CHAPTER 2

LITERATURE REVIEW

As the theme of this dissertation is mainly *water pollution*, it is thought a good idea to begin this literature review with 'water resources' so as to be able in due course to establish a working definition for *water pollution* which is in parallel alignment to the objectives of the present investigation.

2.1 Water Resources

Water and minerals are basic components of geology. If one consider minerals as the essential "nutrients" for modern industrial civilization, then, water is civilization's essential solvent. Water has been the vehicle for the extension of human settlement and development. Water can turn deserts into farmland by irrigation; can provide major transportation routes; can cool people, float boats, and carry off the garbage and sewage waste in densely populated areas. Water has even been used in energy production.

Throughout history, man has been able to increase water supplies by various technologies; both simple and complex. In other locations, man has been able to eliminate water by draining, damming to prevent flooding and reclaiming land near coastal shores. An example of land reclamation in Malaysia is at Tanjong Tokong in the state of Penang where now stands beautiful buildings and is a regular tourist attraction area. At Fukuoka City in Kyushu, Japan, strict geotechnical measures were observed so as to avoid any kind of environmental pollution during coastal reclamation works at the seaside area between 1982 to 1986 (Yamanouchi et al., 1994)

The effect to bring water to arid or semiarid regions have paved the way for settlements which eventually leads to business and industry - all of which are water dependent. Water shortages, like mineral shortages can be overcome only by increasing supply and/ or decreasing demand. In Malaysia, water rationing is practised to conserve water, apart from several other measures that will be mentioned in later sections.

It has been reported during the mid-eighties that there are 400 billion gallons (1520 billion - billion liters) of water above and in the earth but it is not evenly distributed. Water "deposits" occurs as rivers, lakes, streams and oceans. Water is also found in the soil as groundwater and is also bound up in glaciers. The rest of the water would be found in underground aquifer or in the soil. Only about 50% of this is within one mile of the soil surface and of this quantity only about 25% can be extracted with existing technologies. At any one time, only about 0.005% of every 100,000 gallons of water in the world supply is in motion as precipitation, running streams or atmospheric vapour (Kupchella and Hyland, 1986). The rest is stored underground in lakes , in glaciers or in the oceans. Water may be held or stored in the ground for thousands of years, in a lakes for a hundred years, or locked in a glacier for 40 or so years (Lonne, 1997). Eventually, stored water will find its way into the hydrogeological cycle again.

Precipitation obviously plays a vital role in recharging water supply. Precipitation replenishes or recharges reservoirs that have diminished through evaporation, runoffs into the oceans or through human withdrawals. When these factors exceed the rate of water recharge in a particular area for very long, the water supply in that area will be in jeopardy. For example, the water crisis in Malacca State Government request the Geological Department of Malaysia to study groundwater reserves in the state (Mohd Nazan Awang et al., 1992), a total of 13, 320 m^3 per day of potable water was found in several locations in the state of Malacca and this could be supplied to about 112, 750 people.

Water is used for many purposes throughout the world. These purposes can be broadly defined has domestic (cooking, cleaning, bathing) and industrial (manufacturing and cooling). Domestic water used may range from 76 - 270 liters per person per day for European countries to as low as five liters per person per day in some developing countries (Kupchella and Hyland, 1986).

2.2 Groundwater

Almost 13 to 20 times as much water is in the ground as is available on the surface. This water may be contained in the soil or in aquifers - areas underlain by impermeable rock (unconfined) or areas between two impermeable rock layers (confined or artesian), Figure 2.1. Current technologies can extract about one fourth of this water. Currently

22% of all fresh water used in the United States is supplied from groundwater. About 50% of the United States population relies on groundwater reservoirs which are recharged by rainfall (Walsh, 1980). However, with increasing demands on groundwater supplies, the risk increases of pumping more water than is recharged in any given time.

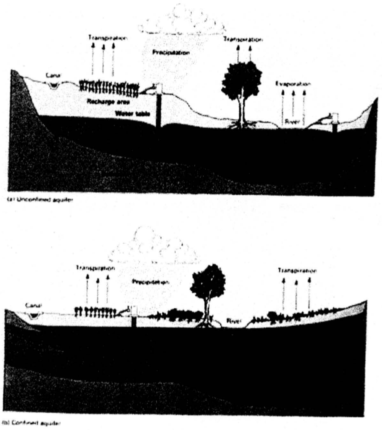

Fig.2.1 The hydrogeological cycle.

According to Mohd. Nazan Awang et al.,(1992), the average annual rainfall distribution received in Malacca is about 2, 000 mm. This is equivalent to 1.8 X 10^{10} m^3 per year or 4 X 10^{12} gallons per year. From this quantity, groundwater gets an additional of 10^9 m^3 per year. As an estimate, the water equilibrium in the state of Malacca can be divided accordingly into 66% evapotranspiration, 28% run-off water and 6% run-off groundwater (J.I.C.A., 1981).

Groundwater is being used on a considerable scale for public consumption in other states as well e.g. in Kelantan, Perlis, Trengganu, Pahang, Kedah, Sarawak and Sabah (Mohd. Nazan Awang and Mohamed. Hatta Abd. Karim, 1998). In Kelantan itself, groundwater supplies about 100, 000 m^3 per day to the people of Kota Bharu constituting about 70% of the state's water supply. In Sarawak, groundwater is the main source of water supply in coastal villages of Belawai, Igan, Oya and Kabong. In Sabah, groundwater is being used for public supply in Sandakan, Kota Belud and Kuala Penyu. In Labuan, groundwater is used in conjunction with surface water to supply the island's water requirements.

Although groundwater is easily exploited in alluvial areas (Lee, 1998), groundwater is also exploited from aquifers in hardrock. The most productive hard rock aquifer is the limestone aquifer and is found mainly in Kedah, Perlis, Perak, Selangor, Kelantan and Pahang (Mohd Nazan Awang and Mohamed Hatta Abd. Karim, 1998). Wells from this type of aquifer can produce up to 30 m^3/h of water. The water quality is high but has moderate to high total dissolved solids due to soluble bicarbonates. Other hard rock aquifers include sedimentary/metamorphic volcanic and plutonic igneous aquifers but the yield from these aquifers are lower. Umar Hamzah (1998), has applied seismic reflections at Pak Pura in Kelantan to study groundwater yield and quality.

When withdrawals exceed recharge, several things may happen. The water table drops. The water table is the upper surface of an unconfined aquifer. This may result in subsidence of the ground surface, that is, a lowering of the ground surface from the voids left because of reduced amount of groundwater. Subsidence permanently diminishes the size of the aquifer. As an example, consider Eloy, a town in Central Arizona, where land has subsided 10 feet in the last 30 years from groundwater (Kupchella and Hyland, 1986). As much as a 30 feet drop has occurred in area of south central California. Along with the subsidence in Arizona, large fissures 25 feet wide and 50 feet deep have been measured. Subsidence in the Houston area has caused structural damages and damage to sewers and other drainage systems. Lower water table are becoming more and more characteristic in western and southwestern dry states. In Florida which receives over 50 inches of rain per year, overuse of groundwater supply has resulted in lower water tables and has caused the intrusion of salt water into the water table, making the groundwater brackish. Saltwater intrusion can be a groundwater problem in any coastal area (Salim Said, 1997). On May 11, 1981, a sinkhole 37.5 meters deep and 120 meters wide appeared in Winter Park, Florida, swallowing a house, six cars, a camper van, and part of a swimming pool. The water level in the aquifer beneath the area had dropped and left the roofs of limestone caverns unsupported. The roof caved in resulting in the massive subsidence. In Malaysia, limestone areas are also found in Kuala Lumpur and several other states like Perak. Such tragedies in Florida and at the Highland Towers in Kuala Lumpur are the results of poor environmental management. Consequences of groundwater over-exploitation has been discussed at length during the World Water Day Seminar held at University Putra Malaysia, in March 1998 (Azuhan Muhammad, 1998; Salmah Zakaria and Zalilah Selamat, 1998). Issues concerning groundwater development (Hasman Ibrahim, 1998) calling for the Malaysian Government to implement and establish strategies for the full utilization of groundwater for the benefit of the country and its people as well as groundwater management have also been raised (Mohammud Che Hussain, 1998). The link between wetland and groundwater was also discussed by Ramakrishnan (1998).

Water resources of which groundwater is an example, has been taken to mean where water can be obtained and be put to a particular use. The next section deals with man's efforts to increase water supply so that water will continue to be available for the particular use it has been assigned to.

2.3 Increasing Water Supply

The most common method used for increasing water supply has been diverting water to where it is needed. Also, streams have been dammed to control water fluctuation, and groundwater supplies have been tapped by means of wells. In recent times, new methods have been tried or proposed for increasing the supply of fresh water, These inculude desalination of seawater, melting of glaciers, and seeding of clouds. Each of the ways of increasing supply carries with it some ecological and other implications.

2.3.1 Diversions

Man has often seen fit to base his technology on models found in nature. It is not surprising then that one of the major ways of redistributing water is through man-made diversion. Artificial steams have been constructed to take water to where it is wanted.

The western United States provides several examples of major diversion projects developed to carry water to the growing population centres in the Western states (Kupchella and Hyland, 1986). The California States Water Plan outlines a system of diversions from the Colorado River and other streams to the north. The Central Arizona Project is piping water 250 miles from the Colorado River to cities and land area of Central Arizona. The state of Pahang has proposed plans to divert water from Janda Baik to Batu Dam, in Selangor so as to ensure sufficient water supply in the state of Selangor (Utusan Malaysia 5th May 1998).

2.3.2 Damming

Another method for increasing water supplies in a given area is to impound water in dams. Dams have been around as long as the beaver and probably from the first time a tree fell across a stream, causing a pileup of debris and a backup of water. Human made dams are large-scale versions with controls for varying water level.

Dams serve human need in several ways. First, dams collect water, hold back the excess water during flooding, and release it gradually during low flow periods. This means that the flood plain below the dam is now available for farming and development with less chance of flooding. Second, the large pool of water in the reservoir provides a constant supply and continuos flow for human consumption, farm irrigation, and industrial uses. A dam may also generate electricity.

However, dams are usually associated with ecological problems. Damming produces a large pool area in the river or tributary. As the moving water enters the pool area, it slows down. This causes sediment to settle out. Eventually, silt buildup makes reservoirs practically nonfunctional because of the decrease in volume of the reservoir. Another ecological problem is that some plants and animals that flourish in streams are not adapted to and will not survive in reservoir impoundments. Lake flora and fauna will take over the niches. Furthermore, the land area flooded by the reservoir is no longer available for land uses; in some cases this has meant relocation of man as well as other inhabitants. The potential for new human inhabitants with different skills in the area served by the reservoir may well be increased, so a sort of "niche" exchange takes place as a dam is built. Such exchanges can have far-reaching negative as well as positive effects.

A classic example of the good news and the bad news about dams is the case of the Aswan Dam in Egypt (Balon, 1978). In 1960, construction was begun on the Aswan Dam, which was to turn the Sahara into a rich farming area. However, a number of major adverse side effects have become apparent since the dam's completion in 1970. Lake Nasser, the reservoir produced by the dam, is filling with silt at a faster rate than was expected causing problems with eutrophication. Before the dam was built, the nutrients and silt were deposited annually downstream in the Nile Delta. As this source of fertilizer for the Delta is now cut off, the productivity of the Delta area has decreased. The newly irrigated Sahara is also plagued with problems of increasing salinity. Another hazard that was overlooked relates to human health. Diseases involving mosquitoes that breed in standing water are on the rise.

2.3.3 Desalination

Almost 97% of the earth's water is salty. Because of the vast amount, it is only logical to consider the feasibility of utilizing salt water for human needs. Salt water can be used directly for power plant cooling along coasted area. However, it is too salty to be used for most industrial processes, agriculture, or drinking. Before sea water can be used for these purpose, the salt must be removed. This is known as desalination. In Saudi Arabia, sea water has been desalinated and used for washing and bathing. Such water can be quite warm to some people and its use in an already hot environment may pose a problem. The Selangor State Government has also looked into the possibility of desalinating salt water for domestic purposes.

2.3.4 Cloud Seeding

Another source of fresh water is the clouds. Cloud Seeding is used to cause rain. Chemicals are sprinkled into the clouds to serve as surface agents on which water vapour can condense.

How successful cloud seeding actually is has been difficult to verify scientifically. There is no formula for producing rainfall at will from cloud seeding. Investigations have been going on since the late 1940s and continue today. Cloud seeding poses interesting legal questions. Who owns the water in the clouds? If clouds are seeded, they may drop their water in Kota Bharu than in Kota Kinabalu. There is only a given amount of water in the condensation phase, if it is used in one place, it will simply not be available to users downwind. Cloud seeding is also practised in Malaysia especially in overcoming the haze problems that affected the whole country in 1997. Substances seeded into the clouds may be sodium chloride or calcium chloride (Encyclopaedia Britannica, 1994).

Clouds form when atmospheric moisture condenses on small particles in the atmosphere called condensation nuclei. Typically, a cloud is composed of tiny spheres of water that range in diameter from a few micrometres to a few tens of micrometres. The number of cloud droplets per cubic centimetre ranges from less than 100 to more than 1,000; 200 droplets per cubic centimetre is approximately an average value. An important characteristic of a cloud is its temperature. When it is above 0° C, the cloud is said to be warm. Often, clouds develop at altitudes where temperatures are below 0° C, but the droplets do not freeze because of the purity of the water. Such clouds are said to be supercooled. In the atmosphere, supercooling to temperatures of -10° C or even -20° C is not unusual. The lower the temperature, the greater the likelihood that the droplets will intercept so-called ice nuclei, which cause them to freeze. At temperatures below about -40° C, virtually all clouds are composed of ice crystals. Many all-liquid clouds, whether warm or supercooled, are stable in the sense that the droplets are limited in size to a few micrometres, and the clouds may last for some time without yielding rain or snow.

Sometimes nature is deficient in ice nuclei, and as a result supercooled clouds may persist for many hours. When this is the case, the addition of ice nuclei can upset the cloud stability by causing ice crystals to form; these can then grow and result in precipitation. The introduction of any substance into clouds for the purpose of changing them is called cloud seeding. Warm clouds (above 0° C) have been seeded with materials such as sodium chloride or calcium chloride particles or by a water spray. The objective of these procedures is to produce giant cloud droplets that will grow by coalescence, fall, and sweep out smaller cloud droplets. Fogs over airports have been seeded in order to reduce the density of the cloud and to improve the visibility and ceiling conditions. Warm convective clouds have been seeded in an effort to increase rainfall.

Aircraft have been used to dispense a water spray or salt particles. In some cases, salt-water sprays have been dispersed. Unfortunately, such solutions tend to be corrosive to aircraft surfaces and have to be handled carefully. In some programs sodium chloride particles in powdered form have been blown up from the ground. Most cloudmodification activities have been concerned with supercooled clouds and have involved seeding with ice nuclei. As noted above, the first substance found to be effective as a cloud-seeding agent was Dry Ice. Its temperature is so low (about -78° C) that it causes ice crystals to form spontaneously from water vapour. It has been estimated that a gram of Dry Ice will produce at least 3×10^{10} ice crystals. The most common procedure for seeding with Dry Ice is to fly over a cloud and disperse crushed pellets, less than a millimetre to a few millimetres in diameter, along the path of flight. A typical seeding rate might be several kilograms of Dry Ice per kilometre of flight.

Dry Ice is no longer widely employed as a cloud-seeding agent because it suffers from the disadvantage of having to be delivered to the supercooled regions of the cloud and from the fact that, once a pellet of Dry Ice has evaporated, it can no longer affect the cloud. Supercooled clouds are now most commonly seeded with tiny particles of silver iodide. There are many techniques for seeding with silver iodide. All of them produce large numbers of minute particles that range in diameter from about 0.01 to 0.1 micrometre. A common procedure is to dissolve silver iodide in a solution of sodium iodide in acetone. The concentration of silver iodide may range from 1 to 10 percent. When the solution is burned in a well-ventilated chamber at a temperature of about 1,100° C, a very large number of ice nuclei are produced. The concentration increases rapidly as the temperature decreases. A typical quantity at -10° C is 10^{13} ice nuclei per gram of silver iodide. Exposure to ultraviolet light causes rapid deactivation of the silver iodide nuclei. The concentrations of nuclei may decrease by perhaps a factor of 10 for each hour of exposure.

2.4 Water pollution

With the meaning that has been given to 'water resources', knowing an example of a water resource, knowing the uses of water and realising the need to increase water supply, a working definition for *water pollution* can now be established.

2.4.1 Definition

Basically, water pollution is any human action that impairs the use of water as a resource. Pollution is relative to the intended use of a water. Nearly pure water may be unsuitable for making liquor. Water of lesser quality may satisfactorily be used for drinking, recreation, fishing, navigation, or irrigation. The problem is that there is much water in the world that might be used for some purpose but that is not used because it is polluted.

Water pollution may be the black, lifeless, human and industrial drainage water of Sg. Pinang near Kampung Rawa in Penang, Malaysia. It is also the ammonium concentrated waters at Sg. Langat, Selangor which is the result of effluent discharge from septic ponds of Indah Water Konsortium. As for some foreign examples, it could also be the detergent-derived phosphate waters in Lake Erie, the asbestos fibres in Lake Superior, Minnesota, the mercury in the coastal waters of the harbours of Japan, and the heated water from the cooling towers of the large electric-generating plant in Pennsylvania. Water pollution is the pesticide-laden silt in the Missouri River and it is also on the beaches of Brittany, Texas, Chile, and Massachusestts (Kupchella and Hyland, 1986). Water pollution is a major environmental problem.

2.4.2 *Types of water pollutants*

Water can be polluted by biological agents, chemicals that enrich and overenrich (both organic and inorganic chemicals), chemicals toxins, physical agents (including heat and suspended solids), radioactive wastes, and salts.

2.4.2.1 Biological Agents

Many ancient civilizations had rules about water sanitation, implying that the relationship between human disease and water has been known for centuries. An outbreak of cholera that occurred in Kg. Kerinchi, Kuala Lumpur and also in the state of Johor in mid-1998 is due to contaminated water infected by the biological microorganism, Italic .
Epidemics of another waterborne disease, typhoid fever, have also occurred worldwide throughout recent centuries. Notable epidemics occurred in Pennsylvania in 1885, New York State in 1890, and Massachusetts in 1890. In each of these epidemics the disease was eventually determined to be spread by drinking water (Lund, 1978).

Near the end of the nineteenth century, after it was demonstrated that cholera could be prevented by water purification and sanitation - keeping *Vibrio cholerae* out of drinking water - there was an abrupt disappearance of cholera and other waterborne disease. In countries with less well developed public health programs and water purification systems, however, current rates are much higher; typhoid fever dysentery, cholera, and viral hepatitis continue to be serious problems.

In any case, the problem of waterborne disease can be simply and somewhat grossly stated as the contamination of humans' drinking water with humans' disease organism-bearing bodily waste. There is a long list of human pathogens (organisms that cause disease) that can remain viable in raw wastewater. Lund has listed four categories of such pathogens e.g. bacteria, protozoa, helminths and viruses, their agents and the disease(s) that they cause.

Microorganisms other than those found in human waste can be a problem. According to Nemerow (1978), this extends to microorganisms that make their way into water supplies as by-products of the processing of fruit and vegetables and as discharges from canneries and slaughterhouses. However, most of the bacterial contaminants that get into water from these sources are relatively harmless and, in fact, may help to degrade organic matter discharged along with the bacteria. Potentially pathogenic (disease-causing) microorganisms might also be transmitted from animals in this way. *Anthrax bacilli* or parasites originating from diseased animals in canneries and slaughterhouses, for example, can enter water supplies and infect animals and people downstream.

2.4.2.2 Energy-Rich Organic Chemicals

Certain chemicals in the right concentrations can distort and disrupt aquatic ecosystems by over-feeding certain components of such systems. Overfeeding (eutrophication) of aquatic ecosystems can occur in two basic ways via two kinds of chemical pollutants. One way is through the addition of inorganic nutrients that are normally limiting for plants. Another way, is through the addition of organic chemicals that serve as food for decomposers.

2.4.2.3 Biochemical Oxygen Demand

The addition of dissolved organic matter to an aquatic ecosystem gives a boost to the decomposers, organisms that use organic materials as sources of energy and nutrients. The problem comes when this activity increases to the point at which the decomposers use up all of the available oxygen as they oxidize organic matter.

The degree to which pollution by organic matter will remove oxygen from water depends on a number of factors, including the amount of oxygen in the water and the amount of water receiving the waste discharge. It would be better from the point of view of a stream community if organic matter were discharged into a very large, rapidly running, cool stream that is saturated with oxygen. Being cool helps in two ways; decomposition is slower and oxygen dissolves better in cool water. The degree to which oxygen dissolves will be depleted by sewage obviously also depends on how much sewage is discharged in a given time. The oxygen-depleting strength of organic matter is a rather precise parameter called biochemical oxygen demand (BOD).

BOD is a quantitative expression of the oxygen-depleting impact (via the action of decomposers) of a given amount of organic matter. It is an expression of how much oxygen is needed for microbes to oxidize that organic matter. (Organic matter will undergo chemical oxidation even in the absence of decomposers; there is also a straight chemical oxygen demand or COD.)

Large amounts of organic matter could also result in a near-absolute depletion of oxygen in a given body or stretch of water. This would clearly make life impossible for the species that need oxygen. Fish and zooplankton die under such circumstances, and even among the bacteria themselves there is a rise in anaerobic species - species that can live in the absence of oxygen. This in turn leads to the production of foul-smelling toxic end products of anaerobic respiration such as methane, hydrogen sulfide and ammonia.

Short of absolute oxygen depletion , the reduction of oxygen in water can still seriously disrupt natural systems. For most aquatic systems, dissolved oxygen should never be lower than 3 ppm at any time and should actually be above 5 ppm for the greater part of every day. Changes in species composition in aquatic ecosystems varies with average oxygen concentrations because different species can tolerate different oxygen limits. Trout require at least 5 ppm of oxygen, whereas certain scavenger fish like carp can survive in water having as little as 1 ppm (Kupchella and Hyland, 1986).

2.4.2.4 Inorganic Chemicals That Enrich

A second way in which aquatic ecosystems can be overenriched (and thus polluted) is through the addition of inorganic matter, for example, phosphates and nitrates. While these substances can be added to aquatic ecosystems indirectly in the form of phosphorus and nitrogen-containing organic pollutants, phophates and nitrates can also be added as pollutants directly. Some detergents contain large amounts of tripolyphosphates, and as much as 10-25% of the nitrate and phosphate fertilizer used in agriculture makes its way into water, contributing to eutrophication. Phosphate pollution (Murphy, 1973) is an especially serious problem because in many if not most parts of the world, this form of the element phosphorus is often the plant growth limiting nutrient in aquatic environments.

The addition of inorganic or organic matter as sewage can have a devastating effect on a pond or a lake. Although these materials tend to have the same kind of oxygen-consuming effect on river, the impact there can be quite variable. Rivers vary considerably in flow, and consequently they have different rates of reoxygenation, mixing, and sediment load, which limits sunlight penetration and consequently plant growth. These factors all determine the impact of agents that lead to overenrichment (eutrophicants).

What happens when water becomes polluted by overenrichment is not so much a complete wiping out of life forms, but rather it is a change in the forms of life and the qualities of water that are perceived to be detrimental and harmful. Sewage-polluted streams are often described by the uninitiated as devoid of life, dead, when in fact they may support much larger populations of living things than clear water. The problem is that they tend to support microscopic organisms to the exclusion of other "desirable" organisms in the aesthetic and economic sense. Biomass may stay the same or increase with eutrophication; species diversity is usually decreased significantly. Protozoans often exist in great numbers in sewage-polluted waters because food chains become shortened by the elimination of upper trophic levels.

Elevated metal concentrations occur in many aquatic ecosystems due to anthropogenic activities (Bervoets et al., 1997). It is often stated that aquatic sediments constitute the most important reservoir or sink of metals and other pollutants (Salomons and Forstner, 1984; Landrum, 1986; Lee, 1992; Adams et al., 1992; Van Hattum et al., 1993). Among the most common organisms of polluted water is the benthic invertebrates such as chironomids and tubificid worms. The presence of these benthic invertebrates in water is almost a certain indication that the water is polluted to some degree. These organisms are closely associated with surficial sediments. They burrow in the upper layer and feed on particulate matter. Trace metals e.g. Cu, Zn, Cd and Pb as observed by Bervoets et al.,(1997) can be taken up by these organisms and accumulated in the food chains (Burton, 1992). The worms are good sources of food for fish and other aquatic life and through these, they find their way into the food chains.

In retrospect, small amounts of either organic matter or certain inorganic chemical compounds can actually be beneficial to an aquatic ecosystem in the same way that fertilizers are beneficial in small amounts to gardens, wheat crops, and terrestrial ecosystem. The problems comes when too much is added too soon in too small a space, pushing the ecosystem beyond the point of resilience.

2.4.2.5 Chemical Poisons

Among the inorganic toxic chemicals found in water supplies are arsenic (which comes from many types of insecticides), cadmium (which comes from electroplating operations), chromate (from various kinds of industrial processes), cyanide, lead, selenium, and mercury. Others are copper, chromium, and zinc. These substances are toxic to fish and other aquatic organisms as well as to human beings because they interfere with the action of enzymes and other biochemicals. Metal toxicity problems are often compounded by the biological magnification of biometallic compounds (metal-organic complexes) in aquatic ecosystems (Lippman and Schlesinger, 1979). Embryo-larval stages of amphibians have also been found to be more sensitive than adults to metal toxicity, and exposure to Pb beginning at the egg stage often causes mortality or tetratogenesis in larvae (Stansley, 1997).

The Minimata Bay incident in Japan has become the classic example of the impact of water contamination by mercury (Kupchella and Hyland, 1986). During one period in the

1950s there were more than 50 deaths in the seacoast village of Minimata, more than three times that many cases of brain damage, and two dozen children born with neurological problems, all linked to the ingestion of mercury introduced into the food chain. The source of the mercury was effluent from a local factory. Nearly all of the victims, it was found, ate fish from the bay three times a day. Cats and other household pets also showed signs of mercury poisoning. This incident established mercury as a bona fide environmental problem and set off a mercury scare that eventually led people to avoid eating swordfish and tuna.

A lot of wastes are being constantly released into soils, rivers, oceans and atmosphere in Hong Kong due to industrialisation and urbanisation (Chen et al., 1997). Coal ash production from thermal power stations emit trace metals (Pacyna et al., 1992). A large amount of agrochemicals containing trace elements has been used repeatedly in agriculture. Dusts and roadside soils near motorways are polluted with lead from trafic vehicles (Lau, 1994; Tam et al., 1987; Wong 1985). Soils near a scrap plastic recycling factory were polluted with Cu, Ni and Mn (Chui et al., 1988) and market garden soils were polluted with Pb, Zn and Cd (Wong, 1996).

Spent lead shots can accumulate in large quantities in soils and sediments as a result of trap and skeet shooting and in some cases exceeding shot densities by several orders of magnitude (Roscoe et al., 1989 and Stansley et al., 1992). Under aerobic conditions, oxidised lead compounds form on the surface of spent shot and are subsequently released into the environment (Jorgensen and Williams, 1987). Elevated lead concentrations have been reported in small mammals at shooting ranges, along with increased kidney to body weight ratios, depressed haemoglobin content and intranuclear inclusion bodies in the renal proximal tubular epithelium (Ma, 1989, and Stansley and Roscoe, 1996). Elevated lead contents have also been reported in surface water at shooting ranges (Stansley et al., 1992) but there is little information about the biological consequences of such contamination.

The incorporation of mercury into an organic methyl (CH_3) compound by microorganisms in the sediment of lakes, river, and waters of other types is apparently the key to the transport of mercury in aquatic food chains leading to human beings. Because inorganic mercury is relatively insoluble in water, the organic variety is much more important. Its organic character makes it lipid-soluble and thus soluble in body tissues; it is therefore subject to biological magnification. Methyl mercury accumulates in organisms in aquatic environments according to their placement in the trophic level, the highest concentrations being found in top carnivores. The greatest effect of inorganic mercury compounds seems to be on the kidney and digestive organs; organic mercury compounds, on the order hand, affect neural tissue, principally the brain, and also cause digestive system problems and even birth defects. Kruuk et al., (1997) have also described rainfall and mercury content relationship in otters (Lutra lutra L.,) in the waters of Scotland.

Many types of organic toxins also get into water supplies as pollutants. Examples of these are pesticides such as DDT and chlordane, chemicals that are actually made to harm living things; hydrocarbons such as benzene that cause cancer; and a host of chemicals that cause genetic damage and birth defects. Certain organic chemicals - phenols, for instance - give an off-taste to water.

A particularly interesting class of organic water pollutants is the family of polychlorinated biphenyls (PCBs). PCBs are chlorinated compounds similar to DDT in their extreme stability. Because highly chlorinated PCBs are very stable and are usually present in only trace amounts, they are not a biochemical oxygen demand problem for aquatic ecosystems; they are extremely toxic, however. PCBs originate in a variety of manufacturing processes including the manufacture of brake linings, grinding wheels, glass, ceramics, various types of coatings, flame-proofing paint, varnishes, sealants, electrical equipment, tyres, plastic coatings, soap, and (ironically) water treatment chemicals, just to name a few (Nemerow, 1978). Because of their stability, PCBs that escape the manufacturing process or that escape from the products into which they have been incorporated make their way into aquatic ecosystems. The maximum PCB levels accepted by the authorities in fish to be eaten by human beings is just 2 ppm. Investigation of larger concentrations of PCBs causes death due to various physiological disturbances. Even until the mid-eighties the long-term effects of chronic ingestion of low levels of these compounds were not yet known (Kupchella and Hyland, 1986).

2.4.2.6 Heat

Water has a high heat capacity; that is, it is able to absorb large amounts of heat with relatively small increases in its own temperature while remaining liquid, making it an ideal cooling medium. For this reason, many industrial plants are located on rivers, where water is available to carry away waste heat. As heat-laden water is discharged back into the main water supply, it raises the temperature of the aquatic environment.

Heat affects the life found in water in several ways. First, every life form has a temperature tolerance range. At some point in the life cycle of every organism there is a most temperature-sensitive stage-hatching eggs (Stansley et al., 1997). All individual organisms have ranges of temperature within which they can survive and specific temperatures at which they function best. Changing water temperatures can therefore result in change in species composition. Waste heat can also adversely affect aquatic ecosystems by increasing temperature variability, keeping the natural system off balance. The most important direct effect of heat on organisms that do not have constant body temperature is the acceleration of metabolic reactions; the warmer it is, the faster the metabolic reactions. Because heat accelerates some kinds of reactions more than others, temperature changes tend to disrupt the chemistry of living things.

Heat also disrupts and changes the chemistry of the abiotic environment. Heat increases the solubility of certain chemicals and generally decreases the solubility of gases. Heat can actually affect the amount of oxygen and other gases dissolved in water in several ways. First, gases dissolve more readily in cold water than in warm water. Second, because higher temperatures accelerate metabolism, heat can accelerate decomposition, making BOD more of an immediate and acute problem while at the same time increasing the need for oxygen by fish and other organisms. A third way in which higher water temperatures can affect dissolved oxygen and other gases is in the stratification that can occur when hot water is discharged into a cooler body of water.

Temperature changes of only 2 or 3 degrees under certain circumstances can have a very serious effect on fish and aquatic life. Trout eggs, for example, take 165 days to hatch in cool water (3°C or 37°F) but will hatch in only a month if kept at 12°C (54°F). They will not hatch if temperatures reach 15°C (60°F). Since temperature is a major key to spawning and reproduction for many, increased heating can result in such important problems as the hatching of fish eggs out of synchrony with normal peaks in food supply for the hungry hatchlings (Malins, 1977). Another problem is that blue-green algae tend to do better in warmer water than other types of algae; population explosions in these types of algae are often accompanied by significant levels of the toxins they produce.

2.4.2.7 Floating Solids and Liquids

Oil, grease, and a number of other materials that float on the surface of water are another kind of pollutant. The effects of these substances can be aesthetic, of course, since they occur where they can be seen, but certain types of organic materials that float are also toxic. Some of the materials in oil, for example, are flammable, creating the kind of fire hazard that resulted in Cleveland's famous Cuyahoga River fire in 1969 (Kupchella and Hyland, 1986). Floating materials also decrease light penetration and can retard the diffusion of gases such as oxygen. Floating materials may also contribute to biochemical oxygen demand. If floating materials break up and become suspended in water, they can concentrate toxins (for example, oil droplets can accumulate fat-soluble toxins such as DDT) in water and deliver these to filter-feeding organisms such as clams and mussels.

2.4.2.8 Suspended or Sedimentary Solids

Among the things that affect water physically are undissolved solids, some of which dissolve over long periods of time and some of which practically never go into solution. Both types of solids decrease water quality in a physical way; silt and other types of insoluble materials clog waterways, fill up dams, and make water cloudy or muddy. Such solids can also be physical problems for gill breathers (fish) and filter feeders (such as clams). By adsorption and in other physical and chemical ways, suspended organic and mineral solids can also concentrate metals and other toxins and then deliver them to various organisms in the food chain. Pesticides can be concentrated in and on suspended solids, for example. Sediment, which gets into streams naturally through runoff, is also contributed by agriculture and industries like the china (clay) industry, construction, and steel.

2.4.2.9 Color

Some pollutants change the color of water. Perhaps the most outstanding example of this is the red and yellow colors in acid mine discharges derived from iron oxide and sulfate. Although these discharge are harmful because of the chemicals, which are only incidentally related to color, coloring agents are among the most objectionable types of pollutants as far as the public is concerned. People seem to be raised to indignation most by things they can see. The problem is that funding has a way of going to things that rasie public indignation, often before it goes to truly serious problems (Kupchella and Hyland, 1986).

2.4.2.10 Radioactive Substances

Radioactive materials make their way into water supplies from:

1. The processing of uranium ore,
2. The laundering of contaminated clothing from laboratories where radioisotopes are used,
3. Wastes from research laboratories,
4. Wastes from hospitals using isotopes in diagnostic and therapeutic procedures,
5. The processing of fuel elements from uranium ore,
6. Water from nuclear power plants, and
7. Fallout generated by nuclear weapons testing.

Low-level waste from hospital and other laboratories can get into water by leaching from what may have been thought to be secure low-level waste depositories, some is simply dumped illegally (Kupchella and Hyland, 1986).

2.4.2.11 Inorganic Salts, Acids and Alkalis

While some inorganic salts dissolved as ions cause overenrichment, others are chemical agents of hardness-calcium salts, for example. The hardness of water is the degree to which certain dissolved salts make it difficult to produce a soapy lather in that water. These salts are present naturally in water supplies, and they are present in high concentrations in certain types of wastes. They can also come out of solution under certain circumstances and become deposited within pipes and water-handling equipment, causing industrial maintenance problem. Agents of hardness also interfere with dyes in the textile industry and cause special problems in the beer-brewing industry. Still other inorganic salts in water pose human health problem. For example, magnesium sulfate, which cannot be absorbed from the digestive tract, has a cathartic effect, causing a chronic chemical type of diarrhea when it is present in significant amounts.

Acids and alkalis represent another kind of chemical pollution problem that has to do with ranges of tolerance for particular associations of living things in aquatic ecosystems. While only a few organisms can survive very high acidity and only a few can withstand very high alkalinity, the acidity of water supplies varies over a broad range; this has an effect on aquatic life and limits the uses of water by humans. Fish can tolerate a pH range from about 4.5 up to 9.5. Discharges from industrial sources have been known to range from as low as 2 to as high as 11 (Kupchella and Hyland, 1986). Acids are produced as a by-product of many kinds of industries including mining and those that contribute the starting materials for acid rain. Alkalis such as sodium hydroxide are produced as a by-product of soap manufacturing, textile manufacturing, and the tanning of leather.

Acids and alkalis influence the chemistry of organisms directly by influencing the shape and function of key cellular molecules. Indirect effects include changes in water chemistry via influences on solubility of abiotic chemicals.

2.5 Water pollution sources

*2.5.1 **Municipal Sewage***

A wastewater discharge inventory completed in 1975 by the National Academy of Science, USA (Kupchella and Hyland, 1986) indicated that municipal sewage constituted one of the largest sources of BOD and suspended solids. Municipal discharges can still be one of the major sources of water pollution. When there are heavy rains, the combined flow exceeds treatment plant capacity, and bypass mechanisms operate to allow the sewage to pass directly into the receiving stream without treatment.

2.5.2 Water Pollutants from Farms

Agricultural sources of pollution include the body wastes of farms animals, the runoff of organic fertilizers and pesticides, sediment, and salt. Fertilizers and animal wastes both contribute to eutrophication. The use of commercial fertilizers has grown considerably since the dawn of the modern age of chemistry in the early 1940s. Unheard of before World War II, nitrate fertilizers are now applied almost everywhere in the world. Such fertilizers are sometimes washed into water, where it contributes to eutrophication; some of it leaches into groundwater (Ableson, 1984), polluting wells.

2.5.3 Water Pollution from the Production of Coal

Coal production presents water pollution problems at two different stages. The first is during mining, and the second is in the processing of coal once it is mined. Acid mine wastes originate as water passes through mines and various iron compounds (particularly iron sulfide compounds) are oxidized. The agent of oxidation is the oxygen dissolved in water or in the air pumped through the coal mines. The acidification process is accelerated by chemosynthetic bacteria, microorganisms that oxidize inorganic chemicals (iron sulfides in this case) as chemical energy sources and use the energy in the same way that photosynthetic organisms use sunlight. The equation for the reaction is as follows

$$2FeS_2 + 7O_2 + 2H_2O \xrightarrow{\text{enzymes}} 2FeSO_4 + 2H_2SO_4 + \text{energy}$$

As can be seen from the equation, the active ingredients are sulfides of iron, oxygen, and water. Sulphate Iron (II) sulphate (Feso4) can be further oxidized to yield still more sulfuric acid (H_2SO_4). The overall effect of these reactions is the conversion of sulfur compounds into sulfuric acid, one of the most powerful acids known. The most important offending microorganism is the bacteria *Thiobacillus thiooxidans*. Coal mining can be thought of as the creation or expansion of habitat for this organism.

Although acid is the most important constituent in acid mine drainage, other chemicals are present in mine effluents as well, and composition varies considerably from one location to another. Acid drainage can also come from piles of waste removed from coal mines. Leachates coming from such gob piles can be very similar to the drainage that comes fom coal mines directly. Acid mine drainage presents a unique problem of control. Nemerow (1978) has given a number of methods for preventing the formation of acid mine water and neutralizing the acid in these waters. These strategies include.

1. using landscaping to control the amount of water that flows into mines;
2. sealing coal mines so that water cannot flow in or out;
3. flooding the mines with water and holding it there to keep oxygen out;
4. using lagoons to impound acid mine water, then feeding this into streams gradually in proportion to the amount of flow in the receiving stream;
5. using the acid mine water for washing coal (this, according to some proponents, neutralizes the acidity at the same time the coal is cleaned);
6. using limestone or lime to neutralize the acid;
7. covering strip mines with earth; and

8. disposing of waste rock from coal mines in layers sandwiched between layers of earth.

After coal is mined, it is usually brought to a coal-cleaning plant, where it is processed by first breaking it into small pieces and then washing out impurities. Many coal-cleaning operations produce significant amounts of sediment and suspended solids containing calcium, magnesium, sulfates, iron, and other minerals found in coal and shale (Nemerow, 1978).

2.5.4 Water Pollution from the Production, Transport, and Use of Oil

The problems of oil pollution of the ocean is not new. Conferences were held as early as 1926 on the pollution of navigable waters by oil, and another such conference was held at the League of Nations in 1935 (Kupchella and Hyland, 1986).

The history of oil pollution in most minds begins with the wreck of the Tarrey Canyon. This infamous tanker, a small one by today's standards, ran aground on what were supposed to have been well-charted rocks in broad daylight in 1967. The ship released over 100,000 metric tons of oil, most of which eventually washed ashore to pollute the beaches of southern England and northern France. There have been a host of similar incident involving larger ships since 1967.

While some of the chemicals in oil spills are very volatile, escaping into the atmosphere rapidly, other components are very stable and can remain in the aquatic environment for many years. Some of the latter effectively disappear via dipersion and emulsification (division into very fine droplets). Some is oxidized by sunlight, degraded by microorganisms and some deposited in ocean sediment.

On an evening in March 1978 the supertanker Amoco Cadiz lost its steering and ran aground near Portsall on the Brittany coast of France. Nearly a quarter of a million metric tons of oil were lost, contaminating 300 km of seacost. An accounting of the oil after the first few months showed that 13% was incorporated into the water column (water between the surface and the bottom) another 4.5^% graded quickly in the water; 8% ended up in tidal sediments; 28% washed into the intertidal zone; 30% evaporated; and a little more than 20% was not accounted for. After three years, little evidence of oil remained, although estuaries and marshes still had elevated hydrocarbon levels (Gundlach et al., 1983).

Much more of the oil pollution in the world's waters results from routine operations than from high-visibility accidents such as the blowouts (oil escaping under pressure from the bore hole into the water) in the North Sea and off Mexico and the breakup of tankers like the Torrey Canyon, the Amoco Cadiz, the Argo Merchant, and others (Atlas, 1978). Routine operations include a practice in which oil wastes mixed with seawater that had been taken on as ballast are dumped from oil tankers when the ships return to the sources of oil for refills. While technology is available for recovering oil from the ballast tanks, sometimes the crews of outmoded oil tankers ignore international law and simply dump this mixture of seawater and oil overboard as soon as they are out of danger of detection.

Two other sources of oil pollution are the occasional accident in offshore wells and inadvertent leakage from oil deposits through cracks developed in the ocean floor offshore as side effects of the drilling and capping processes. There is also a considerable amount of natural oil pollution in the ocean. When the oil washes ashore, there are obviously some immediate physical, aesthetic, and even toxic chemical effects.

A leaking offshore well pollute miles of beaches and have dramatic effects on shorebirds, coating their feathers with oil, preventing them from feeding or flying, and killing them. Apart from The Torrey Canyon, Amoco Cadiz and Argo Merchant oil spilling tragedies, the Gulf War which took place as a result of Iraqi invasion of Kuwait in 1991 is perhaps the latest such tragedies of sea water pollution and shorebirds contamination that had taken place. As yet, there is not much data (Kupchella and Hyland,1986) on the effect of oil pollution on human health. Oil pollution seems to have little long-range effect on fish, and there does not yet seem to be evidence for food chain magnification of the hydrocarbons in oil. Although many microscopic marine animals appear to take them up, the general fate of these hydrocarbons is to be rather quickly converted (photochemically and metabolically) to oxygenated metabolites (some of which may be more toxic than the parent compounds) and then to simple, harmless compounds.

Strategies for dealing with oil pollution once it has occurred have not been very effective. The failures include using detergents to disperse oil that can do more harm than the oil using absorbants like straw to hold the oil, creating a new disposal problem. Burning the oil is usually not very effective because flammable materials escape quickly and leave the more fire-resistant chemicals behind. Various new containment methods are being tried and tested, for example, deploying barriers that contain the oil so that it can be siphoned up, skimmed off, or recovered in some other way.

Some of the latest methods being considered include the use of microorganisms that can degrade oil. According to Atlas (1978), microorganisms can attack the hydrocarbons in petroleum at temperatures that range from less than 0°C to well above 60°C. He suggests that a combination of adding microorganisms and enhancing the environment for the action of microorganisms might be the best way to deal with oil spills once they have occurred. It is clear, however, that the best way to deal with this problem is to prevent it from happening in the first place. This can be done by better enforcement of regulations governing bilge pumping and tanker cleaning operations, better control of loading and unloading operations, maintenance and controls in the construction of supertankers, better training of tanker crews, and better training methods for managing offshore drilling rigs.

2.6 The pollution of Groundwater

Groundwater is also subject to pollution. Since a great deal of this water source is tapped for various uses (Ableson, 1984 and Rogers, 1983), groundwater pollution has important implications. The four most common pollutants of groundwater are chloride, nitrate, heavy metals, and hydrocarbons (Pye and Patrick, 1983). The groundwater contamination is especially difficult to solve because of the out-of-sight nature of the problem compared to solving contamination of surface water (Arrate et al., 1997). In the European alluvial valleys, agricultural activity combined with water recirculation have caused an increase in concentration of nitrogen compounds and pesticides in the groundwater (Gustafon, 1983; Andersen and Kristiansen, 1984; Bernhard et al., 1992). Wastes can in fact be effectively removed from groundwater by surface adsorption, dilution, mechanical filtration, precipitation following chemical interaction, buffering, chemical neutralisation, microbial degradation and plant uptake (Kupchella and Hyland, 1986).

This review has tried to show the importance of water in man's daily life and how one should realise the effects of water pollution to man himself in particular and to his surroundings in general.