Environmental Management Systems: Applications and Potential

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Potential and Representatives for Application of Environmental Management System (EMS) to Food Industries

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Current state of Environmental Management System (EMS) implementation

The management of environmental issues is of growing interest today. There is a need to understand the important environmental impacts on the community and then consider the advantages and disadvantages associated with various levels of environmental management (Norman, 1997). The Ministers of Environment of the United Nations Economic Commission for Europe (UN/ECE) reaffirmed their strong commitment, developed over the three previous Ministerial Conferences in Dobris (1991), Lucerne (1993) and Sofia (1995), to cooperate on environmental protection within the ECE region. They committed themselves to comply with the obligations arising from the stipulated declaration and environmental conventions. They promised to enhance their efforts toward a sustainable development by supporting the work of the United Nations Environment Programme (UNEP) and other global organization conventions (4th Ministerial Conference).

Emissions and wastewater management

Consideration of environmental issues is growing, bringing about the need for more sophisticated control of industrial emissions and waste and faster and more advanced on-board diagnosis (Spetz et al., 1998). Pollution can originate from mobile (emissions for vehicles) or stationary sources (industries) (Treshow and Anderson, 1991). There is a growing interest in reaching zero emission in power plants, similarly to hazard analysis and critical control points (HACCP) for zero-defective products (Spetz et al., 1998). Quantification, control and modeling of wastewater emissions received greater attention in 1999. The Clean Air Act Amendments (CAA) have established regulatory requirements which considerably affected wastewater operations (De Hollander, 1998). The Water Environment Federation (WEF) sponsored a conference on water reuse and water reclamation (Van Riper and Geselbracht, 1998).

Chemical sensors operating at high temperatures and fast enough to record infinitesimal time changes between an oxidizing and reducing ambient can be used for cylinder-specific monitoring of petrol car engines. Gas molecules, like carbon monoxide, reacting with oxygen will lower the sensor signal, while decomposition of nitric oxide releases oxygen on the surface leading to a stronger sensor signal (Spetz et al., 1998). The first report on gas-sensitive field-effect devices based on silicon with a catalytic gate of palladium was published in 1975 (Lundstrom et al., 1975). Chemical sensors with catalytic metal gates operating at high temperatures provide new horizons for emission control. Their operation principle is very simple and based on surfaces/interfaces phenomena with very small time constants, thus enabling very fast responses. They also constitute an interesting combination of material physics, heterogeneous catalysis, in conjunction with electronic devices (Spetz et al., 1998).

The CAA requires industrial facilities to address the accidental release of regulated substances to the community and also sets regulations governing emissions of hazardous
air pollutants (HAPs) from wastewater using maximum achievable control technology (MACT) (Spetz et al., 1998). In a case study for a publicly owned installation treatment in Virginia, controlled by industrial users, the wastewater had a high volatile organic chemical (VOC) content, which was stripped and emitted into the atmosphere. The standards for publicly owned installation treatment implemented a financially viable controlled technological approach to comply with state and federal clean air laws (Rogers and Steidel, 1998). Several traditional treatment processes can be used to reduce the VOC content of waste and comply with air emissions requirements, such as closed sewer systems, nitrogen- or gas-blanketing vessels and strippers on biological reactors (Venkatesh, 1997).

Wastewater can be purified by various treatments. The natural treatments can be classified into several categories:

1. soil-based systems
2. wetland systems, which include free water surface, submerged flow and vertical flow systems; aquatic systems, including pond and floating aquatic plant systems
3. on-site systems
4. phyto-remediation.

In soil-based systems, a study in overland flow, where the phosphorus removal from swine lagoon effluent was examined, showed that system slope did not affect sediment phosphorus concentrations, even at various application rates (Liu et al., 1997). The use of constructed wetlands showed advantages, such as low cost and ease of incorporation into agricultural systems, whereas the main drawbacks were the required training. Wastewater treatment is the primary goal of many wetland systems, followed by ancillary benefits of public use and wildlife habitat (Knight, 1997). Aquatic systems and, more specifically, waste-stabilization ponds, could be implemented by means of sustainable development. The spatiotemporal dynamics and removal efficiency of pollution-indicator bacteria were studied in two high-rate oxidation ponds. Although bacteria removal was correlated with season (highest removal in summer), removal was always well correlated with retention time. Comparison with treatment lagoons showed advantages for the high-rate ponds (Bahlaui et al., 1998). The high land area requirements and limited cool season growth in temperate climates proved to be significant limitations in floating aquatic plant systems. Although biological oxygen demand (BOD), total suspended solids (TSS) and algae removal is favorable in duckweed treatment systems, the limited nitrogen removal constitutes an impediment to extensive implementation (White and Burken, 1998).

Numerous articles and reviews have summarized and evaluated available water reclamation processes to meet current water-quality requirements. A seven-month pilot-plant study in Los Angeles County (California) evaluated three filtration systems for water reuse using high-purity oxygen-activated sludge plant effluent: a deep-bed anthracite filter, a shallow depth pulsed-bed sand filter and a continuous backwash deep-bed sand filter. All three filters were capable of consistently meeting the State of California’s effluent turbidity limit and were characterized by similar costs (Kuo et al., 1997). Field-scale evaluation of gravel-bed hydroponic wetlands in Egypt...
demonstrated the capacity for removing eggs of human parasites and producing effluents which met the World Health Organization (WHO) microbiological guidelines for reuse (Stott et al., 1997). Conventional reclamation technologies were judged too expensive for rural communities in Brazil, so treatment of degritted wastewater through grass was investigated at two sites leading to promising results (Freire, 1997).

**Food industry and agricultural waste**

The problem of classification arose when it came to describing the regulatory aspects of composting food-processing waste. Solid, agricultural and/or industrial wastes were of great concern, as well as the marketability of composted materials. The impact of CAA on food processing waste operations identified yeast manufacturing, cellulose food casing manufacturing and vegetable oil production as target industries for future specific regulations (Walsh et al., 1993).

**Dairy industry**

A large portion of the chemicals used in the dairy industry has been traditionally discharged in the dairy wastewater. The type and quantity of chemicals used, and the method of wastewater treatment employed, substantially affected the extent of environmental pollution (Pankakoski et al., 1993). An ice cream factory was one of two examples reported on waste reduction programs. After implementation of appropriate measures, BOD was reduced by 63% with investment costs for the post-control wastewater treatment system dropping by 43% (Hiddink, 1995). The ecological evaluation of dairy chemicals shows the impact of individual chemicals on the environment. Retail samples of cow milk were collected in the UK, both in winter and summer, and analyzed for ortho and non-ortho substituted polychlorinated biphenyls (PCBs). The determined values varied in the range 2–25 ng/kg and 0.05–0.6 ng/kg for the ortho and non-ortho substituted PCBs, respectively (Krokos et al., 1996). The concentrations of polychlorinated dibenzo dioxins and dibenzofurans (PCDD/F) in human blood and human milk from non-occupationally exposed persons were determined in the vicinity of a municipal waste incinerator in Germany. Since the individual concentrations of PCDD/F in blood fat ranged within acceptable limits, it was concluded that no direct health hazard related to PCDD/F emissions from the local waste incinerator should be expected (Deml et al., 1996).

Acids and alkalis, due to be replaced within the frame of a cleaner environment, seem to be generally less problematic than surfactants. However, this does not imply that cleaning should be conducted only with caustic soda and nitric acid. Additives are added to optimize the cleaning effectiveness of the detergents. When choosing additives, ecological aspects have to be considered as well. This becomes a problem for the industry because all the new products have to be analyzed for their environmental effects. The end-users usually buy a mixed product and they have problems on how to treat the contained chemicals. Therefore, the manufacturers have to report their findings related to the environmental impacts of their products (Pankakoski et al., 1993). DDT residues in numerous milk samples were determined by using gas–liquid chromatography (GLC) and possible links between DDT exposure and breast cancer were investigated (Deka
et al., 1996). Although the determined DDT levels in human milk were attributed to campaigns against malaria and partly to DDT in fatty foods, no clear-cut connection between DDT and breast cancer could be established (Lopez-Carillo et al., 1996). Process water in a dairy factory should be of drinking quality. When the dairy factory employs sources such as surface water, ground water and condensates, considerable attention to meeting quality requirements is needed. These controls of water quality should be incorporated into the quality management system of a dairy factory, specifying both frequency and parameters to be checked (Hiddink, 1995).

Fermentation industry

Brewery waste
Wastewater from fermentation industries is characterized by variable flow rates, often seasonal in nature, and high in organic loading, BOD and COD (chemical oxygen demand), low pH and high carbon-to-nitrogen (C:N) ratios (Grismer and Shepherd, 1998). In a review where the performance of anaerobic and aerobic biological wastewater treatment processes at a German brewery was compared, the former treatment achieved 91% COD reduction, whereas the aerobic treatment averaged 76% reduction (Mayer, 1995). An anaerobic fluidized bed (AFB) reactor treating brewery wastewater at 25°C achieved a COD removal of 85% and hydraulic retention times (HRT) of 2.5 h. The average biogas production rate was 0.45 m³kg⁻¹ COD removed, out of which 72% was CH₄. After seven days aerobic treatment of brewery wastewater, its pH rose from 6.5 to 8.9, while the BOD and suspended solids were reduced by 67% and 75%, respectively (Liang et al., 1997).

The effects of various mixing rates of brewery wastewater with municipal solid waste on methane generation and landfill leachate were studied by using laboratory columns. It was found that codisposal of brewery wastewater stimulated methane production and did not negatively affect the leachate quality in terms of pH or volatile fatty acid concentrations. At very high loading organic rates, however, leachate quality temporarily deteriorated, as elevated concentrations of acetate and propionate were detected (Rahim and Watson-Craik, 1997). In a study where potential disinfection interferences by organic nitrogen compounds, such as those present in high concentrations in brewery effluent, may occur, the results showed that wastewater containing high ratios of total organic nitrogen to ammonia (TON:NH₃) was poorly disinfected by aqueous chlorine. Furthermore, disinfection rate tended to decrease with increasing TON:NH₃ ratios (Scully et al., 1996). The operation of anaerobic plants for wastewater, including brewery wastewaters in Germany was reviewed. A survey was conducted to identify filamentous microorganisms in six activated sludge plants. A gram-positive, Neisser negative filament resembling both Microthrix spp. and Nostocoida limicola was the predominant filament in sludge from a plant treating brewery wastewater (Weathers, 1996).

Winery waste
Treatment of winery wastewater was evaluated both on a laboratory and industrial scale. The treatment of winery wastewater using a full-scale, modular, multistage activated sludge treatment plant was examined. The removal of COD averaged 98% when
the influent COD varied between 2000 and 9000 mg/l. The plant proved to be flexible enough to withstand large variations in the temperature, hydraulic, and COD loading rate, and was shown to have a low running cost. Studies in Portugal describe 1 m³ pilot-plant studies of the winery wastewater treatment capability of an adsorption activated-sludge process devised for use in the mainland. The addition of nitrogen and phosphorus nutrients was required to increase biomass accumulation and to stabilize the reactors to obtain high removal efficiency from the wastewater of 96.0 and 97.7%, COD and BOD₅, respectively. In France, there have been several attempts to optimize the rate of aerobic treatment of winery wastewater through seeding winery bacteria, pH adjustment and addition of nitrogen and phosphorus nutrients. Their goal was to reach sufficient treatment levels (<500 mg BOD₅/l) within a few days so that the treated effluent could be safely discharged to the municipal treatment system (Morais and Santos, 1995). The catalytic oxidation of p-coumaric acid, a compound representative of the polyphenolic fraction typically found in wine distillery, was investigated using Fe²⁺, Cu²⁺, Zn²⁺ and Co²⁺ ions and metal oxide catalysts in suspension. Results showed that catalysts increased the decomposition rate of p-coumaric acid while the solution pH controlled the distribution of intermediate compounds (Graham and Weathers, 1997). Vinasse is a serious problem in wastewater treatment. It was determined that 90% COD removal of vinasse purified with mesophilic aerobic/mesophilic anaerobic or thermophilic anaerobic treatment required minimum HRTs varying from 4 to 8 days respectively. A substrate utilization model was accurate except when HRTs dropped to minimum values (Romero et al., 1996). Resveratrol, a phytoalexin found in grapes and other food products, was purified from grape skin waste and shown to have cancer chemopreventive activity in assays representing three major stages of carcinogenesis. These data suggest that resveratrol, a common ingredient of the human diet, merits investigation as a potential cancer chemopreventive agent in humans (Jang et al., 1998).

**Distillery waste**

In a comparative study of anaerobic digestion of untreated and previously fermented (with *Penicillium decumbens*) molasses, continuous-stirred tank reactors were used. The observed difference in digestion process could possibly be attributed to interference and inhibition of anaerobic bacteria activity by higher concentrations of phenolic compounds in the untreated wastewater (Jimenez et al., 1997). Assessment of several alcohol distillery plants treating sugar beet molasses showed that the use of open stream and recycle of spent mash affected wastewater volume up to 25%, the COD load remained practically unchanged with recycling whereas total dissolved solids (TDS) significantly increased. Twelve potentially inhibitory phenolic compounds present in sugar beet molasses distillery wastewater were isolated and identified as follows: six benzoic acids, two cinnamic acids, three phenolic aldehydes and one phenolic alcohol (Graham and Weathers, 1997). A method for precipitation and flocculation of ethanol fermentation wastewater using a combination of various media such as black pulping liquors, lime and polyacrylamide was recently suggested. This promising process yielded water suitable for reuse in ethanol fermentation and residue and is
potentially acceptable for animal feeds and microbial culture media (Morais and Santos, 1995). Several technological options were developed for recycling or treating sugar-processing by-products, including stillage. Studies on anaerobic treatment of various distillery effluents employed full-scale upflow anaerobic sludge blanket (UASB) reactors and highlighted the treatment of effluents from sugar cane based distilleries with COD concentrations of 60 000 to 160 000 mg COD/l (Weathers, 1996).

Beverage industry

The problems encountered in the operation of anaerobic filters at several soft drink bottling facilities used for pretreatment include odor, problems of a biological nature with the reactor and problems caused on-site in plant operations. A soft drink wastewater treatment process, consisting of coagulation/flocculation followed by extended aeration, was introduced and fully described. Despite the high level of COD removal provided by the two processes, the system performance was inhibited by variations in hydraulic and organic loading, contamination by petroleum oils and the carry-over of solids from the clarifier to the biological system (Hiddink, 1995). In a recent pretreatment technology review for a soft drink manufacturer, high-pressure reverse osmosis was preferred over the other membrane filtration technologies. Biological pretreatment was rejected after a cost analysis was carried out on pilot testing of various membrane filtration technologies. This process was selected because of its high processing capacity and a 99% BOD removal. Another article focused on bringing a soft drink production facility into regulatory compliance through waste minimization. The latter was accomplished by employing the waste beverage as a feed supplement for a local beef cattle facility (Schulte, 1994).

Fruit and vegetable industry

The agricultural industry waste proves to be an immense reservoir of materials of natural origin. The exploitation of this waste provides natural products of inexpensive starting material like antioxidants. VIORYL SA (Athens, Greece) is a representative example of a Greek company where research is carried out on pressed grape skins from the winery waste and the citrus peel after juice removal. The main features of this approach are: choice of solvent(s), for efficient extraction and recycling, environmentally innocuous as possible and selecting conditions for non-destructive product recovery (Kefalas, 1991). An extensive literature search on disposal and utilization of solid vegetable, fruit and other organic waste was conducted. The study considered the implementation of anaerobic digestion, animal feeding, composting, edible fiber recovering, fermentation, incineration, pyrolysis and soil amendment as options for environmental management systems (EMS) (Walsh et al., 1993). The factors involved in the land application of strong citrus wastewaters were described (Jones and Horvath, 1993). Typical flavonoids, such as hesperidin and naringin, which have pharmacological properties, were extracted from orange, grapefruit and bergamot peels.
Both flavonoids were released by extraction of peel with hot water and Ca(OH)$_2$. The effect of peel maturity and recycling of the extracting liquor led to an increase in yield of both hesperidin and naringin. The highest yield of naringin and hesperidin were 15.2 g/kg and 12 g/2 kg peel, respectively (el Nawawi, 1995).

Three sequencing batch reactors (SBR) pilot plants for treating potato processing wastewaters were operated at various temperatures, in order to study the differences occurring at these temperatures. Although only slight differences in effluent soluble COD concentration related to temperature were reported, nitrification was substantially reduced at low temperatures (12°C). Phosphorus removal significantly dropped at the highest temperature (32°C) (Grant et al., 1994). Utilization of waste mushroom compost as an adsorption medium and as a microorganism source to remediate insecticide rinsate was also investigated. The compost was shown to absorb carbamate pesticides from aqueous solutions and does not have an inhibitory effect within the concentration range of 0–30 mg/l. Another relevant study reported the composting of potato peel waste which, amended with sawdust and urea over a 3- to 4-week period, resulted in a 51% loss in weight and 27% loss in dry matter (Lowe and Buckmaster, 1994). The process selection methodology and analytical problems are associated with phosphorus removal from oil seed and wastewater from vegetable production. The performance of an anaerobic upflow blanket type reactor for the treatment of olive oil production wastewater was evaluated (Ozturk et al., 1992).

**Meat and poultry**

The biosolids produced by dissolved air flotation (DAF) wastewater treatment systems at meat and poultry processing plants constitute a crucial disposal problem and handling of these materials was addressed in several papers. Carr (1992) recently presented an overview of the aerobic composting process comprising comparison of various novel systems for handling DAF biosolids and for dewatering. The stabilization of offal and dissolved air flotation sludges using lactic acid was evaluated as well. The study focused on measuring pH, ammonia, protein, fat and bacterial pathogens in an effort to assess sludge quality. A comprehensive study of the foaming and bulking problems in poultry processing wastewater activated sludge system was conducted. Among the investigated factors were the process type, the food microorganisms (F:M) ratio, the dissolved oxygen levels, the liquid operating temperature, the changes of production rate and the inlet/outlet design of the aeration cell (Walsh et al., 1995). The source of odors from several already discussed control techniques, including combustion in boilers, wet scrubbers and biofilters was recently reviewed. The technical and economic details of biofilters applications were presented (Prokop, 1992).

**Agricultural waste**

Water pollution, particularly by pesticides and herbicides, has been recognized as a very serious problem since the 1970s. Industrial compounds and product contaminants such
as polychlorinated biphenyls (PCBs), polychlorinated dibenzo-\textit{p}-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were found to be present in a large fraction of tested humans (Price and Welch, 1972; Sielken \textit{et al}., 1987). As was the case with DDT and other chlorinated insecticides, background levels of PCBs, PCDDs and PCDFs occur in high portions in tested humans. These lipophilic compounds, occasionally suspect carcinogens and abundant in fatty foods, could easily be introduced into human beings when these compounds abound in the terrestrial environment (Fries, 1991). Of great concern is the extent to which pesticides reach rivers and lakes, because this may have impact both on aquatic life and humans if contamination extends to drinking waters. These concerns were addressed by the EC Drinking Water Directive, which stipulates a maximum concentration of any pesticide in potable waters of 0–1 \( \mu \text{g/l} \).

Although the toxicity of different pesticides to humans varies greatly, there is a general lack of epidemiological data regarding the pesticides effect on human health, probably because research tends to be reactive, rather than proactive.

The effects of pesticide drift on flora and fauna have been reported in English Nature (Anonymous, 1997). Despite the reported measurable short-term impact on wildlife, the time scale and long-term effects continue to be uncertain. Research into nitrogen fertilizer used in agriculture has highlighted three main areas of potential environmental impact: water contamination, gaseous losses and effects on humans. The secondary economic costs, notably related to the water industry, are also significant, although research is starting to show how good management practices can reduce losses (Skinner \textit{et al}., 1997). Herbicide contamination of shallow groundwater beneath claypan soils has been the subject of several investigations. Spatial variability was determined to be larger than the effects of atrazine and arachlor application rates. In samples taken from approximately 75 monitoring wells, atrazine and arachlor were detected in 7.2 and 0.4\%, respectively. No significant differences in arachlor, atrazine and nitrate concentrations were detected between pre- and post-flood distributions in alluvial aquifers in the USA (Chung \textit{et al}., 1998).

Compost from agricultural and other waste and granular activated carbon biofilters operated at a wastewater treatment plant simultaneously removed low concentrations of \( \text{H}_2\text{S} \) and VOCs. Microorganisms on both media demonstrated an increase in microbial densities, varying degrees of environmental stress and predominance of gram-negative bacteria. Lowering pH had little effect on compound removal, which was >99\% for the \( \text{H}_2\text{S} \) and >70\% for the oxygenated and aromatic hydrocarbons (Webster \textit{et al}., 1997). A pilot-scale composting of chlorophenol-contaminated soil was set up to compare chlorophenol degradation by two different inoculants, straw compost and bioremediated soil, with that of indigenous soil microbes. The biodegradation was found to be highly efficient, fast and, most importantly, independent of the inocula type (Laine and Jørgensen, 1997).

Gergova \textit{et al}. (1994) studied the production of activated carbon from agricultural residues, including apricot and cherry stones, almond shells and grape seeds. The study involved a low temperature process and it was concluded that the characteristics of the activated carbon depend upon the feedstock composition and structure. Mazza (1995) reported the flow diagram for resource recovery from grape pomace. Another investigation topic was nitrification and denitrification in an activated sludge system.
for wastewater from settled sow manure with molasses addition as a supplemental carbon source. Full denitrification proved impossible with supernatant from manure as the only carbon source. When nitrifying and denitrifying conditions were improved, only small amounts of nitrogen oxide were found to be present (Marr and Facey, 1995). Olive oil production is of great importance especially for Mediterranean countries because of its high consumption rate. Milling of olive paste during olive oil production is accompanied by continuous washing with water malaxation leading to considerable wastewater quantities, which are discarded. A study disclosed that the wastewater extracts have powerful antioxidant action due to the presence of natural antioxidants. If the latter were successfully recovered and could show that the waste from olive oil production had a powerful anticarcinogenic activity, it would be a promising non-expensive source of antioxidants (Visioli et al., 1995).

Effects of pollution on organisms

Many articles reported on the effects of a wide variety of pollutant forms, including individual complex chemicals and metals to freshwater and seawater aquatic organisms. In a rapid bioassay, 96 cell culture plates for screening herbicides and other phytotoxins for selective toxicity toward cyanobacteria were developed. Oscillatoria cf. chalybea and Selenastrum capricornutum were chosen as representatives of cyanobacteria (Cyanophyta) and green algae (Chlorophyta), respectively (Schrader et al., 1997).

A number of ectomycorrhizal fungi, from sites uncontaminated by toxic metals, were analyzed to determine their sensitivity to Cd$^{2+}$, Pb$^{2+}$, Zn$^{2+}$, and Sb$^{3+}$. Significant interspecific variation in sensitivity to Cd$^{2+}$ and Zn$^{2+}$ was recorded, whereas Pb$^{2+}$ and Sb$^{3+}$, individually, had little effect. The presence of Pb$^{2+}$ and Sb$^{3+}$ in these media did, however, ameliorate Cd$^{2+}$ and Zn$^{2+}$ toxicity in some cases. Among various heavy metals, mercury, cadmium and cobalt were shown to be the most toxic to selected strains of wood-rotting basidiomycetes (Baldrian and Gabriel, 1997). Among 75 strains of iron-oxidizing bacteria obtained from natural environments, only one strain, Thiobacillus ferrooxidans Funis 2-1, grew on Fe$^{2+}$-medium with 1.25 mM of sodium molybdate (Mo$^{6+}$). Further studies revealed the inhibition site of molybdenum for the iron-oxidase enzyme system and the mechanism of molybdenum resistance in Funis 2-1 cells (Yong et al., 1997). Sampling of faunal species near a lead smelter in South Australia revealed no consistent patterns in numbers of taxa among study areas and times. In fact, it was shown that Heteromastus filiformis, Capitella capitata, Glycera americana and the crustacean Tanais dulongii were abundant at intertidal sites with high metal concentration in the sediments (Reish et al., 1997).

There is only limited available evidence indicating that chlorinated compounds occurring in the environment had an adverse effect on earthworm populations. Applications of DDT at rates exceeding 100 ppm had no effect on earthworm survival and concentrations of DDT or dieldrin as high as 64 ppm did not affect the survival of L. terrestris and A. caliginosa in laboratory studies. It was shown that earthworm activity was more or less normal in the area around Seveso, most highly contaminated
by TCDD (dioxin), but there may have been an effect on the ratios of *A. caliginosa* to *A. rosea*, which were the most abundant species (Fries, 1991).

Birds have provided the most notable examples of adverse and disastrous effects of organic contaminants on terrestrial wildlife. The effects of chlorinated hydrocarbons on eggshell thickness were further confirmed in laboratory studies. The frequency and severity of the reproductive problems were greatest for aquatic predators followed by terrestrial predators, insectivores and herbivores. Improper disposal of contaminated waste oils has caused acute poisonings of cattle and horses by PCBs and PCDD (Beeson et al., 1997). The carcinogenic dioxins have entered the life of European citizens and managed to undermine the current food safety system in zero time. It is believed that the European Union (EU) was aware of at least some of the occurring safety problems but was reluctant to enforce stricter regulation because of the ensuing higher production cost. However, prior to dioxin detection, extremely high hormone residues had been measured in meat carcasses originating from the USA (Papanidis, 1999). Kittiwakes from a colony within the area oiled by the crude oil spill in the Shetland Islands had relatively good breeding success and foraging activity compared with colonies in non-oiled areas. However, birds from the oiled area were anemic and the adult return rate and male fidelity were low (Reish et al., 1998). Due to large spatial and temporal variability, ichthyoplankton surveys both at outfall and non-outfall failed to reveal any consistent differences in taxa or abundances of fish due to treatment either at the surface or at a 20-m depth. However, a mixture of primary and secondary wastewater sludge produced significant toxic effects, even at 0.1% dilution, to herring embryo vitality, hatching mortality, post-hatch larval survival and larval feeding under laboratory conditions. Toxic effects were confined to the discharge point. Chlorine, commonly used to disinfect wastewater and power plant discharges, was shown to be toxic to various stages of anchovy eggs and larvae at concentrations well below the recommended treatment doses (0.1–0.2 versus 3.0 ppm, respectively) (Rosales-Casian, 1992).

The frequency and mechanism by which organic compounds are introduced into the environment have an important impact on food products. Combustion sources, such as municipal waste incinerators and automobiles, have been identified as the main sources of low-level dioxin and furan environmental contamination (Skinner et al., 1997). Bouchard et al. (1992) described the various natural and synthetic sources of nitrate contamination of groundwater, the sources of human exposure to nitrate and the potential health effects and the challenge to manage groundwater protection from nitrate. The relationship between nitrate levels in private and public sources of drinking water and gastric cancer mortality in Wisconsin (USA) was investigated in a case-control study. Death resulting from gastric cancer could not be significantly associated with exposure to nitrate in drinking-water sources.

**Glass, chemicals and other products**

New technology in the field of glass production lowered the gas release of substances such as NOx and particulates, and parameters such as BOD, but there is still room for
improvement. Although attaining zero pollution is a virtually impossible target, striving to improve the environment is a constant goal (Slater, 1997).

Industry provides a selection of techniques and pollution arrestment plans available for meeting current or even future (most probably stricter) legal requirements. As to the recent EU legislation, the Integrated Pollution Prevention and Control (IPPC) reported in a British newspaper (became UK law in October 1999), that consideration should also be given to the possible reversal of enforcement from local authority to the HM Inspectorate of Pollution (Environmental Protection Act, 1990). The use of toxic heavy metals is subjected to severe restrictions in order to reduce their effects on the environment, to guarantee health and safety at the workplace and, in general, to minimize their mean daily intake by individuals (Guadagnino, 1996).

The impact of the Clean Water Act (CWA) on industry was reviewed from the historical perspective of the National Pollutant Discharge Elimination System (Kobylnski and Hunter, 1992). Gemar (1991) suggested how industries could comply with the new pretreatment regulations for discharge to a publicly owned treatment works (POTW). These regulations focused on both mass and concentration of specific compounds discharged to the municipal sewer.

A waste management plan for the chemical and petrochemical industry in Brazil included regional management of hazardous wastes, strict control of landfill content and pretreatment facilities. The improvement of groundwater quality at a major industrial complex was initiated in three phases: baseline data collection, establishment of monitoring programs and recommendations for new management practices. Increase in polluted areas due to poor landfill operations at a chemical industry in the Netherlands was the main factor that led to a program of waste management/minimization for this facility. A recovery process for nitrophenols addressing possible thermal instabilities was developed to meet the limits set on phenolic compounds sent for biological waste treatment (Teixeira and Balassiano, 1991). Biological treatment is a very important process for removing dissolved organics from refinery wastewater. Microbial cultures were studied to compare the ability to biotreat refinery spent sulfidic caustic from a refinery. Both cultures, *Thiobacillus denitrificans* strain F and an acclimated culture enriched from an activated sludge treatment system at a refinery, proved to be capable of complete oxidation of caustic sulfides to sulfates at specific activities of 1.0–1.3 mmol sulfide/h·g mixed liquor suspended solids (Kolhatkar and Sublette, 1996).

Anaerobic treatment of petrochemical wastewater has become a very popular topic over the past few years. Cheng *et al.* (1997) conducted a pilot study of UASB process treating wastewater from purified terephthalic acid (PTA) manufacturing. One of the major constituents, *p*-toluic acid, in PTA wastewater restricted the biodegradation. Phenolic compounds are abundant both in natural products and industrial and municipal waters (Gerard *et al.*, 1995). Their presence might prove to be harmful, especially if they are submitted to chlorination which results in chlorinated phenolic compounds, highly toxic even at ppb levels. The phenolic compounds contained in this wastewater are used as feedstock for the production of polymers, drugs and dyes despite their poor environmental performance. Therefore, an extraction of phenols from water samples by liquid–solid phase extraction is employed (Pissolato *et al.*, 1996).
Strict emission legislation has currently rendered many existing emission-control measures inadequate. The effect of automotive catalysts to offset the incomplete combustion in automobile engines in response to the Clean Air Act of 1970 was reviewed. Measurements of emission data of unburned hydrocarbons and carbon monoxide at both upstream and downstream sides of a catalyst converter showed that significant reductions in emissions could be obtained with appropriate ignition-control strategies (Zhu et al., 1996).

**Environmental attitudes and politics**

The economic growth of modern industrialized society has been mainly based (80%) on utilization of energy stored in fossil fuels. Although humans have learned to exploit them rather efficiently, consumption of fossil fuels has become a tantalizing force because of emissions, spills, leaks, strip mining and carbon dioxide accumulation which leads to highly dangerous and threatening situations in terms of global warming (greenhouse effect), risking sea levels and earthquakes (Kordesch and Simander, 1995). By 1990, public concern for the environment in the USA had reached unprecedented levels. In one of the most thorough and comprehensive reviews of American public opinion toward the environment, it was concluded that, after a decline in environmental concern in the 1970s, there has been a significant and steady increase in public awareness of environmental problems (Steel, 1996).

Modern environmental policy is discussed largely in terms of assessing the usefulness to humans of preserving services provided by the environmental systems. Environmental concern is often expressed by rejection of directly anthropocentric and economic calculations (Spash, 1997). The pollution abatement schemes can be successfully implemented only when the causes of pollution have been properly identified. Pollution problems, arising from ‘free rider’ behavior, result in high costs of negotiation among users of a common resource. These costs are occasionally due to misspecification and/or to non-enforceability of property rights on the use of common resources. Alternatively, when well-defined property rights exist and their enforceability is possible, the presence of technological non-convexities makes impossible the establishment of competitive markets for pollution emission rights (Bellas and Skourtos, 1996).

Solid waste audits, aimed at the identification of opportunities for waste reduction, reuse or recycling, were described by the ‘Go Green team’, which also identified these opportunities in the original 1995 audit, forming the basis for the waste diversion initiatives. In particular, the 1995 initiatives were very successful in increasing the reuse and recycling activities. The next audit, however, should include protocols for characterizing the material in the mixed waste bags (Dowie et al., 1998). In effective networks, information and research, in conjunction with grass-roots involvement are to be pursued, since a more professional approach has to be endorsed through government support, appropriate funding and proper staffing. Indeed, it is argued that lack of formal government recognition and endorsement of the forum approach inhibits their credibility, since potential members and staff time are not properly prioritized (Scott, 1998).
Although various factors may lie behind the recent upsurge of interest in green taxes, the predominant factor might be disenchantment with efficiency and effectiveness of the direct regulation approach to environmental policy. Nevertheless, wider public finance employment and social concerns contributed to a ‘build up’ of pressure for change. Instruments such as charges, permits and subsidies score well on efficiency grounds, but they are more problematic in terms of their institutional requirements and their political feasibility. On the other hand, product prohibitions, technology specifications and information provision, for example, face relatively little political resistance and have no institutional demands, but are relatively inefficient because of the high costs of involved meetings and ambient standards (Turner et al., 1998).

Several industrialized countries such as the USA, the UK and France have long realized the need for environmental impact assessment (EIA). As a result, they have adopted formal EIA principles and practices for various activities including the construction of highways (Glasson et al., 1999) and for the mining and industrial sector. Current trends in environmental degradation suggest that if the rate at which the environment is depleted continues, the world will cease to be a viable place. Reports about global warming and the depletion of the ozone layers suggest the need for urgent action to avoid an imminent catastrophe.

Progress in alternative energy

Solar energy

Energy from the sun is vital for the living world. It is harnessed by plants, which use it to turn water and carbon dioxide into complex energy-rich molecules. More than $10^{17}$ kJ of energy from sunlight is captured and used by photosynthetic organisms (Durrant, 1998). Solar electric power was developed to overcome a specific power problem within the frame of NASA space programs of the 1960s. Like many other space technologies, solar radiation was later on adapted and used on Earth, but initially used in remote areas where power was desirable but difficult to provide by other means.

The potential financial savings made by generating solar electricity depend on cost of national power, which varies considerably, and the price paid by the operator for the exported solar power. Since solar power generates direct current electricity which has to be converted to alternating current to interface with the grid, there are additional infrastructural and familiarization barriers to overcome with the therein participants (architects, builders, electricians and electricity operators). These are being rapidly addressed as international experience develops (Wolfe, 1998). Although this is still a relatively expensive technology, the cost for solar power is gradually decreasing and the market is expanding. New lower cost technologies are currently commercialized and, in fact, the World Energy Council predicts substantially greater sales by 2025. With the issues of climate change and environmental depletion increasingly at the forefront of the political agenda, the prospects for this technology are extremely promising (Hammonds, 1998).
Aeolian energy and air pollution

Over 700 MW of wind energy has been produced worldwide, making it the fastest growing energy technology. The reason for this rapid growth in wind energy can be traced back to the oil crisis of the 1970s, but more recent stimuli have included the urgent need for electricity in third world countries and the need to find non-polluting energy sources. Wind energy is now a viable option for generating electricity because it is technically proven, enjoys public support, has huge resources and is rapidly becoming cost-competitive with the ‘conventional’ sources of electricity generation. There are good prospects for future cost reduction and improvements in performance. ‘Economic optimization’ in turn, depends on a proper understanding of the complex nature of wind turbine loadings and is reflected in further work on dynamics and fatigue (Milborrow, 1998).

A future of melting ice caps and changing climates has been predicted as a result of global warming due to the ‘greenhouse effect’. Essentially linked to the emissions of greenhouse gases into the atmosphere (most notably carbon dioxide), this disruption in the Earth’s ecosystem is causing great concern. It is widely accepted that the greenhouse effect, caused by rises in atmospheric CO₂ levels, will result in extensive warming of the Earth’s surface with potentially disastrous environmental impact (Ormerod, 1998).

There are four main options for capturing carbon dioxide: adsorption, absorption, cryogenics and membrane systems. Gas adsorption commonly involves the utilization of molecular sieves which, however, require the release of absorbed gas after its capture. Varying the process to release the gas is preferable to altering the temperature because the absorber can start re-functioning much faster. Limited capacity and poor sensitivity makes this method unattractive for CO₂ capture from the conventional (PF = pulverized fuel and NGCC = natural gas fired combined cycle) generation process. Several solvents can be applied to each type of power plant to achieve physical and chemical absorption. Cryogenic processes are only worth considering where there is a high concentration of CO₂ in the gas, as may be the case in future integrated gasification combined cycle (IGCC) designs, or from CO₂ recycle systems. Cryogenic processes have the advantage of producing liquid CO₂ ready for transportation via pipelines. Although they are commercially used, the membranes need further development and their cost has to come down before they can be more widely used for capturing CO₂.

Scientific responses to climate change deserve serious consideration as ways of limiting greenhouse gases while continuing to satisfy human aspirations for improved life quality. If CO₂ emissions have to be substantially reduced, capture and storage of CO₂ is a presupposition. Such technologies have only recently attracted scientific interest and there are currently available practical examples of capture and storage techniques around the world (Riemer, 1998).

Hydropower, geothermal, fuel cell systems and other alternative energies

Hydropower is a clean, non-polluting, reliable, long-lasting and renewable energy source. It produces nearly a fifth of the world’s electricity, making it far and away the most productive renewable source. Wind, biomass energy and hydropower are the
most utilized renewable sources, accounting for more than 90% of overall electricity
generation. Based on the potential of hydropower and the move towards reducing
power plant emissions that contribute to global warming, it appears that hydropower
can be one of the major factors in building up a sustainable worldwide economic
growth well into the future (Hunt and Hunt, 1998).

Geothermal energy, heat from the Earth, is available at many sites across the world
and is only being partially used to replace conventional fuels. The enormous potential
of this clean, reliable energy source is only now being realized with increasing con-
struction of electricity generating stations, district heating systems, food processing
plants and greenhouses throughout the world. In the years ahead, when environment-
tally friendly energy sources become even more important, geothermal energy is
expected to help fill our needs. Although it is not a final solution for the world’s clean
energy needs, it constitutes a significant contributor and has great potential for expan-
sion in the future. Advanced research and technology development will eventually
enable mankind to use the enormous amount of geothermal heat contained in rocks at
any depth and not just in volcanic areas. When this stage of development is reached,
geothermal energy might well supply as much as 25–50% of the world’s electrical and
heating needs (Wright, 1998).

A fuel cell is an electrochemical device which can continuously convert the energy
from a chemical reaction and an oxidant fuel to electrical energy by a process involving
an electrode–electrolyte system. Fuel cells are characterized by high efficiency and
lower emission levels than those prescribed by the strictest environmental standards.
Fuel cell systems can be classified according to their working temperature/pressure as
high-, medium- and low-temperature/pressure systems. Another categorization may be
based on the nature of employed fuels and oxidants: gaseous (hydrogen, ammonia), liq-
uid (alcohols, hydrocarbons) and solids (coal). The most important features of fuel cell
systems in terms of advantages could be summarized as follows:

1 savings in fossil fuels due to high energy conversion/good load characteristics
2 low pollution level/noise level/maintenance costs
3 ability to use low cost fuels with high temperature systems and increased efficiency.

However, there are also disadvantages consisting of the initial high cost of catalysts,
membranes and accessories, high fuel weight, electrode degradation in conjunction
with complete carbon dioxide removal and infrastructure weaknesses for hydrogen
transportation and distribution (Kordesch and Simander, 1995).

Although harvesting waste may sound like a strange idea, it is one of the safest ways
for cleaning up contaminated land. Using plants that preferentially absorb toxic metals
from the soil and then simply harvesting and disposing of them could revitalize land con-
aminated with metals both inexpensively and in an environmentally friendly way. Many
practical and research challenges remain to be met prior to bio- and phyto-remediation
application on a large scale to decontaminate metal-polluted soils. However, this ‘green’
approach using hyperaccumulator plants to decontaminate polluted sites is believed to
have considerable potential in the quest to safeguard soil fertility, one of the world’s most
precious natural assets (McGrath et al., 1998).
Environmental impact assessment

Cost-benefit analysis (CBA) is a methodology which aims to select projects and policies which are efficient in terms of resource use. As the name suggests it is, in principle, extremely simple. All the positive and negative effects of a proposed project or policy are valued in monetary terms, providing a list of benefits and costs. If benefits are seen to outweigh costs, then the proposed plan represents a potential gain in terms of social welfare. Although CBA is widely practised and accepted, it has also been strongly criticized from perspectives outside economics, particularly the environmental and social spheres. Criticisms generally revolve around:

1 the uncertainty
2 the accuracy and acceptability of monetary valuations of impacts
3 the distribution of costs and benefits among the population
4 the practice of discounting the future in estimating total costs and benefits
5 the treatment of irreversibility in development decisions
6 the institutional impartiality of the CBA process
7 the lack of a sustainability criterion in cost-benefit decision-making.

The various stages of the cost-benefit analysis methodology are the following:

1 project definition
2 classification of impacts:
   i timing impacts
   ii irrelevant impacts
   iii estimation of impacts
   iv additionality of with-minus-without
3 conversion into monetary terms:
   i adjustments for inflation
   ii adjustments for shadow prices
4 discounting:
   i pure time preference and opportunity costs
   ii productivity of capital
5 project assessment under the net present value (NPV) and internal rate of return (IRR) tests:
   i net present value
   ii distributional assessments
6 sensitivity analysis (Edwards-Jones et al., 2000).

The high uncertainty about the estimations of the external environmental costs is one of the main reasons why the classic cost-benefit analysis is not considered very useful to support environmental policies. The literature on external costs provides several studies accounting for a large part of uncertainty by means of appropriate statistical and sensitive analysis. By elaborating these results, the analysis described seems to
support the conclusion that centralized supply, and especially the completely electric solution (based on the reversible electric heat pump), is still preferable to natural gas-fired combined heat and power (CHP) distributed generation. This is not a definitive conclusion but a useful (scientific based) contribution for policy decisions under the state of the art. The European Commission is indeed advocating combined heat and power distributed generation (CHP DG) as a contribution to greenhouse gas (GHG) emission reduction as well as the recent European Directive on the promotion of cogeneration is very favourable to micro-cogeneration and small CHP plants, on the basis of their supposed environmental benefits (Gulli, 2006).

Environmental Impact Assessment (EIA) is the process of predicting the impact of a planned activity, usually a project or policy, on the environment before that project/policy is initiated. It is not an end in itself, rather the purpose of any EIA is to aid the development decision. A good EIA ensures that decision-makers have available as good information as possible when considering projects. The second layer within the EIA is concerned with the process and structure of the EIA, while the third layer within the EIA is concerned with the actual activities that take place within the EIA structure (Glasson et al., 1999; Edwards-Jones et al., 2000). The examples of computer models which could be used to predict impacts as part of environmental impact assessments are given in Table 1.1.

The United Nations Economic commission for Europe (1991) has an altogether more succinct and pithy definition: ‘an assessment of the impact of a planned activity on the environment’. EIA is a systematic process that examines the environmental consequences of development actions, in advance. The emphasis, compared with many other mechanisms for environmental protection, is on prevention. The process involves a number of steps, as outlined in Figure 1.1. EIA is normally wider in scope and less quantitative than other techniques, such as cost-benefit analysis. The EIA process has the potential, not always taken up, to be a basis for negotiation between the developer, public interest groups and the planning regulator. The environmental impacts of a project are those resultant changes in environmental parameters, in space and time, compared with what would have happened had the project not been undertaken. The parameters may be any of the type of environmental receptors noted previously: air quality, water quality, noise, levels of local unemployment and crime. Types of impact are physical and socio-economic, direct and indirect, short-run and long-run, local and strategic, adverse and beneficial, reversible and irreversible, quantitative and qualitative, actual and perceived.

EIA was first formally established in the USA in 1969 and has since spread, in various forms, to most other countries. A 1985 European Community Directive on EIA (Directive 85/337) introduced broadly uniform requirements for EIA to all EU Member States and significantly affected the development of EIA in the UK. The object of prediction is to identify the magnitude and other dimensions of identified change in the environment with a project or action, in comparison with the situation without that project or action. Prediction involves the identification of potential change in indicators of such environment receptors. Scoping will have identified the broad categories of impact in relation to the project under consideration. If a particular environmental indicator (e.g. SO₂ levels in the air) revealed an increasing problem
Table 1.1 Examples of computer models which could be used to predict impacts as part of environmental impact assessments

<table>
<thead>
<tr>
<th>Model</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop estimation through resource and environment synthesis (CERES) – maize</td>
<td>To test quickly and easily a variety of different fertilization and irrigation schedules to maximize maize (corn) production from a given piece of land</td>
</tr>
<tr>
<td>Atmospheric greenhouse model (AGM)</td>
<td>To analyze the consequences for the global climate of various scenarios regarding the production of carbon dioxide from fossil fuel combustion</td>
</tr>
<tr>
<td>Range, livestock and wildlife model</td>
<td>To help decision-makers understand and evaluate policy alternatives for rangeland management</td>
</tr>
<tr>
<td>Enhanced stream water quality model</td>
<td>To provide tools for water quality planning by simulating the behaviour of the hydrologic and water quality components of a branching stream system or lake under the impact of a wide range of pollutants</td>
</tr>
<tr>
<td>Waterborne toxic risk assessment model</td>
<td>To estimate the risks of adverse human health effects from substances emitted into the air, surface water, soil and groundwater from a source such as a coal-fired power plant</td>
</tr>
</tbody>
</table>

Adapted from Edwards-Jones et al., 2000

in an area, irrespective of the project or action (e.g. a power station), this should be predicted forwards as the baseline for this particular indicator (Glasson et al., 1999). Assessment of effects (including direct and indirect, secondary, cumulative, short-, medium- and long-term, permanent and temporary, positive and negative effects) are effects on:

1. human beings, buildings and man-made features
2. flora, fauna and geology
3. land
4. water
5. air and climate
6. other indirect and secondary effects associated with the project (DOE, 1989).

Methods and models for prediction (how to predict) can be classified in many ways; they are not mutually exclusive. In terms of scope, all methods are partial in their coverage of impacts, but some seek to be more holistic than others. Partial methods may be classified according to type of project (e.g. retail impact assessment) and type of impacts (e.g. wider economic impacts). Some may be extrapolative, others may be more normative. Normative approaches work backwards from desired outcomes to assess whether a project, in its environmental context, is adequate to achieve them.
Figure 1.1 Important steps in the EIA process

1. Is an EIA required?
   - Yes
     - Decision-making
     - Identification of key impacts
     - Prediction of impacts
   - No
     - Post-decision monitoring
     - Audit of predictions and mitigation measures

2. Description of the project/development action and alternatives
3. Post-decision monitoring
4. Identification of key impacts
5. Prediction of impacts
6. Evaluation and assessment of significance of impacts
7. Decision-making
8. Identification of mitigating measures
9. Presentation of findings in the EIS
10. Identification of the environmental baseline
11. Is an EIA required?
Methods can also be classified according to their form, as the following six types of model illustrate:

1. Mechanistic or mathematical models: describe cause-effect relationships in the form of flow charts or mathematical functions. Mathematical models can also be divided into deterministic and stochastic models. Deterministic models, like the gravity model, depend on fixed relationships. In contrast, a stochastic model is probabilistic.

2. Mass balance models: establish a mass balance equation for given ‘compartments’. Inputs to the compartment could be, for instance, water, energy, food or chemicals; outputs could be outflowing water, wastes, or diffusion to another compartment.

3. Statistical models: use statistical techniques such as regression or principal components analysis to describe the relationship between data, to test hypotheses or to extrapolate data.

4. Physical, image or architectural models: are illustrative or scale models that replicate some element of the project-environment interaction.

5. Field and laboratory experimental methods: use existing data inventories, often supplemented by special surveys, to predict impacts on receptors.

6. Analogue models: make predictions based on analogous situations. They include comparing the impacts of a proposed development with a similar existing development (Glasson et al., 1999).

The Environmental Impact Statement (EIS), sometimes known as the environmental effects statement (EES), the environmental statement (ES) or as the environmental impact assessment (EIA), depending upon country, is a document, prepared by a component, describing a proposed development, or activity (or a plan, or program) and disclosing the possible, probable, or certain effects of that proposal on the environment. An EIS should be comprehensive in its treatment of the subject matter, objective in its approach and should be sufficiently specific for a reasonably intelligent mind to examine the potential environmental consequences, good and bad, of carrying out, or not carrying out, that proposal.

An EIS usually includes the following: a full description of the proposed project, or activity; a statement of the objectives of the proposal; an adequate description of the existing environment likely to be affected by the proposal; the identification and analysis of the likely environmental interactions between the proposal and the environment; the justification of the proposal; economic, social and environmental considerations; the measures to be taken with the proposal for the protection of the environment and an assessment of the likely effects of those measures; any feasible alternatives to the proposal; and the consequences of not carrying out the proposal for the component, community, region and state. The characteristics of a good EIS, EES or ES are:

1. A summary of the EIS
2. Acronyms and initials should be defined
3. The list of contents
4. The authors of the EIS should be clearly identified
5 a brief outline of the history of the proposed development
6 a full description of the proposed project or activity, its objectives and geographical boundaries
7 a full description of the existing environment likely to be affected by the proposal; the baseline conditions; deficiencies in information; data sources; the proximity of people, other enterprises
8 the alternative locations considered or alternative processes
9 the justification of the proposal in terms of economic, social and environmental considerations
10 the planning framework, relevant statutory planning instruments, zoning
11 the identification and analysis of the likely environmental interactions
12 the measures to be taken with the proposal for the protection of the environment and an assessment of their likely effectiveness
13 the implications for public infrastructure such as housing, schools, hospitals, water supply, garbage removal, sewerage, electricity, roads, recreational facilities, fire, police, emergency services
14 any cumulative effects from similar enterprises should be considered
15 proposals for annual reporting to the decision-making body on the implementation and environmental auditing
16 the contribution to sustainable development.

Structure of an EIA report is:

1 letter of transmittal to the decision-making body or person
2 recommendation
3 main findings
4 background history
5 proposal and EIS
6 the issues:
   a) environmental
   b) economic
   c) social
7 mitigation measures
8 planning context
9 appendices:
   a) list of submissions from the public
   b) location and site boundaries
   c) layout of buildings
   d) transport network
   e) visual assessment
   f) air and water quality
   g) noise, equipment and traffic
   h) industrial wastes
   i) alternatives
   j) energy considerations
k) risks and hazards
l) emergency arrangements
m) rehabilitation.

The direct compliance costs of the assessment process do not appear to have proved a significant problem for large companies, especially if the EA is integrated with feasibility studies. Usually direct costs are generally less than 1% of total project costs. In some instances this involves planning 5 to 10 years ahead, or even longer in the case of electricity generation or requirements. However, unexpected problems and delays might arise which could not have been anticipated. These delays could arise from:

1 a lack of coordination
2 conflicting demands between agencies
3 the failure of agencies and governments to observe time limits
4 an unexpectedly large volume of public opposition
5 parliamentary opposition not reasonably anticipated
6 significant deficiencies.

These indirect costs can be considerable, amounting to about 10% of total project costs. They are particularly onerous in the case of a large electricity generating system and transmission network. Typically, pollution control costs as a percentage of total plant and equipment costs for: iron and steel industry, 20%; non-ferrous metals, 12%; electricity generating plant, 11%. A most effective tool for improving the process is the audit. Its primary purpose is to ensure that the development has taken place under the terms and conditions imposed by the initial EIA process and its associated development consent or planning approval (Gilpin, 1995).

A UNECE task force (1990) serves the following purposes: to monitor compliance with the agreed conditions, to review predicted environmental impacts, to modify the activity or develop mitigation measures in case of unpredicted harmful effects and to review the effectiveness of environmental management. A preliminary plan for auditing should be prepared during the EIA process and fully developed when a favourable decision is made and it is given in Figure 1.2.

During recent decades, there have been notable changes in the global and European climate. Temperatures are rising, precipitation in many parts of Europe is changing and weather extremes show an increasing frequency in some regions (IPCC, 2001). According to the UN Intergovernmental Panel on Climate Change (IPCC), ‘there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities, in particular to the emission of greenhouse gases’ (IPCC, 2001).

Atmospheric indicators show that the concentration of carbon dioxide (CO₂) in the lower atmosphere has increased from its pre-industrial concentration of 280 ppm (parts per million) to its 2003 concentration of 375 ppm. This is the highest level in the last 500,000 years. The impacts of climate change on the marine environment are covered in this report by assessing the rise in sea level, the sea surface temperature and changes in the marine growing season and species composition. Climate change
affects agriculture in many ways. Increasing atmospheric CO₂ and rising temperatures may allow earlier sowing dates, enhance crop growth and increase potential crop yield. Extreme weather events cause damage to industry, infrastructure and private households. In Europe, a large number of all catastrophic events since 1980 are attributable to weather and climate extremes: foods, storms and droughts/heatwaves. Economic losses resulting from weather and climate related events have increased significantly during the past 20 years (http://reports.eea.europa.eu/climate_report_2_2004/en/impacts_of_europes_changing_climate.pdf). The summary of trends and projections of indicators is shown in Table 1.2.
### Table 1.2 Summary of trends and projections of indicators

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Key messages</th>
</tr>
</thead>
</table>
| **Atmosphere and climate**                | **Greenhouse gas concentrations**  
● Due to human activities, the concentration of carbon dioxide (CO₂), the main greenhouse gas, has increased by 34% compared with pre-industrial levels, with an accelerated rise since 1950  
● To achieve the EU long-term objective of limiting global temperature rise to 2°C, global emissions of greenhouse gases need to be reduced substantially from 1990 levels |
| **Global and European air temperature**   | **Global and European air temperature**  
● The global average temperature has increased by 0.7 ± 0.2°C over the past 100 years. The 1990s were the warmest decade in the observational record; 1998 was the warmest year, followed by 2002 and 2003 |
| **European precipitation**                | **European precipitation**  
● Annual precipitation trends in Europe for the period 1900–2000 show a contrasting picture between northern Europe (10–40% wetter) and southern Europe (up to 20% drier). Changes have been greatest in winter in most parts of Europe |
| **Temperature and precipitation extremes**| **Temperature and precipitation extremes**  
● In the past 100 years the number of cold and frost days has decreased in most parts of Europe, whereas the number of days with temperatures above 25°C (summer days) and of heatwaves has increased. |
| **Glaciers, snow and ice**                | **Glaciers**  
● Glaciers in eight out of the nine glacier European regions are in retreat, which is consistent with the global trend  
● From 1850 to 1980, glaciers in the European Alps lost approximately one third of their area and one half of their mass. Since 1980, another 20–30% of the remaining ice has been lost  
● By 2050, about 75% of the glaciers in the Swiss Alps are likely to have disappeared |
| **Marine systems**                        | **Rise in sea level**  
● The projected rate of sea level rise between 1990 and 2100 is 2.2 to 4.4 times higher than the rate in the 20th century and sea level is projected to continue to rise for centuries |
| **Sea surface temperature**               | **Sea surface temperature**  
● No European sea shows a significant cooling |
| **Marine species composition**            | **Marine species composition**  
● Over the past 30 years there has been a northward shift of zooplankton species by up to 1000 km and a major reorganization of plankton ecosystems |
| **Terrestrial ecosystems and biodiversity**| **Plant species composition**  
● Climate change over the past three decades has resulted in decreases in populations of plant species  
● By 2050 species distribution is projected to become substantially affected in many parts of Europe |
| **Plant phenology and growing season**    | **Plant phenology and growing season**  
● The average annual growing season in Europe lengthened by about 10 days between 1962 and 1995 and is projected to increase further in the future  
● Greenness (a measure of plant productivity) of vegetation increased by 12%, an indicator of enhanced plant growth |
| **Agriculture**                           | **Crop yield**  
● Agriculture in most parts of Europe, particularly in mid and northern Europe, is expected potentially to benefit from increasing CO₂ concentrations and rising temperatures (Continued) |
An ‘Air Pollution Index’ can be defined as a scheme that transforms the (weighted) values of individual air pollution related parameters (for example, sulfur dioxide concentration or suspended particulate matter) into single number or set of numbers. Index calculation is shown in Figure 1.3. Air quality indices can be broadly classified into two groups: i) short-term indices and ii) long-term indices. These indices are commonly used by the local and state air pollution control agencies. These indices are very helpful for the purpose of assessing the effectiveness of enforcement policies with regard to pollution control measures, in improving air quality. A typical rating scale for indices is indicated in Table 1.3. Generally the parameters used for calculating the air pollution index are

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Key messages</th>
</tr>
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<tbody>
<tr>
<td>● The cultivated area could be expanded northwards</td>
<td></td>
</tr>
<tr>
<td>● During the heatwave in 2003, many southern European countries suffered drops in yield of up to 30%</td>
<td></td>
</tr>
<tr>
<td><strong>Economy</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Economic losses</strong></td>
<td></td>
</tr>
<tr>
<td>● In Europe, 64% of all catastrophic events since 1980 are directly attributable to weather and climate extremes: foods, storms and droughts/heatwaves; 79% of economic losses caused by catastrophic events result from these weather and climate related events</td>
<td></td>
</tr>
</tbody>
</table>

suspended particulate matter (SPM), sulfur dioxide (SO₂), carbon monoxide (CO), nitrogen dioxide (NO₂), photochemical oxidant (principally ozone O₃) and hydrocarbons. A standardized index (uniform air pollution index) should satisfy the following criteria:

1. include major pollutants
2. calculated in a simple manner
3. consistent with perceived air pollution levels
4. spatially meaningful
5. exhibit day-to-day variation
6. relate to ambient air quality standards and goals
7. can be forecast a day in advance (if possible).

There are several methods and equations used for determining the air pollution index (Rao and Rao, 2000). A few of these methods and equations are given in Table 1.4.

Large amounts of fuels, burned in various types of furnaces, are one of the main sources of pollution in the environment. Flue gases pollute the atmosphere and the associated ashes pollute soil and water. To compare the influence of various fuels burned in different installations on the environment, one universal index would be helpful. Such a coefficient, which represents the harmfulness of combustion processes of a particular fuel in a particular installation, is defined in a report. This coefficient takes into account the composition of the fuel, the thermal efficiency of the installation, the type and process efficiency of creation of harmful compounds in the combustion chamber, efficiency of cleaning devices, ability of emitter to propagate pollutants into the atmosphere, as well as the relative toxicity of various components. Finally, methods of calculation of propagation of pollutants in the atmosphere are introduced. All these factors are essential for a reliable assessment and comparison of fuel and installations. An individual coefficient of harmfulness could be calculated for each compound present in the fuel gases as well as a total coefficient for all compounds. Each compound created in the combustion processes is the source of many types of environmental impact. It could have significant influences on human health, plants and animals as well as, for example, on the corrosion process taking place in many different installations. It has to be taken into consideration that the result of a combustion process could appear in many different places, sometime distant from the place of the process itself. All these results should be analyzed and introduced into the universal coefficient of ‘harmfulness’ of

<table>
<thead>
<tr>
<th>Table 1.3 Typical rating scales for air pollution indices</th>
</tr>
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<tbody>
<tr>
<td><strong>Index values</strong></td>
</tr>
<tr>
<td>0–25</td>
</tr>
<tr>
<td>26–50</td>
</tr>
<tr>
<td>51–75</td>
</tr>
<tr>
<td>76–100</td>
</tr>
<tr>
<td>&gt;100</td>
</tr>
</tbody>
</table>

Adapted from Rao and Rao, 2000
Levitan (1997, 2000) proposed a typology to distinguish among three quite different types and applications for pesticide impact assessment tools (which are also known as ‘pesticide risk indicators’):

1. decision support systems for farmers and other property managers
2. ‘ecolabeling’ or ‘green labeling’ systems designed to influence consumer opinion and market behavior

### Table 1.4 Methods and equations used for determining the Air Pollution Index

<table>
<thead>
<tr>
<th>Method</th>
<th>Characteristics</th>
<th>Equation and examples</th>
</tr>
</thead>
</table>
| 1st method | ● It is tried to relate the existing pollution level of various pollutants to their ambient air quality standards, with the standard being assumed as the reference base line for each pollutant and then converting the concentration of pollutants into a percentage of the standard. <br>● The Air Pollution Index is then obtained by adding the percentages for the several pollutants considered | For example, there are six pollutants:  
I = \( \frac{1}{6} \sum A_i \)  
\( A_i = \frac{C_i}{S_i} \times 100 \)  
I = \( \text{Air Pollution Index} \)  
\( A_i = \text{Air Pollution Sub-index} \)  
\( C_i = \text{Concentration of pollutant} \)  
\( S_i = \text{Air quality standard for pollutant} \) |
| 2nd method | ● The average of the sum of the ratios of three major pollutant concentrations to their respective air quality standards is obtained. <br>● The average is then multiplied by 100 to obtain the index. | For example, there are three major pollutants in a city: particulate matter, sulfur dioxide and carbon monoxide:  
\( \text{API} = \frac{1}{3} (\text{PM}/\text{SPM} + \text{SO}_2/\text{SSO}_2 + \text{CO}/\text{SCO}) \times 100 \)  
\( \text{PM}, \text{SSO}_2, \text{and SCO} = \text{ambient air quality standards for particulate matter, sulfur dioxide and carbon monoxide, respectively} \) |
| 3rd method | ● Air Pollution Index is calculated from five sub-indices. <br>● Each sub-index is obtained by assigning sub-index values for particular ranges of pollutant concentrations. | I = \( \sum A_i \)  
I = \( \text{Air Pollution Index} \)  
\( A_i = \text{Air Pollution Sub-index} \) |
| 4th method | ● This method is known as the maximum type. <br>● It is used for only one pollutant index among the several pollutants. | The only one pollutant index is the highest one |
| 5th method | ● This method is used for only two common pollutants. <br>● These pollutants are taken into account while calculating the Air Pollution Index. | For example, the pollutants are particulate matter and sulfur dioxide |
| 6th method | ● This method is used for only one major pollutant. <br>● This pollutant is taken as the basis for reporting the Air Pollution Index. | For example, the pollutant is ozone concentration |

Adapted from Rao and Rao, 2000
3 indicators of impact and risk used by governments, industry and academia to assess policies and programs.

These types are differentiated by their objectives, decision-makers, factors or variables considered, arena of activity, scale and unit of analysis, handling of an economic dimension, format of results and method or approach. A number of different types of risks are associated with pesticides including the risk of:

1. unintended adverse effects on non-target biota
2. exposure, i.e. risk of pesticide residues on food
3. pest resistance of pest controls
4. disease or loss of food and fiber because pests are not controlled
5. harm to natural or agro-ecosystem
6. greater cost for pest control
7. consumption and degradation of resources.

Both the Environmental Impact Quotient (EIQ) developed by Kovach et al. (1992) and the California Seminar system developed by Pease et al. (1996) focus on agricultural pesticides use.

In this typology, a range of assessment systems used for many distinct purposes fall under the rubric of policy tools. More specifically, the types of policy tools include:

1. screening systems to assess quickly preliminary data for danger signals
2. analyses by regulatory agencies that evaluate pesticide use and risks over time
3. evaluations of risks from individual pest control products and practices
4. criteria for pesticides usage tax programs
5. evaluations of the success and/or relative or absolute costs and benefits of programs and policies
6. assessments of the adoption of IPM on farms and in schools
7. evaluations of the success of IPM in meeting its objectives to control pests. The typology of pesticide risk indicators is given in Table 1.5.

A number of pesticide ranking systems are based on simple algebraic equations, using a format similar to plant breeding selection indexes (Cotterill and Dean, 1990) and multiattribute indicators used in the social sciences (Putnam, 1993). A generalized form of these equations is:

\[
\text{Environmental Impact Index Value}_{\text{COMPOSITE}} = f(b_1x_1 + b_2x_2 + b_3x_3 + \cdots + b_ix_i)
\]

An array of index values for a set of variables, with no composite index value calculated is given in Table 1.6.

Consumers Union’s agricultural pesticide risk index was developed by Charles Benbrook and others (1996) to assess whether regulatory policies have succeeded in reducing pesticide risk since the US Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) was revised in 1972. Two weighted indexes of risk were derived, one from acute toxicity indicators for mammals and another from chronic toxicity indicators.
These indices were used in combination with US agricultural pesticide usage data for 1971, 1982 and 1992 to assess trends (Table 1.7). Results indicate that the trend in pesticide risk to public health has been flat – neither acute nor chronic risks to human beings have declined from 1971 to the present. For each of three years studied, a dozen or fewer active ingredients account for most (≥75%) of the pesticides applied in each major class (herbicides, insecticides and fungicides). Charles Barnard, an economist with the Environmental Indicators Branch of USDA Economic Research Service (ERS), has developed two indicators of pesticide risk to human beings that were publicly unveiled in the ‘Pesticide Use’ module of the USDA ERS Agricultural Handbook.
entitled ‘Agricultural Resources and Environmental Indicators’ (1997). Historically, ERS has relied on pounds of pesticides applied as the basis of pesticide usage data. Pesticide weight was therefore also being used as the de facto proxy for pesticide risk. Currently, several initiatives are underway at ERS to develop other risk indicators. Among these are Barnard’s potential risk measures for acute and chronic toxicity based upon ‘toxicity/persistence units’ (TPUs). The objective is to improve time series analysis of national pesticide risk by using these as toxicity-weighted measures of pesticide use. The method also enables identification of geographic regions at greater risk from pesticide use and identification of pesticide classes and uses posing greatest risk.

### References


