally, the emission of toxic gases is of great importance. The problem is related to the following compounds: carbon monoxide, nitrogenous gases with the composition NO_x, where x is between one and two, sulphur dioxide, particulate matter, chlorine, hydrogen chloride, hydrogen sulphide and hydrogen flouride and the formation of the so-called photochemical smog, which consists of ozone, PAN (peroxyacetyl nitrate), PPN (peroxypropanyl nitrate) and PBN (peroxybuturyl nitrate).

In this context we must also mention the possible effects of nitrogen oxide input to the stratosphere by supersonic aircrafts. Although we do not know enough to predict in detail the effect of these emissions, they could not only alter global climatic patterns, but also partially deplete the ozone layer, which protects us from harmful wave length of ultraviolet radiation. Johnston (1972) has projected that 500 supersonic aircrafts could halve the amount of ozone within as little as one year. The possible risk is easy to understand when it is added that a 5% decline in ozone would produce at least 8000 additional cases of skin cancer per year among the U.S. white population (National Academy of Sciences, 1972).

Table 5.1 gives a survey of gaseous pollutants, their sources, major effects and concentration levels.

Carbon monoxide is toxic because of its ability to supersede oxygen bound to hemoglobin (Hb) in blood. The relationship between the carbon monoxide concentration and the percentage COHb has been found by a statistical analysis.

TABLE 5.1
Survey of gaseous pollutants, their sources, major effects and concentration levels

Gaseous pollutants	Source	Effect	Concentration level
CO_2	Fossil fuel	Global heat balance	0.032%
CO	Vehicles	Toxic	10-75 ppm (motor ways, free ways)
SO_2, SO_3	Fossil fuel	Toxic Corrosive	≥ 0.15 mg m^{-3} in cities
NO_x	Vehicles	Toxic	Few ppm
Carbon hydrides	Fossil fuel Industry Vehicles	Toxic Photochemical smog	1-25 ppm
Particulates	Fossil fuel Industry Vehicles	Respiratory damage	≥ 200 µg m^{-3} in cities
Photochemical oxidants, ozone aldehydes and others	Fossil fuel Industry Vehicles	Photochemical smog Damage to rubber	Ozone 0.1 ppm PAN 0.01 ppm
Chlorine, hydrogen chloride	Industry Incineration of PVC, Organic chloride	Toxic	Local
Hydrogen fluoride	Industry	Toxic Damage to glass	Local
Iron dust	Industry	toxic	Local

5.3. PESTICIDES, AND OTHER TOXIC COMPOUNDS.

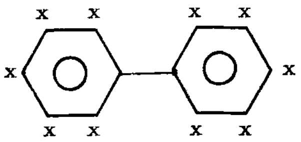
Pesticides are chemical compounds devised to kill insects (insecticides), weeds (herbicides), rodents (rodenticides), fish (piscicides), mites (miticides) and fungi (fungicides). Before the second world war, most pesticides were non-persistent naturally occurring compounds. For example, nicotine sulphate was widely used as pesticide.

The use of pesticides is vast and increasing. More than 1 billion tons of pesticides were produced in the U.S. during 1970.

The problems of using persistent pesticides have already been touchen upon in 2.8, 2.13, 4.2 and 4.4. They can be summarized as follows:

1. Low biodegradability, which implies accumulation in the environment.
2. Resistance is developed relatively quickly (see 4.2).
3. Biomagnification (see 2.8 and 3.4)
4. Toxicity for humans (see 2.3).
5. Destruction of non-target organisms, often including the target pests natural predators (see 4.4).

Pesticides are not the only compounds to be magnified in the foodchain. PCBs (polychlorinated biphenyls) were found in relatively high concentrations in fish, eagles, human tissue, etc. (Jensen, 1966). PCB is a mixture of many compounds derived from biphenyl by chlorination:



(x possible Cl-substitutions)

It is used widely for a variety of purposes (as transformator oil, and as a softener in paint and plastics). Today the use of PCB in many countries is limited to such uses where its emission into the environment can be avoided because of its observed biomagnification.

Appendix 5 gives a list of LD_{50} values for some commonly used pesticides. Table 5.2 summarizes the properies of environmental interest of some commonly used pesticides and PCB.

Many organic compounds represent a threat to the environment. It is not possible here to list all these chemicals, as more than 30,000 compounds are commercially applied in such quantities as to be of environmental concern.

TABLE 5.2
Some commonly used synthetic pesticides

Class	Examples	Major use
A. Chlorinated hydrocarbons	DDT, DDE, DDD, aldrin, dieldrin, endrin, heptachlor, toxaphene, lindane, chlordane	Broad spectrum insecticides (kill a wide variety of target and nontarget organisms)
B. Organic Phosphates	Malathion, parathion, Azodrin, Phosdrin, Diazinon, TEPP	Broad and narrow spectrum insecticides and a few fungicides and herbicides
C. Carbamates	Carbyl (Sevin), Zireb, Maneb	Broad and narrow spectrum insecticides, fungicides and herbicides
D. Phenoxy herbicides	2,4-D and 2,4,5-T	Herbicides

Class	Action	Persistence	Toxicity
A.	Attack central nervous system of insects causing convulsions, paralysis and death	High (2 to 15 years)	Relatively low for humans
B.	Nerve poisons that inactivate the enzyme that transmits nerve impulses	Low to moderate (normally 1 to 12 weeks but up to several years)	Very high for humans and other animals
C.	Nerve poisons	Usually low (days to 2 weeks)	Low to high for humans and other animals
D.	Cause metabolic changes in plants leading to leaf drop or death	Low to moderate (days to several weeks)	Low for humans and other animals

5.4. THE PROBLEM OF HEAVY METALS.

In recent years there have been a series of alarms about toxic metallic substances, such as lead, mercury and cadmium. Although the latter is not a heavy metal, i.e. one which has a specific gravity equal to or greater than that of iron, it is often considered with them, as its environmental effects are similar to those of lead, silver, chromium, nickel, mercury and others. Accurate knowledge of the environmental effects of metals and their compounds is very difficult to obtain, as some metals are essential to life in small concentrations but toxic in higher concentrations. The situation is further complicated because they are introduced into the environment as may different compounds or become converted into other compounds in the environment with different effects and toxicity.

Environmental problems related to the use of metallic compounds have been illustrated for lead in 2.10, but to complete the picture we should take a broader view.

Recently a number of pollution-producing industries have moved to Thailand, where environmental legislation is relatively ineffective. One of the results of this development is shown in Table 5.3 A + B.

Mercury contamination of fish in Thailand has been one of the lowest in the world, with a mean of 0.07 ppm (range 0.002/0.30 ppm) in flesh. Recently mercury values varying from 0.32 to 3.6 ppm in fish flesh have been observed in the vicinity of an established caustic soda factory. In other words the pollution problem has been exported from a developed country (in this case, Japan) to a developing country (compare with Fig. 5.1), but the problem of mercury pollution in connection with caustic soda production has not been solved.

TABLE 5.3 A

Development of chemical industry in Thailand. The data indicates production in thousands of metric tons

Type of industry	1967	1968	1969	1970	1971	1972	1973	1974	Average increase in annual rate of production (%)
Caustic soda	10	18	25	33	39	47	47	53	30
Sulphuric acid	12	14	18	15	14	47	47	47	39
Cement	1734	2168	2403	2627	2771	3378	3706	3923	13
Printing and writing paper	21	24	30	32	38	42	40	34	8
Hydrochloric acid	13	25	31	32	37	34	46	56	26
Washing powder and detergents	21	24	27	27	32	40	47	46	12
Non-cellusic continuous fibers	0.5	0.5	0.9	1.2	4.8	9.8	16.3	15.2	82

TABLE 5.3 B

Mercury content (on wet weight basis) in flesh of fish from some freshwater localities in Thailand. The caustic soda factory (TACSCO) is to be found in locality 8.

Species lity	Loca- analyzed	No. of fish samples (g)	Weight range (cm)	Length range range	mg Hg/kg
Ophiocep-	1	12	280 - 660	29 - 41	0.002 - 0.19
halus	2-6	8	300 - 600	30 - 40	0.004 - 0.16
striatus	7	11	240 - 1120	31.5- 51	0.008 - 0.30
	8	10	120 - 360	21 - 35.5	0.32 - 3.6
Mystus	3	1	660	40	0.10
nemurus	5	1	900	41	0.08
Notopterus chitala	3	3	500 - 2080	38 - 63	0.07 - 0.12
Charias					
macroce-	1	1	280	30	0.04
phalus	6	3	300 - 400	32 - 33	0.003 - 0.004
Pangasius pangasius	1	1	4540	64	0.23

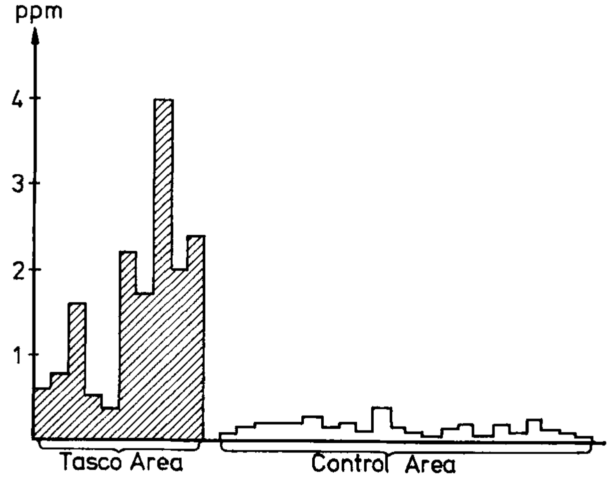


Fig. 5.1. Mercury contents in the flesh of the fish Ophiocephalus striatus collected from the vicinity of the TACSCO caustic soda factory, compared with fish from other parts of Thailand (control area).

That severe legislation is of great importance as illustrated in Fig. 5.2, where the decrease in mercury contamination was pronounced after the use of mercury in fungicides was banned in 1969 (compare also with Fig. 5.3).

How widely the use of all metallic compounds is spread is illustrated in Table 5.4. Even the sludge from biological treatment plants receiving only municipal waste water contains metals in minor concentrations, although sludge from plants treating mixed minicipal and industrial waste-water has a higher content of metals originating from specific industries (see Table 5.5). This indicates that industrial waste-water, which contains substantial amounts of heavy metals, should be treated on the spot.

Table 5.6 gives a survey of sources and effects on health of some widely used metals. Table 5.7 shows the electronegativity of carcinogenic metals.

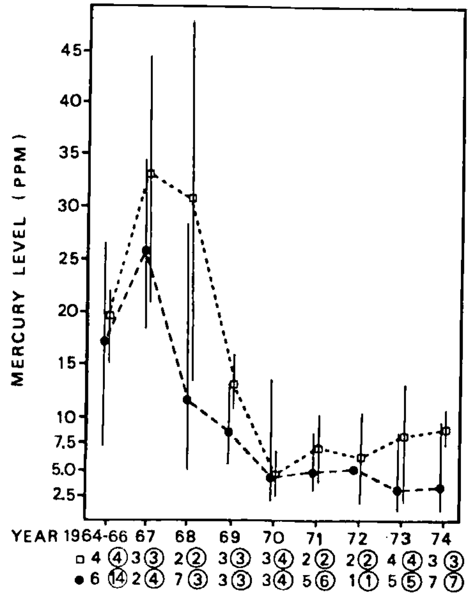


Fig. 5.2. Mercury levels (ppm) in feathers of adult eagle owls from southeast Sweden. □ annual means for the coastal population. • annual means for the inland population. The range in each year is also given. The figures below the year classes show the number of nests from which feathers were collected. The figures in circle represent the number of feathers analyzed.

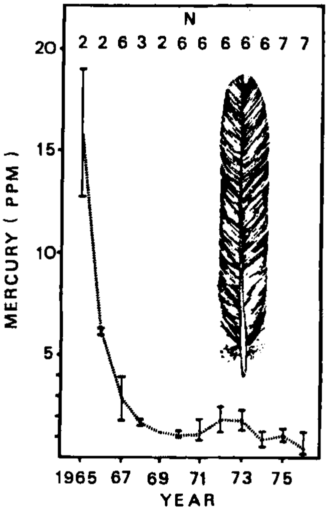


Fig. 5.3. Mercury levels in tail feathers of young marsh harrier in Kvismaren, in central Sweden 1965-1976. The levels are given in ppm on a dry weight basis. The number of nests (N) from which feathers from young were analyzed is given in the upper part of the graph. The intervals between the highest and the lowest levels are given annually.

Two factors of major importance for future trends of heavy metal pollution should be mentioned.

The current increase in the price of oil has accelerated the use of coal as an energy source. However, coal ash is rich in heavy metals as can be seen from Table 5.8. The concentration of metals in ash is not only dependent on the composition of coal, but is also influenced by the combustion temperature, the filter efficiency, etc. Table 5.9 shows the average concentration of several elements in coal with indications of their typical ranges. Their emission can be found as follows:

Emission = consumption of coal • concentration * emission factor.

Typical emission factors are given in Table 5.10.

TABLE 5.4

A. Global heavy metal pollution

Element	Extracted per year (10^6 t y^{-1})	Transported to the sea (10^6 t y^{-1})	Washout by precipitation (10^6 t y^{-1})
Pb	3.5	0.74	0.3
Cu	6	0.25	0.2
V	0.02	0.03	0.02
Ni	0.5	0.01	0.03
Cr	2	0.04	0.02
Cd	0.01	0.0005	0.01
As	0.06	0.07	
Hg	0.009	0.003	0.08
Ca	5	0.7	
Se	0.02	0.007	
Ag	0.01	0.01	

B. Heavy metal transportation in the River Rhine

Element	t/year	Ratio: $\frac{\text{conc. in the Rhine}}{\text{conc. in the North Sea}}$
Cr	1000	20
Ni	2000	10
Zn	20,000	40
Cu	200	40
Hg	100	20
Pb	2000	700

TABLE 5.5

Concentration of heavy metals in municipal sludge from mechanical-biological treatment plants with more than 5,000 p.e. (Denmark) (g t^{-1} dry matter)

Locality	Cr	Ni	Co	Zn	Cd	Cu	Pb	Hg	Ag	Bi
Vejen	50	49	8	1386	10	123	218	5.2	13	<25
Græsted	46	17	4	1538	6	190	261	2.7	14	75
Farum	56	22	8	1487	9	284	305	6.8	27	<25
Ringe	42	20	6	1586	7	232	293	6.5	19	<25
Randers V	70	37	6	1545	10	186	332	3.6	12	<25
Sorø	43	19	7	2105	8	263	296	4.4	38	<25
Sønderborg N	40	18	4	2446	10	298	239	5.3	18	<25
Rungsted	51	18	4	2694	8	322	396	4.8	23	200
Slagelse	47	23	2	2896	7	309	222		32	<25
Hillerød	56	28	6	1778	9	219	261	12.7	97	<25
Odense, Ejby	268	50	3	3484	12	302	401	5.0	55	<25
Ringkøbing	37	22	3	1687	7	220	1164		39	<25

TABLE 5.5 - continued

Locality	Cr	Ni	Co	Zn	Cd	Cu	Pb	Hg	Ag	Bi
Kjellerup	85	37	3	1218	6	106	188	21.7	24	<25
Ringsted	76	21	4	2288	5	273	412	11.9	56	<25
Usserød	179	25	10	4235	7	336	229	6.0	45	75
Århus Viby	163	33	4	3665	10	514	317	32.5	100	<25
Odense NV	525	34	3	3941	13	771	768	5.1	18	<25
Roskilde	3575	218	3	4165	24	377	367	3.2	41	150
Herning	808	327	3	17414	30	217	322	5.0	21	<25
Ålebækken	1068	212	8	2302	11	2264	3898	27.8	87	50
Anlæg Y	201	100	3	4657	58	571	2517	9.3	55	<25
Lundtofte	825	251	59	2532	51	1568	2774	20.5	56	<25

TABLE 5.6

Sources and health effects of some widely used metals

Element	Sources	Health effects
Class 1: Pose serious threats now		
Cadmium	Burning of coal, zinc mining water mains & pipes, tobacco smoke	Cardiovascular disease and hypertension in humans
Lead	Auto exhaust (leaded gasoline) and paints (made before 1948)	Brain damage, convulsions, behavioral disorders, death
Mercury (as methyl mercury)	Burning of coal, electrical batteries, and many industrial uses	Nerve damage, death
Nickel (as nickel carbonyl)	Diesel oil, residual oil, burning of coal, tobacco smoke, chemicals and catalysts, steel and non-ferrous alkyls, gasoline additives	Lung cancer
Beryllium	Burning of coal and increasing industrial use (includes nuclear power industry and rocket fuel)	Acute and chronic respiratory diseases, lung cancer, beryllosis
Class 2: Potential hazards if levels increase		
Antimony	Industry, typesetting, enamel ware	Shortened life span in rats, heart disease
Arsenic	Burning of coal and oil, detergents, pesticides, mine tailings	Cumulative poison at high levels, may cause cancer in man
Selenium	Burning of coal, oil and sulphur, some paper products	Essential to man in trace amounts but rising use could increase levels of exposure, causes cancer in rats, may cause dental caries in man
Manganese	Metal alloys, smoke suppressant in power plants, may be used in place of lead as an anti-knock agent in gasoline	Essential to man in trace amounts but if it replaces lead in gasoline, levels could rise and imperil health from nerve damage

TABLE 5.7
Electronegativity of carcinogenic metals

Element	Chemical carcino-genicity	Electro-nega-tivity	Element	Chemical carcino-genicity	Electro-nega-tivity
Cs	none	0.7	Ni	positive	1.8
K	none	0.8	Sn	positive	1.8
Ru	none	0.8	Pb	positive	1.8
Na	none	0.9	Mn	suspected	1.8
Ba	none	0.9	Fe	suspected	1.8
Li	none	1	Si	suspected	1.8
Ca	none	1	Mo	none	1.8
Sr	none	1	Tl	none	1.8
La	none	1.1	Ge	none	1.8
Y	suspected	1.2	Cu	suspected	1.9
Ha	none	1.2	Te	none	1.9
Sc	suspected	1.3	Re	none	1.9
Zr	positive	1.4	Hg	none	1.9
Be	positive	1.5	Sb	none	1.9
Cr	positive	1.5	Bi	none	1.9
Al	suspected	1.5	As	suspected	2
Ti	suspected	1.5	Te	none	2.1
Zn	positive	1.6	Rh	suspected	2.2
Ga	suspected	1.6	Ru	none	2.2
V	none	1.6	Os	none	2.2
Cd	positive	1.7	Ir	none	2.2
W	none	1.7	Pt	none	2.2
In	none	1.7	Se	positive	2.4
Co	positive	1.8	Ag	none	2.4
			Au	none	2.4

As the consumption of coal is increased emission of harmful elements will also increase, unless the emission factor is reduced. A radical reduction in the emission factor is absolutely essential if a drastic increase in the global pollution of heavy metals is to be avoided. The second factor is the increasing cost of many metals due to speculation on price fluctuations and shortage of easily mined ores. This has caused a growing interest in the recovery of metals, which must be considered a positive development from an ecological point of view. Table 5.11 lists the percentage recovery for a number of widely used metals in the U.S. and Sweden.

TABLE 5.8
Concentration of metals in coal ash

Element	mg per kg
As	10 - 2000
Ag	1 - 100
B	20 - 2000
Be	1 - 200
Bi	5 - 100
Co	5 - 500
Cu	10 - 3000
Cd	1 - 200
Cr	3 - 2000
Mo	2 - 600
Hg	0.01 - 50
Pb	10 - 7000
Ni	3 - 1300
Mn	30 - 4000
Zn	30 - 10,000
Sb	1 - 500
Se	1 - 700
V	30 - 10,000
Tl	4 - 100
W	0.1 - 20
Te	15 - 60
U	10 - 60
Sr	10 - 10,000
Zr	10 - 2000

TABLE 5.9
Concentration of metals in coal (typical ranges are indicated in brackets)

Element	mg per kg
As	5 (1-15)
Ag	0.5 (0.1-1)
B	50 (10-200)
Ba	100 (20-400)
Be	1 (0.1-3)
Bi	1 (0.1-2)
Cd	1 (0.3-10)
Co	10 (1-20)
Cr	20 (5-30)
Cu	15 (5-40)
Ga	4 (1-10)
Hg	0.2 (0.05-1)
La	10 (0.1-40)
Mn	50 (10-100)
Mo	4 (1-10)
Ni	20 (5-50)
Pb	15 (2-70)
Sb	1 (0.2-2)
Se	2 (0.5-5)
Sn	3 (0.1-5)
Sr	100 (20-200)
Tl	2 (1-4)
U	1 (0.1-5)
V	30 (10-50)
Zn	30 (10-100)
Zr	100 (10-200)

TABLE 5.10
Typical emission factors (mg kg^{-1})

Ag	0.01	La	0.005
As	0.04	Mn	0.005
Ba	0.002	Mo	0.01 (0.001-0.1)
Be	0.003	Ni	0.02 (0.01-0.2)
B	0.05	Pb	0.03 (0.02-0.08
Cd	0.03	Sb	0.03
Co	0.01	Sc	0.05
Cr	0.01	Se	0.15 (0.1-0.4)
Cu	0.01	Sn	0.002
Hf	0.003	U	0.007
Hg	0.9 (0.5-0.98)	V	0.01
		Zn	0.03

TABLE 5.11
Percentage recovery of metals in U.S. and Sweden (relative to production)

Metal	% U.S.	% Sweden	Metal	% U.S.	% Sweden
Al	5	5	Mo		12
Au	9	32	Ni	25	14
Fe	25	27	Ag	3	39
Co	2		Sn	20	50
Cu	20	23	Pb	34	45
Cr	9	12	Ti	33	
Mg	0.3		W	3	
Mn		9	Zn	6	6

References related to the tables:
Anderson and Smith (1977), Baby (1975), Bencko and Symons (1977), Billings and Matson (1972), Block and Dams (1976), Bolton et al. (1975), Bouilding (1976), Coles et al. (1979), Davidson et al. (1974), Eriksson and Jernelöw (1978, Friberg (1977), Gladney et al. (1978), Gutenmann et al. (1976), Joensuu (1971), Kalb (1975), Kantz et al. (1975), Klein et al. (1975a), Klein et al. (1975b), Klein and Russel (1973), Kaakinen et al. (1975), Lindberg et al. (1975) Linston et al. (1976), Magee et al. (1973), Natusch (1978), Natusch et al. (1974), Piperno (1975), Ragaini and Ondov (1975), Schwitzgebel et al. (1975), Smith et al. (1979a), Smith et al. (1979b), Swaine (1977), van Hook (1978), von Lehmden et al. (1974).

5.5 WATER POLLUTION PROBLEMS.

Water pollution problems can be divided into four groups:

1. The discharge of biodegradable organic waste, which consumes oxygen by the processes of mineralization. This problem has been discussed in detail in paragraph 2.6.
2. The discharge of nutrients from fertilizers, which might cause eutrophication problems, as discussed in paragraph 2.7.
3. The discharge of hydrocarbons into marine ecosystems. Massive oil pollution, as observed by a few catastrophies (for example, in the North Sea in 1976, in Brittany in 1977, and in the Gulf of Mexico in 1979) damages the entire ecosystem involved. Experience from the two former catastrophies shows, that it takes years for the ecosystem to recover and even though all the possible technical equipment and methods have

been applied to remove the oil. At this stage it is not possible to state whether the ecosystem will suffer any long-term effects. In addition to this problem is the effect of the continuous discharge of small amounts of oil into the oceans. Although facilities are available in most ports, all over the world, for oil deposition, many tankers and oil-industries discharge oil directly into the sea. The possible effects of this pollution problem include

a. An alteration in the rate of thermal energy transfer between the oceans and the atmosphere due to the formation of a thin oilfilm.
b. An alteration in the rate of oxygen transfer between the atmosphere and the oceans.
c. Increased cancer risk as some hydrocarbons are carcinogenic.
d. Damaged biochemical signals in some species of aquatic animals.
e. Possibel biomagnification of hydrocarbons.

4. The discharge of toxic compounds, such as pesticides and PCB, heavy metals and others (see 5.3 and 5.4).

5.6. NOISE POLLUTION.

Everyday noise or unwanted sound is assaulting citizens of all big towns. This is a very subjective form of pollution and one which runs into the problem of human value judgements. In general, however, sounds classified as noise include 1) loud sounds, 2) unpleasant sounds and 3) sudden sounds.

Noise is most commonly measured in decibels (db). This unit indicates the loudness, or sound intensity, which is related to the pressure on the ear. Since high frequency tones are more annoying, another scale has been introduced, which gives more weight to the high frequency tones and less weight to the low frequency tones. This scale is represented by dbA (A indicating the weighting used). The db and dbA scales are both logarithmic so that a rise of 10 db represents a tenfold increase in sound intensity, and a rise of 30 db represents a one thousandfold increase in loudness.

Table 5.12 lists some common noise levels to illustrate the scale.

TABLE 5.12
Common noise levels

Examples	Decibel (dbA)	Relative sound intensity	Effects with prolonged exposure
Jet takeoff (close range),	150	1,000,000,000,000,000	Eardrum raptures
Aircraft carrier deck	140	100,000,000,000,000	
Armoured personnel carrier	130	10,000,000,000,000	
Thunderclap, jet takeoff (200 feet)	120	1,000,000,000,000	Human pain threshold
Steel mill, live rock music, riveting, autohorn (3 feet)	110	100,000,000,000	
Jet at 1,000 feet, subway,outboard motor, power mower, motorcycle (25 feet, farm tractor, printing plant, jackhammer, blender	100	10,000,000,000	Serious hearing damage (8 hours)
Busy urban street, diesel truck, garbage disposal, clothes washer	90	1,000,000,000	Hearing damage (8 hours)
average factory, freight train (50 feet), noisy office, dishwasher	80	100,000,000	
Freeway traffic (50 feet), vacuum cleaner	70	10,000,000	Annoying
Conversation in restaurant, typical suburb	60	1,000,000	Intrusive
Quiet suburb (daytime), conversation in living room	50	100,000	Quiet
Library	40	10,000	
Quiet rural area (nighttime)	30	1,000	
Whisper, rustling leaves	20	100	Very quiet
Breathing	10	10	
	0	1	Threshold of audibility

5.7. SOLID WASTE POLLUTION.

The amount of waste per capita in the developed countries has increased rapidly during the last few decades. In the richer countries the average per capita amount has now reached approximately 20 t per year, including waste produced both directly and indirectly.

The direct production of solid wastes in Western Europe and North America is around 600 kg per capita per year:

Paper and paper products	260 kg/capital/year
Metals	130 kg/capital/year
Glass	110 kg/capital/year
Organic matter (excl. paper)	60 kg/capital/year
Ash	30 kg/capital/year
Other	20 kg/capital/year

In addition to direct production, waste is produced indirectly from agriculture and industry:

Agricultural wastes	8000 kg/capital/year
Mining and mineral wastes	6500 kg/capital/year
Industrial wastes	500 kg/capital/year

TABLE 5.13
Summary of advantages, disadvantages and cost for various methods of waste disposal now in use

Most of these wastes are dumped (more than 50% or left uncollected (24%). Sanitary landfills use 10-15% of the wastes, while 5-10% is incinerated. Only a relatively minor amount is composted, a method which from an ecological point of view must be considered the most attractive for organic wastes such as paper and sludge produced in biological plants treating municipal waste water. The ecological and economic advantages and disadvantages of these various disposal methods are summarized in Table 5.13. Notice, as is characteristic for many environmental problems, *that some of the methods solve one problem but simultaneously create another.* In environmental management it is therefore vital to attempt to find total solutions, and to take all aspects of an environmental problem into consideration.

5.8 FOOD ADDITIVES.

More than two thousand different chemicals are used as food additives in most developed countries, and it is vital to determine whether there are potentially harmful chemicals in both natural and synthetic foods. Unfortunately, the answer is not simple because 1) individuals vary widely in their suspectibility to different chemicals, and 2) otherwise harmless chemicals may interact synergistically. Extensive tests for a single food additive or drug are therefore complicated, can take up to 8 years to complete and are very expensive.

Table 5.14 summarizes some of the major classes of food additives. In most countries a positive list principle for food additives is used, meaning that only chemicals included in an authorized list can be used as food additives.

Although it is safer to use a positive than a negative list (i.e. one which lists chemicals that must not be used), knowledge about the effect of chemicals on man is very limited, because the problem is very complex.

In addition to the problems of food additives are several pollution problems related to food production, such as:

1. Accidental contamination, for example with residues of DDT, PCB, vinylchloride, heavy metals, etc. (see also 5.3 and 5.4).
2. Bacterial contamination that can cause Salmonella food poisoning and botulism.

TABLE 5.14
Some common food additives, processes and contaminants

Class	Function	Examples	Some typical uses
Preservatives	To retard spoilage from bacterial action and molds (fungi), especially in foods containing carbohydrates and proteins	Processes: drying, smoking, curing, canning process (heat and sealing), dehydration, freezing, pasteurization, refrigeration Chemicals: salt, sugar cure, sodium nitrate, sodium nitrite, calcium and sodium propionate, sorbic acid, potassium sorbate, benzoic acid, sodium benzoate, citric acid, sulfur dioxide	Breads, cheeses, cakes, jellies, chocolate syrups, fruits, vegetables, meats
Anti-oxidants (oxygen interceptors or freshness stabilizers)	To retard spoilage of fats by excluding oxygen or slowing down the rate of chemical breakdown of fats (rancidity)	Processes: sealed cans, wrapping, refrigeration Chemicals: lecithin, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate	Cooking oils, shortenings, cereals potato chips, crackers, salted nuts, soups, Pop Tarts, Dream Whip, Tang, and many other foods
Nutrition supplements*	To increase nutritive value of natural food or to replace nutrients lost in food processing †	Vitamins and essential amino acids	Bread and flour (vitamins and amino acids), milk (vitamin D), rice (vitamin B-1), corn meal, cereals
Flavors and flavor enhancers	To add or enhance flavor	Over 1,100 substances including saccharin, monosodium glutamate (MSG), essential oils such as cinnamon, banana, vanilla, bitter almond	Artificial flavors for ice cream, artificial fruit juices, toppings, soft drinks, candy, pickles, salad dressings, spicy meats, low-calorie foods and drinks (sweeteners), and most processed heat-and-serve foods
Coloring agents	To add color for esthetic or sales appeal or to hide colors that are either unappealing or show a lack of freshness	Natural color dyes and synthetic coal tar dyes	Soft drinks, butter, cheese, ice cream, breakfast cereals, candies cake mixes, sausages, puddings and many other foods
Acidulants	To provide tart taste or mask undesirable aftertastes	Phosphoric acid, citric acid, fumaric acid	Cola and fruit soft drinks, desserts fruit juices, cheeses, salad dressings, gravies, soups
Alkalis	To reduce natural acidity	Sodium carbonate, sodium bicarbonate	Canned peas, some wines, olives, coconut cream pie, and chocolate eclairs
Emulsifiers	To disperse droplets of one liquid (such as oil) in another liquid (such as water)	Lecithin, propylene glycol, mono- and diglycerides, polysorbates	Ice cream, candy, margarine, cake icings, nondairy creamers, desser toppings, mayonnaise, salad dressings, shortening
Stabilizers and thickeners	To provide smooth texture and consistency, prevent separation of components, and provide body	Vegetable gums (gum arabic, gum ghatti, and others), sodium carboxymethyl cellulose, seaweed extracts (agar, algin), dextrin, gelatin	Cheese spreads, ice cream, sherbet, pie fillings, salad dressings, icings, dietetic canned fruits cake and dessert mixes, syrups, pressurized whipped creams, instant breakfasts, beer, soft drinks diet drinks
Sequesterants (chelating agents or metal scavengers)	To tie up traces of metal ions that catalyze oxidation and other spoilage reactions in food, to prevent clouding in soft drinks, and to add color, flavor, and texture	EDTA (ethylenediamine-tetraacetic acid), citric acid, sodium phosphate, chlorophyll	Soups, desserts, artificial fruit drinks (Tang, Awake), salad dressings, canned corn and shrimp, soft drinks, beer, cheese, canned frozen foods
Contaminants	Not deliberately added to foods	DDT, PCBs, compounds of mercury, lead, and other heavy metals, radioisotopes, bacteria from poor hygiene and improper storage and processing, insects	Can occur in a wide variety of foods depending on accidental exposure or improper food processing

5.9. ALTERNATIVE ENERGY.

Most of the energy used today comes from finite sources, such as nuclear energy and fossil fuel. In addition, these energy sources are connected with serious pollution problems. The problems associated with the use of fossil fuels have already been mentioned in 2.5 and 3.5.

There is general agreement that nuclear fission is potentialy the most harzardous of all energy sources in use today. It is not possible here to enter into a debate on the nuclear energy dilemma, as it requires answers to several questions, about which the experts are not in agreement at present.

These questions include:

1. what are the problems and the risks of storing nuclear wastes for long periods of time?
2. what are the short- and long-term risks and benefits of energy produced by nuclear fission as compared to other energy sources?
2. how safe are nuclear power plants?
4. what are the consequences of radioactive fuel escapes?

One major disadvantage of today's nuclear reactors is that they consume our limited supply of uranium-235 fuel. Most experts agree that the supply of relatively low cost uranium is very limited, while there are relatively large amounts of medium and high cost uranium. That is the background for current research program aimed at developing a so-called fast breeder reactor, which uses a mixture of abundant non-fissionable uranium-238 and fissionable plutonium-239 produced by present reactors. Under bombardment with fast neutrons, plutonium-239 undergoes fission and the uranium-238 is converted to plutonium-239. The net results is a hundredfold mulitplication of our usable uranium reserves.

Fast breeder reactors using only known uranium resources could provide all our electricity needs for at least 50,000 years. However, there are several technical problems to be solved before large-scale breeder reactors become commercially feasible. An even more serious drawback is the fact, that each typical commercial reactor will contain over 1 metric ton of plutonium, which is an extremely dangerous element. Only 30 g of plutonium would be needed to kill every human being on earth if it was widely dispersed.

Plutonium-239 emits alpha-particles, which have a low penetration power, but inhalation, ingestion or absorption of only a few particles can eventually cause cancer or death.The present maximum tolerance limits of 2 µg plutonium are 150,000 to 300,000 times too high because of its long half-life of 24,000 years. In addition plutonium must be stored for 200,000 years or more, before it decays sufficiently to be released with safety into the environment. Consequently it can be concluded that the breeder reactor is not a safe overall solution to the coming energy demand.

A long-term solution must rely on essentially infinite and unpolluting energy sources, such as nuclear fusion, solar energy, geothermal energy and wind power. These energy alternatives will be mentioned briefly below, and their advantages and disadvantages surveyed.

Advantages of fusion energy:

1. Its fuel sources are essentially infinite and cheap. The deuterium in the oceans could supply all the world's power for several billion years.
2. It is much less dangerous than fission energy. The amount and hazard of the radioactive materials produced would be less than with conventional fission reactors.
3. Fusion energy could be used for the cheap production of hydrogen gas, which could serve as a cleaner replacement for natural gas and gasoline (petrol).

Disadvantages of fusion energy:

1. Release of radioactive tritium either as gas or in water. This pollution problem requires a solution.
2. Thermal pollution equal to or slightly lower than that from fossil fuel plants.
3. It will require several decades of research before all the technical problems involved in the use of this energy source can be managed safely and effectively.

Advantages of solar energy:

1. It is an infinite and readily available energy source.
2. It is the cleanest and safest energy source of all.
3. No entropy is built up in the atmosphere.
4. It could be used to produce hydrogen gas as a replacement for natural gas and gasoline (petrol).

Disadvantages of solar energy:

1. Its economic feasibility on a large scale is a major problem today, but further development during the next two decades might improve the efficiency sufficient to solve this problem.
2. Solar energy is not directly available at night when the needs for electricity are higest. Thus we must have a method of storing energy received in the daytime to solve this problem in other ways.

Advantages of geothermal energy:

1. Almost infinite energy source.

2. Easily converted into electricity.

Disadvantages of geothermal energy:
1. Geothermal deposits are located at specific underground sites.
2. Mineral-laden water wastes are produced.
3. Present techniques limit the available resources.

Advantages of wind power:
1. Almost infinite source.
2. Relatively clean and safe.
3. Easily converted into electricity.

Disadvantages of wind power:
1. Relatively high cost at present technical level.
2. Causes landscape pollution on a large scale.

In this context, however, we should also mention a fifth energy alternative. Better insulation and improved efficiency in the conversion of energy from one form to another, in homes as well as in industry, could cut the energy consumption more than 50% of the present level. The interrelation between pollution problems and energy consumption underlines the possibilities. Increased consumption of energy will create more pollution, so to reduce pollution, energy exploitation must be reduced or eliminated.