Appendix III

Toxicological Profiles of Chemicals Referred to of the Mission Report on Pancevo

Ammonia (NH_3)

Ammonia is a chemical that is formed in nature, for example, from the natural breakdown of manure and dead plants and animals. Ammonia is a gas, but it is also soluble in water where it forms ammonium. It is present in water, soil and air and acts as a source of nitrogen for plants and animals. Ammonia is also produced industrially, largely for use as a fertiliser. A smaller proportion is used to manufacture plastics, synthetic fibres and explosives. It is not persistent in the environment, but unusually high levels in the environment, such as at hazardous waste sites, are usually associated with anthropogenic activities.

Exposure to very high levels of ammonia gas is fatal. Death may occur immediately or from secondary complications after a few weeks. High exposure may cause burns to the skin, eyes, throat and lungs, which, if serious, may cause permanent blindness, lung disease or death. Short-term exposure to lower levels of ammonia causes nasal and throat irritation. In laboratory animals, long-term exposure to low levels of ammonia causes inflammation and lesions of the respiratory tract (ATSDR 1997).

Benzene

Benzene is found in the environment due to both human activities and natural processes. It was first discovered and isolated from coal tar. However, today it is mostly produced from petroleum sources. Various industries use benzene to make other chemicals, such as styrene (for plastics), cumene (for various resins), and cyclohexane (for nylon and synthetic fibers). It is also used for the manufacturing of some types of rubbers, lubricants, dyes, detergents, drugs, and pesticides (ATSDR 1997). In terms of toxicity, acute exposure, either from inhalation, ingestion, or skin absorption, can cause irritation to mucous membranes. It can also cause restlessness, convulsions and depression. Death may follow from respiratory failure. Chronic exposure to lower levels can cause bone marrow suppression, which can, albeit rarely, lead to leukemia. Because of this benzene is listed as a known human carcinogen (ATSDR 1997).

Cadmium

Cadmium is a heavy metal. The most often mentioned sources of cadmium entering the aquatic environment are industrial effluents and sewage (Butler and Timperley 1995). Small amounts of cadmium enter the environment from the natural weathering of minerals, but most is released through human activities (Elinder 1985). It most frequently used in the production of nickel-cadmium batteries (35%) and for metal plating (30%). It is also used for pigments (15%), for plastics and synthetics (10%), and for alloys and other miscellaneous uses (10%) (ATSDR 1997), and the incineration of any of these products could result in high levels of cadmium being present in the residual sludge.

Cadmium has no biological function, and is highly toxic to both animals and plants. The low concentrations of cadmium usually encountered in the environment do not cause acute toxicity, however elevations above background concentrations can have deleterious effects on plant and animal health (Bryan and Langston 1992, Alloway 1990).

Toxic effects on exposed aquatic biota include observed correlations between increased levels of cadmium found in limpets and a reduced ability to utilise glucose (Shore *et al.* 1975, Bryan and Langston 1992). Reductions in reproduction rates and thus population numbers in copepods and isopods (Giudici and Guarino 1989) have also been observed. The toxicity of low sediment-cadmium concentrations was also suggested by observations showing that in San Francisco Bay, the condition of certain species of clam declined as cadmium concentrations rose from 0.1 to 0.4 mg/kg (Luoma *et al.* 1990).

Regarding potential human exposure, food, water and cigarette smoke are the largest sources of cadmium for members of the general population. Eating food or drinking water with very high cadmium levels can severely irritate the stomach, leading to vomiting and diarrhoea (ATSDR 1997). Eating lower levels of cadmium over a long period of time can lead to a build up in the kidneys. This cadmium build-up causes kidney damage, and also leads to the weakening of bone (Nriagu 1988). Studies concerned with the effects of eating and drinking high levels of cadmium are not strong enough to show that such exposure can lead to an increased rate of cancer. However the U.S. Department of Health and Human Services and the U.S. Environment Protection Agency have both determined that cadmium and cadmium compounds may reasonably be anticipated to be carcinogens (ATSDR 1997).

Chlorine (Cl_2)

Chlorine is a gas that is produced industrially by passing electricity through a salt solution. The chlorine industry manufactures chlorine primarily to combine with petrochemicals to produce organochlorine products such as solvents, pesticides, plastics (especially PVC) and many other chemicals. A much smaller proportion of the chlorine gas is sold outside the chemical industry, primarily as bleach in the production of paper and a very small proportion for drinking water disinfection.

Chlorine gas was used as a chemical weapon in the First World War. It is intensely irritating and causes oedema of the lungs (production of fluid in the lungs), and exposure can be rapidly fatal. Since its production by industry, there have been numerous releases of chlorine from industrial facilities, many of them resulting in deaths (Marshall 1987). Long-term exposure to lower levels of chlorine is reported to cause respiratory complaints and corrosion of the teeth. Chlorine is a potent irritant to the eyes, lungs and skin. Chlorine is not carcinogenic in animals or humans. However, chlorination of drinking water results in the formation of other chlorinated organic substances in the water which are reported to increase the risk of bladder and rectal cancer (eg. Cantor 1994).

Chromium

Chromium is a heavy metal. Elevations above the background range are nearly always due to anthropogenic discharges, with two industrial sectors responsible for the majority of releases: metallurgical and chemical (e.g. tanning agents, pigments, catalysts).

Information on the effects of elevated environmental levels on aquatic biota, fish, deposit feeding and wading birds is limited; and how sediment-bound chromium reaches animal and plant tissues is uncertain, although it is recognised that the speciation of chromium determines its bioavailability. Chromium (VI) will be accumulated more readily than chromium (III), as it has been shown to cross biological membranes more readily (Bryan and Langston 1992). Whereas chromium (III) is a trace nutrient at low concentrations, chromium (VI) is non-essential and toxic. Its compounds have been classified as carcinogenic by the International Agency of Research on Cancer (ATSDR 1997).

An average daily intake of 50-200 ug/day of chromium (III) is recommended for adults (ATSDR 1997), chromium (III) being an essential nutrient, required for normal energy metabolism. However the consumption of contaminated fish, other foodstuffs and contaminated drinking water could increase the daily intake levels far beyond those recommended. Ingesting small amounts of chromium (both III and VI forms) has not been reported to cause harm. However, ingesting higher than recommended levels over long periods of time can result in adverse health effects including gastro-intestinal irritation, stomach ulcers, kidney and liver damage (ATSDR 1997).

Dermal exposure to both chromium (III) and chromium (VI) can result in severe redness and swelling of the skin (ATSDR 1997). Breathing in high levels of chromium can cause irritation of the nasal and respiratory membranes. These effects have primarily occurred in factory workers who make or use chromium (VI) for several months to many years. Long term occupational exposure to chromium (VI) is believed to be responsible for the increased lung cancer rates in workers (ATSDR 1997).

Copper

Copper is a heavy metal. Anthropogenic sources of copper arise mainly from mining, smelting and metal plating operations; chemical discharges, agricultural runoff and domestic sewage effluents are also significant sources (ATSDR 1997).

Like zinc, copper is necessary for good health. However very large single or daily intakes of copper, or prolonged exposure to lower levels can have adverse effects on human health. Consumption of food or drinking water containing elevated levels of copper can result in vomiting, diarrhea, stomach cramps and nausea (ATSDR 1997).

1,1-Dichloroethane

1,1-Dichloroethane is used in the production of a number of chemicals and is also used as a solvent, for instance, for paints and varnishes, and as a degreasing agent. Most 1,1-dichloroethane that is released from industrial sources is emitted to air. It can also be found as a contaminant in soil and groundwater. In the environment, 1,1-dichloroethane can also be formed as a breakdown product from 1,1,1-trichloroethane. 1,1-dichloroethane emitted to air remains as a vapour for about 2 months. It is not known how long this chemical remains in soil before it is broken down. There is very little information on the effects of 1,1-dichloroethane in humans and laboratory animals. Exposure to very high levels for a short time period caused death in laboratory animals and would be expected to have the same impact on humans. 1,1-dichloroethane was once used as an anaesthetic until it was discovered that it caused cardiac arrythmias at the high doses used. It is expected to depress the central nervous system at high doses. Long-term exposure to 1,1-dichloroethane in laboratory animals caused kidney injury and cancer and caused delayed growth in the developing young when given to pregnant females.

1,2-Dichloroethane (EDC)

1,2-Dichloroethane (EDC) is a man-made chlorinated solvent. The largest individual use of EDC is as an intermediate in the manufacture of other products, particularly vinyl chloride (ATSDR 1997). The manufacture of EDC for PVC production generates large quantities of dioxins (ICI 1994, Stringer et al. 1995).

Reliable information on how EDC affects the health of humans is scarce. Brief exposure to dichloroethane in the air at very high levels has caused death in animals, and it is likely that exposure to similar levels would cause death in humans. Some studies in animals have shown that EDC can cause kidney disease after long-term, high-level exposure in the air. Also, delayed growth was observed in the offspring of animals who breathed high concentrations of EDC during pregnancy. However, there is no information as yet to indicate that these effects do occur in humans (ATSDR 1997). Inhalation of high concentrations of EDC by humans can upset the nervous system and gastrointestinal system causing dizziness, nausea and vomiting. The liver, kidney and adrenal gland may also be damaged.

Exposure to EDC has so far not been associated with cancer in humans. One epidemiological study revealed a relationship between cancer incidence and exposure to environmental pollutants in groundwater, including EDC; however, subjects were probably exposed to numerous other chemicals at the same time. Cancer studies in animals have shown that dermal exposure to dichloroethane can lead to the development of lung tumors. Further studies showed that inhalation of EDC may also cause cancer in animals.

In view of the cancer findings in animals, the possibility of EDC exposure causing cancer in humans cannot be ruled out. The International Agency for Research on Cancer (IARC) has determined that EDC is possibly carcinogenic to humans. The US EPA has determined that EDC is a probable human carcinogen (ATSDR 1997).

EDC has toxic effects on aquatic organisms including many species of fish, algae and water fleas at concentrations of about 100 mg/l. Some more sensitive species may die as a result of exposure to lower concentrations of only 1 mg/l. The earthworm is also sensitive to EDC toxicity.

1,1-Dichloroethene

1,1-Dichloroethene is used in the production of certain plastics and flame-retardant coating for fiber and carpet backing. It is a man-made chemical that is not found naturally. Very low levels of 1,1-dichloroethene are found in air and drinking water. Levels in air can be somewhat higher at factories using this chemical and at hazardous waste sites, but not generally higher than levels which are known to cause adverse effects in experimental animals. Exposure to 1,1-dichloroethene in the work place for long periods has been associated with abnormal liver function, although other chemicals could also have contributed to this effect. Long term exposure causes liver and kidney toxicity in laboratory animals. Short term exposure to high levels of 1,1-dichloroetherne has been associated with adverse neurological effects. The US EPA have classified 1,1-dichloroethene as a possible human carcinogen, and the Internatioal Agency for Research on Cancer determined that it is not classifiable as to it carcinogenicity in humans (ATSDR 1997).

Trans-1,2-dichloroethene

There are two forms of 1,2-dichloroethene, the cis and the trans forms. Sometimes both forms are present as a chemical mixture. 1,2-dichloroethene is used industrially and may also be formed as a breakdown product of other chlorinated solvents. Once released into the environment its half-life in air is 5-12 days and in groundwater is 13 to 48 weeks. There is a slight chance that 1,2-dichloroethene in landfills may break down to vinyl chloride, which is even more hazardous. Inhalation of very high levels of 1,2-dichloroethene can lead to death. Inhalation of high levels can cause nausea and tiredness. Little or no information exists on the effects of long-term exposure to 1,2-dichloroethene in humans. A number of different adverse effects have been recorded in laboratory animals that were exposed to trans-1,2-dichloroethene by inhalation and ingestion (ATSDR 1997).

Dichloromethane

Dichloromethane is widely used as a solvent for many purposes. Dichloromethane is of low acute toxicity. Based on studies in animals it is classified by the International Agency for Research on Cancer (IARC) as a probably human carcinogen.

Dioxins

The terms 'dioxin' or 'dioxins and furans' generally refers to a group of 210 chlorinated pollutants, the polychlorinated dibenzo-p-dioxins and dibenzofurans. Dioxins are organochlorines (substances based on carbon and chlorine) and are regarded as the world's most toxic organic pollutants. They are not produced intentionally but are generated as by-products from combustion sources (eg. by all types of industrial incinerators) and from certain chemical and industrial processes (eg. those processes involving chlorine and organochlorines). Dioxins and furans are very persistent (long-lived) in the environment and build up in the bodies of animals and humans and remain there for many years. In the general population, the greatest intake of these chemicals occurs through the consumption of fatty foods including meat, fish and dairy products. In mammals and humans, dioxin and furans are passed to the developing foetus in the womb through the placenta and to the nursing young via mother's milk.

The most toxic of the 210 dioxins and furans, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is used as the toxicological model for the group and has been extensively researched. The International Agency for Research on Cancer have classified TCDD as a human carcinogen. In addition to causing cancer, animal studies have shown that it causes damage to the nervous system, the immune system, the reproductive system and malformations in the unborn. A draft review of TCDD by the US Environmental Protection Agency concluded that some of the more sensitive effects could be occurring at the levels of exposure that are experienced by ordinary men and women in the general population. In particular, there is concern that the developing foetus/embryo appears to be very sensitive to the toxic effects of dioxins and adverse effects caused during development could be irreversible. Studies on "healthy" women from the general population in Holland showed that the current level of dioxins and PCBs in some women's bodies may be sufficient to cause subtle adverse effects on the nervous system and immune systems of their children. This is due to the transfer of these chemicals through the placenta to the foetus in the womb and/or through breast milk to the nursing infant (eg. Weisglas-Kuperus et al. 1998).

Heavy Metals

"Heavy metals" is a group name for metals and metalloids that have atomic densities of greater than 6 grams per cubic centimetre. Many of these metals are toxic at very low concentrations. They are also persistent in the environment and have the potential to build up (bioaccumulate) through the food chain. Heavy metals discharged into the aquatic environment will bind predominantly to suspended material and finally accumulate in the sediment, thus providing a reliable history of pollution. As concentrations in sediment can exceed those of the overlying water by between three and five orders of magnitude (Schuhmacher et al. 1995, Bryan and Langston 1992), the bioavailability of even a minute fraction of the total sediment metal assumes considerable importance. The two most direct potential routes of exposure to humans following discharges of heavy metals to a river would be consumption of the water, or of fish, or other food derived from the river.

Hydrochloric acid (HCl) - Hydrochloric acid has many industrial uses. Exposure via inhalation in the short-term may cause chest pain, coughing, inflammation and ulceration of the respiratory tract, and higher exposure can cause a build-up of fluid in the lungs, which can lead to death. Skin contact may produce severe burns, ulceration and scarring. Exposure of workers to hydrochloric acid over long time periods has been reported to cause chronic bronchitis, dermatitis, gastritis and photosensitization. Prolonged exposure to low concentrations may also cause dental discoloration and erosion.

Lead

Unlike some heavy metals, lead is not required by animals (including humans) or plants for normal growth and development. It has no known nutritional or biochemical function and if present in sufficient quantities will inhibit animal and plant growth, development and health (Nriagu 1988).

It is not considered to be one of the most environmentally mobile metals, often heavily bound to suspended particulate and sediment material (Berg *et al.* 1995, Hapke 1991). However, there is appreciable evidence to show that sediment-bound lead is available to deposit-feeding species (Bryan and Langston 1992). With high bioconcentration factors (BCFs) being determined in studies using oysters (6,600 for *Crassostrea virginica*), freshwater algae (92,000 for *Senenastrum capricornutum*) and rainbow trout (726 for *Salmon gairdneri*) (Eisler 1988). It is toxic to all aquatic biota, and organisms higher up the food chain may experience lead poisoning as a result of eating lead-contaminated food.

In terms of human health the effects of lead are the same irrespective of whether it is inhaled or ingested (ATSDR 1997). Lead can cause irreversible central nervous system damage and decreased intelligence at extremely low doses (Needleman *et al.* 1990, ATSDR 1997). At higher levels of exposure anaemia may result, along with severe kidney damage (ATSDR 1997). Children are especially susceptible to lead poisoning because they absorb and retain more lead in proportion to their weight than adults (ATSDR 1997).

Mercury

Mercury is a non-essential trace metal, having no biochemical or nutritional function. Biological mechanisms for its removal are poor, and mercury is the only metal known to biomagnify i.e. progressively accumulate through the food chain (WHO 1989, ICME 1995). It is extremely toxic to both animals and plants even at low concentrations. Therefore any elevation above baseline levels could have a deleterious effect on any biota exposed (ATSDR 1997).

In the mid-1950's at the fishing village of Minamata in Japan, mercury leaked from industry into the bay and in subsequent years many people suffered from adverse effects of mercury from consuming locally caught fish. This included a cerebral palsy-like illness in children born to apparently healthy women who had eaten local fish. Since the poisoning incident that devastated the Japanese town of Minamata, the implementation of widespread regulations on mercury disposal has greatly reduced the threat of similar incidents. However, the retention of mercury by sediments may delay the elimination of contamination for many years. Thus, for example, concentrations as high as 100 mg/kg were still present in sediments at certain sites in Minamata Bay, ten years after discharges ceased (Bryan and Langston 1992, Tsubaki and Irukayama 1977). The importance of this is the fact that mercury accumulation from sediments may be a dominant pathway for uptake in aquatic organisms and accounts for relatively high concentrations in deposit-feeders both in freshwater and estuarine systems (Bryan and Langston 1992, Kiorboe et al. 1983).

It is known that inorganic mercury can be methylated by microorganisms within the sediment to form organic forms of mercury such as methylmercury (MeHg). It is widely accepted that organic forms of mercury are even more toxic than the inorganic forms (ATSDR 1997). Although there is evidence which links levels of total mercury in the environment with those in higher predators such as fish, concern centers on MeHg accumulation.

MeHg exhibits high lipid solubility. It is able to cross cell membranes easily, and therefore quickly enters the aquatic food chain. It also has a long biological half-life, and due to increased longevity of top predators in association with these other properties, it provides one of the rare examples of metal biomagnification in food chains. For example, MeHg concentrations in carnivorous fish at the top of freshwater and salt-water food chains (e.g., pike, tuna and swordfish) are biomagnified in the order of 10,000-1000,000 times the concentrations found in ambient waters (Callahan et al. 1979, EPA 1980, 1984, ATSDR 1997).

The significance of this is that biomagnification of MeHg in aquatic food chains is considered the most important source of non-occupational human exposure to the element (EPA 1984, ATSDR 1997), and as mercury is highly toxic and persistent, anomalous environmental levels warrant concern. Mercury has no beneficial effects in humans, and there is no known homeostasis (i.e. maintained equilibrium between mercury entering the body and leaving for it. Any long-term exposure may therefore be expected to progressively cause severe disruptions in the normal functioning of any accumulating organ (Nriagu 1988). Accumulating organs include the kidneys, liver and central nervous system. Excessive exposure to metallic, inorganic or organic mercury can permanently damage these organs (ATSDR 1997).

Nickel

Nickel is a heavy metal. The most obvious anthropogenic source of nickel is scrap metal waste, notably alloyed metals including stainless steel. However it is also used in electroplating, ceramics, pigments, and as catalysts. Nickel is also used in alkaline (nickel-cadmium) batteries.

Nickel is considered an essential trace element at very low concentrations. It does bioaccumulate in aquatic systems, and as such elevations above normal concentrations can result in deleterious aquatic effects (ATSDR, 1997).

The most common adverse health effect of nickel in humans is an allergic reaction. People can become sensitive to nickel when jewelry or other things containing nickel are in direct contact with the skin. Once a person is sensitized to nickel, further contact with the metal will produce a reaction. The most common reaction is a skin rash at the site of contact. In some sensitized people dermatitis may develop at a site away from the site of contact.

The most serious effects of nickel, such as cancer of the lung and nasal sinus, have occurred in people who have breathed nickel dust while working in nickel refineries or in nickel processing plants. Other lung effects include chronic bronchitis and reduced lung function. The International Agency for Research on Cancer (IARC) has determined that some nickel compounds are carcinogenic to humans and that metallic nickel may possibly be carcinogenic to humans.

Nitrogen oxides (NOx)

Covers the gases nitric oxide (NO) and nitrogen dioxide (NO_2). Both can be toxic but nitrogen dioxide is considered to be of most concern for asthmatics. Nitrogen oxides are produced from the combustion of fossil fuels, that is coal and oil. The main source of the gases in urban areas are motor vehicle exhaust and gas cookers and kerosene heaters indoors. The brown haze sometimes seen over cities is mainly nitrogen oxides. These gases are also partly responsible for the generation of ozone, when acted upon by sunlight in the presence of other chemicals. Acid gases such as nitrogen dioxide can influence the pH of precipitation making it acidic. Over time, the falling of "acid rain" can have deleterious impacts on soil and water quality.

In terms of human health, exposure to very high levels of nitrogen dioxide can result in some changes in lung function of individuals with pre-existing respiratory disorder, but does not cause significant effects in normal individuals. It is not certain whether rises in the level of nitrogen dioxide in air lead to increased mortality or morbidity because it is difficult to discern the effects from impacts of other air pollutants. It is likely though that long-term exposures may have an impact on chronic effects of respiratory health (Ayres 1998).

PCBs - Polychlorinated biphenyls (PCBs) are organochlorines (substances based on carbon and chlorine). There are a group of 209 different PCBs, known as congeners. PCBs were manufactured until 1977 in the USA and until the mid-1980s in some countries, after which they were banned due to their toxicity and persistence in the environment. PCBs were widely used as coolants and lubricants in transformers, capacitors and other electrical equipment. Presently they are still found in old electrical equipment and releases into the environment continue from leakages at waste dumps. PCBs are also released into the environment from the burning of organic wastes in industrial and municipal waste incinerators. Accidental releases may occur from leakages or fires of transformers or other electrical equipment containing PCBs. Dioxins and furans (PCDD/Fs) are also generated in fires involving PCBs. There are no natural sources of PCBs in the environment (ATSDR 1997).

PCBs are very persistent in the environment and take years, even decades to degrade. In aquatic systems some may remain in the water but most becomes bound to particles and sediments. PCBs are fat-soluble and they build up (bioaccumulate) in the tissues of animals where they become stored in fat for many years. Predator animals at the top of food chains, such as fish-eating birds and birds of prey, toothed whales (including dolphins), otters, and humans have the highest levels in their bodies.

Due to their long distance transport on air currents, PCBs have become world-wide pollutants. For example, levels in some arctic species such as the polar bear are particularly high (Norheim et al. 1992, Norstrom et al. 1998).

The greatest intake of PCBs for the general population is from fatty food, such as meat, fish and dairy products. In mammals and humans, PCBs are passed via the placenta to developing young in the womb and via breast milk to new-borns. A woman may pass a substantial proportion of the PCBs stored in her body to her nursing infant (Lindstrom et al. 1994).

A wide range of adverse effects have been associated with exposure to PCBs in wildlife, including mass die-offs of seals and dolphins, large population declines of European otters, and adverse effects on reproduction and development of young in many species (Colborn et al. 1992, Allsopp et al. 1997 and 1999). PCBs cause toxic effects on the nervous system, immune system, reproductive system, and development in laboratory animals. PCBs are classified as probably carcinogenic to humans by the International Agency for Research on Cancer and as probable human carcinogens by the US Environmental Protection Agency. Accidental exposures to high levels of PCBs and dioxins/furans in food poisoning incidents in Japan and Taiwan caused serious health effects (ATSDR 1997). Studies indicate that current body levels in some women of the general population could be sufficient to cause subtle adverse effects on the nervous system and immune systems of their children. This is due to the transfer of these chemicals through the placenta to the developing foetus in the womb and/or through breast milk to the nursing infant (eg. Jacobson and Jacobson 1996 , Weisglas-Kuperus et al. 1998).

Petroleum hydrocarbons
Petroleum is a complex mixture of hydrocarbons that is formed from the partial decomposition of biogenic material, over geological time-scales. Petroleum hydrocarbons are released into the environment through natural seeps, non-point source urban runoffs, and by large quantities of accidentally released oil. Refined petroleum products principally contain the alkanes. It is often difficult to distinguish the origin of the hydrocarbons found in environmental samples. In cases of anthropogenic pollution, i.e. crude oil or petrol spills, alkanes are present together with monoaromatic hydrocarbons (benzenes) and polyaromatic hydrocarbons (naphthalene and others) (Overton 1994).

Phosgene (CCl_2O) - Phosgene is a widely used chemical that is manufactured for use in the production of various chemicals and to manufacture dyes, insecticides, pharmaceuticals and in metallurgy. In the past it was used as a chemical warfare agent. Exposure to phosgene may occur from direct industrial emissions and by combustion of chlorinated hydrocarbons, including VCM. Exposure to phosgene in the short-term and long-term causes severe respiratory effects.

Phthalates
The phthalate esters are a group of compounds which are used as additives in a variety of products. They are the most widely used softeners for PVC plastic (Bizzari et al. 1996). Due to their widespread usage they have been reported to be the most abundant man-made chemicals in the environment. They are moderately persistent in the environment and can bioaccumulate to some degree. The general population are exposed to phthalates from background contamination in air, food and water, but may also be exposed through direct contact with soft PVC products such as children's toys and teethers (Stringer et al. 1999). Studies on laboratory animals show that they cause a variety of toxic effects on health.

The majority of research on phthalates has been carried out on di(2-ethylhexyl)phthalate (DEHP), the most commonly used phthalate in PVC. It causes kidney changes and adverse effects on fertility and foetal development in laboratory animals. It is classified as possibly carcinogenic to humans by the International Agency for Research on Cancer. Recently, there has been concern about the ability of DEHP to interact with hormone receptors in animals. Research has suggested that atmospheric DEHP could have a role in childhood asthma (Oie et al. 1997). The phthalate ester di-butylphthalate (DBP) has toxic effects on the liver, kidneys and reproductive systems of laboratory animals, and may cause malformation of offspring.

Polycyclic Aromatic Hydrocarbons (PAHs)
PAHs are a group of compounds formed during the incomplete combustion of coal, oil, gas, wood, garbage or other organic substances. They are also found in coal and oil. More than 100 different PAHs are known. In most cases PAHs occur as a mixture of several compounds, not as a single chemical. In addition to PAHs formed during incomplete combustion, synthetic PAHs are produced mainly for research proposes. There are also several PAHs that are produced commercially to be used in industrial organic synthesis.

Once released into the aquatic environment, degradation by microorganisms if often slow, leading to their accumulation in exposed sediments, soils, aquatic and terrestrial plants, fish and invertebrates. PAHs can cause toxic effects to living organisms (Monson *et al.* 1995; Ankley *et al.* 1995), and toxicity of certain PAHs increases during exposure of aquatic organisms to sunlight (Arfsten *et al.* 1996; McConkey *et al.* 1997).

In terms of human health, the biggest concern about PAHs is carcinogenicity of certain representatives from this class of compounds. Individuals exposed for long period of time to mixtures of PAHs and other compounds by breathing or skin contact, have been found to develop cancer (ATSDR 1997).

PVC

Polyvinyl chloride (PVC) is a plastic that is used for many purposes. In the production of PVC, chlorine gas is used to make EDC, which in turn is used to make VCM. VCM is polymerised to make PVC. PVC on its own is brittle and of little use for making products; it is therefore always mixed with additives (Ehrig 1992). There are many additives used in PVC including phthalates (plasticisers), lead and cadmium compounds, chlorinated paraffins and organotin compounds (Matthews 1996). Almost every stage of the PVC lifecycle can create pollution problems, for example, environmental contamination with mercury, chlorinated solvents and dioxins. In terms of health, PVC dust can damage the lungs of workers (Lee et al 1989, Studnicka et al. 1995). A recent study showed that individuals who had worked with PVC had a greater chance of contracting testicular cancer, although further research is needed to confirm these findings (Hardell et al. 1997).

Sulphur dioxide (SO_2)

Sulphur dioxide is a gas that is produced from the combustion of fossil fuels, that is coal and oil, and from the production of sulphuric acid and roasting of sulphide ores. In terms of human health, there is evidence that sulphur dioxide has an effect on lung function, particularly in asthmatic individuals. Rises in levels of sulphur dioxide have been associated with increases in hospital admissions and in mortality. The increased deaths are evident in individuals who already have pre-existing disease, particularly respiratory disease (Ayres 1998).

Acid gases such as sulfur dioxide and nitrogen oxides can influence the pH of precipitation making it acidic. Over time, the falling of "acid rain" can have deleterious impacts on soil and water quality over wide geographical areas. A pulse of acid rain arising from a single pollution event would not normally be expected to cause widespread ecological problems in terms of adverse effects on soil or water quality. However, if falling in catchments where soils have particularly poor buffering capacity, such an event might be sufficient to have a detrimental effect on invertebrate larvae in rivers. Many insect larvae and other freshwater invertebrates are highly sensitive to pH and, if not killed directly by acid pulses, may nevertheless detach from the substrate and drift downstream in order to escape low pH environments. Some fish species, particularly salmonids, are also very sensitive to acid pulses and the associated changes in bioavailability of aluminium and other toxic trace metals. They may also be negatively impacted by the reduction in densities of the invertebrates on which they feed. Given that they are strongly linear environments recolonisation of the upper reaches of acid pulsed rivers can take several years even if no further acid events occur.

Tetrachloroethene (TCE)

Tetrachloroethene is used extensively as a solvent, most commonly in dry-cleaning and metal-degreasing operations. It is also used as a starting material in the production of other synthetic chemicals. Furthermore it is frequently found in PVC industry wastes (Johnston et al. 1994). Due to its volatility, the most common exposure comes from inhalation. Human exposure to high concentrations can cause dizziness, headaches, sleepiness, confusion, nausea, and possibly unconsciousness and death if exposed to high concentrations in a closed, poorly ventilated area. As expected, these symptoms have occurred almost entirely in the working environment. The long-term effects to humans exposed to lower level have not yet been fully identified (ATSDR 1997). The International Agency for Research on Cancer (IARC) has determined that tetrachloroethene is possibly carcinogenic to humans (ATSDR 1997).

Tetrachloromethane (carbon tetrachloride)
Tetrachloromethane is most commonly used as a solvent for oils, fats, varnishes, rubber, waxes and resins, and is the starting product in the manufacture of many organic compounds. It is often produced as an unintentional by-product of PVC manufacturing (Johnston et al. 1994). It is highly toxic, and acute exposure, via inhalation, ingestion or skin absorption can cause nausea, vomiting, diarrhea, headaches, renal damage and liver failure. Chronic exposure to lower concentrations over a longer period of time can result in permanent liver damage, along with kidney failure and visual impairments. Repeated skin contact can cause dermatitis (Merck 1989). The International Agency for Research on Cancer (IARC) has determined that carbon tetrachloride is possibly carcinogenic to humans (ATSDR 1997).

1,1,1-Trichloroethane
1,1,1-Trichloroethane is used as a solvent, for example, in paints and glues, in household cleaning agents and as a degreasing agent. It is a man-made chemical that is not found in nature. The manufacture of this chemical was scheduled to stop in the USA in 1996 because it affects the ozone layer. Spills, improper disposal, industrial emissions and consumer use can lead to large releases of this 1,1,1-trichloroethane into the environment. It is very persistent in the air and one study showed it has a half life of 200 to 300 days in groundwater. It is often present in higher levels in indoor air than outdoor air because of its use in consumer products, and it has been found in soil and in aquatic systems.

Breathing in high levels of .1,1,1-trichloroethane for a short time period can lead to dizziness, loss of coordination, nausea, vomiting and diarrhea. Exposure to higher levels can cause a decrease in blood pressure, unconsciousness and cause the heart to stop beating. Intentional inhalation (solvent abuse) of this chemical and accidental exposure to high levels has caused deaths from respiratory or cardiac arrhythmias. Effects of long term exposure to 1,1,1-trichloroethane are in humans are unclear, although adverse effects from exposure are not usually seen in workers. Studies on laboratory animals showed that inhalation for long periods caused adverse effects on development of young and application to the skin caused liver damage. Available information does not suggest that 1,1,1-trichloroethane cause cancer (ATSDR 1997).

Trichloroethene
Trichloroethene is most commonly used as a degreasing solvent (ATSDR 1997) and is widely produced as a by-product of PVC manufacturing (Johnston et al. 1994). In the past it was used as an anesthetic for surgery. Hence, as expected, people exposed to large amounts of trichloroethene can become dizzy or sleepy and may become unconscious. Death may occur from inhalation of large amounts. Animals that were exposed to moderate levels of trichloroethene had enlarged livers, and high-level exposure caused liver and kidney damage. However, it is not known whether these changes would occur in humans although research continues (ATSDR 1997).

Trichloromethane (Chloroform)
Trichloromethane is most commonly employed as a solvent. However it is often found as an unintentional by-product of the PVC production process (Johnston et al. 1994). In humans exposed to highly contaminated air or water, chloroform can affect the central nervous system, the liver and the kidneys. If smaller amounts are consumed over a long period of time, liver and kidney damage may still result (ATSDR 1997). Furthermore, studies in which humans were exposed to chloroform-contaminated drinking water showed a possible link

between the chloroform in chlorinated drinking water and the occurrence of cancer of the colon and bladder. Based on these studies, the U.S. Department of Health and Human Services has determined that chloroform may reasonably be anticipated to be a carcinogen. The International Agency for Research on Cancer (IARC) has determined that chloroform is possibly carcinogenic to humans.

Zinc

Zinc is a heavy metal. It is most often employed in electroplating, smelting and ore processing, however it is also present in acidic mine drainage, and effluents from the chemical industry (organic synthesis, textiles, pigment and paint, fertiliser, and PVC production). Compounds of zinc can also be used as fungicides and herbicides, e.g. simple inorganic compounds such as zinc chloride, zinc sulphate and zinc phosphide, as well as more complex organic compounds such as the Zn containing fungicides Metirem, Mancozeb, Zineb and Ziram (Agrochemicals Handbook 1987, USPHS 1997).

Environmental releases of zinc from anthropogenic sources far exceed the releases from natural sources (ATSDR 1997). Although zinc is not regarded as being especially toxic, it is sometimes released into the environment in appreciable quantities, and can thus have deleterious effects on certain species at specific concentrations. For example, effects on fertilisation and embryonic development have been observed in species of fish and harpacticoid copepods (Ojaveer et al. 1980, Verriopoulos and Hardouvelis 1988).

Although most of the studies relating to the human health effects of zinc concentrate on exposure via inhalation (which can cause a specific short-term disease called metal fume fever) less is known about the long term effects of ingesting too much zinc, through food, water or dietary supplements. It is an essential trace element, but ingestion of higher than recommended levels can have adverse effects on health. The recommended Dietary Allowances for zinc are 15 mg/day for men and 12 mg/day for women. If doses 10 –15 times higher than these recommendations are taken by mouth, even for a short time, stomach cramps, nausea and vomiting may occur (ATSDR 1997). Ingesting high levels for several months may cause anaemia, damage to the pancreas, and decreased levels of high-density lipoprotein (HDL) cholesterol (ATDSDR 1997).