ECOTOXICOLOGICAL STUDIES OF STREAMS, RIVERS, SOIL AND VEGETATION IN ABUJA MUNICIPAL AREA, FEDERAL CAPITAL TERRITORY.

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A THESIS SUBMITTED TO THE DEPARTMENT OF BIOLOGICAL SCIENCES (BIOCHEMISTRY UNIT), FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

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BY

HUSAINI .D. CHIROMA

M.TECH. BIOCHEMISTRY (TOXICOLOGY)

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CERTIFICATION

This project work titled "Ecotoxicological study of Abuja Municipal Area of the Federal Capital Territory" was carried out by HUSAINI D. CHIROMA (Reg. No.: M.Tech/SSSE/1999/2000/457) after having satisfactorily completed the requirements for course work. This research work was undertaken under my supervision and has been read, examined and found to meet the regulations governing the award of the degree of Masters of Technology in Biochemistry (with specialty in Toxicology) of the Federal University of Technology Minna, and is approved for its contribution to knowledge and literary presentation. The work reported is original and to the best of my knowledge has not been submitted either in part or in full for the award of any other degree or diploma of this or any other university.

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External Examiner

DEDICATION

Dedicated to God Almighty for sparing my life long enough to study His Creation –

THE ENVIRONMENT.

ACKNOWLEDGEMENT

To God Almighty for his faithfulness upon life and for the strength to study.

To My wonderful supervisor and mentor **Prof. T.A. Gbodi** for exposing me to the knowledge of Toxicology. Also for his patience and time in giving me guidance and godly counsel during this research work. God will reward you abundantly according to his riches in glory, Prof. God bless you, you are not just a supervisor, but a father.

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To my external examiner, though I don't know you; I will acknowledge you with the words of our fathers "Let sleeping Dogs lie". God bless you.

To others, be careful how you handle the environment.

ABSTRACT

The ecotoxicological profile of the municipal area of the Federal Capital Territory was investigated with a view to determine the water, soil and food contamination pattern in the city and to provide a basis for the need for regular monitoring programmes for the environment. Tap water, river, soil and food samples collected from the municipal were analysed for physico-chemical properties and for heavy and trace metals. The presence of macro-organisms (ants, insects, etc.) was noticed at all sampling sites, which is an indication of the biological integrity of water and soil. The pH range of water samples (6.1 – 6.9) is within the normal range and is capable of sustaining aquatic life. The pH range (5.4 – 6.5) of soil samples is within the range for a favourable agricultural activity. Data on conductivity, acidity and alkalinity indicate a significant ($p<0.05$) increase in all river samples from all the districts when compared with tap water samples; however, the differences obtained in salinity were not statistically significant ($p>0.05$). Increase in seepage of fluid and water from, organic matter sources into rivers during rainy season may explain the significant ($p<0.05$) increase in conductivity, acidity and alkalinity levels observed in river samples during the rainy season when compared to dry season. The range of conductivity in food samples for both dry and rainy season samples was 42-69μs. Data on suspended solids (SS), Total Dissolved Solids (TDS) and Total Hardness (TH) for all samples were presented. Low TDS obtained for all samples calls for a reinvestigation. All water samples analysed were considered soft. A significantly ($p<0.05$) high BOD levels were obtained in both dry and rainy season Wuse river. BOD in all river samples ranged from 14-29 for both dry and rainy season and is sufficient to sustain aquatic activity. With the exception of Wuse river, nitrate levels obtained for all the samples analysed fall below the WHO recommended maximum safe level for human consumption (45ppm). Significant ($p<0.05$) increase in the number of bacterial and fungal colonies was recorded in all rainy season soil samples when compared with dry season soil samples. Wuse soil samples had the highest level of bacterial and fungal colonies when compared to Garki and Maitama districts. There was an uneven distribution of all the heavy metals analysed in all the samples. The presence of Cd (with a high value of 0.017ppm) and that of Pb (1.923-4.316ppm) in samples analysed is noteworthy. The levels of other metals analysed were low and may not pose an immediate ecological danger. The ecotoxicological study of Abuja Municipal revealed the presence of pollutants in the environment even though at low levels; a regular monitoring programme need to be in place to check the pollution with increase population.

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CHAPTER ONE

1.0 INTRODUCTION / LITERATURE REVIEW

1.1 INTRODUCTION

Most developing countries face the enormous challenge of improving living standards against a backdrop of serious environmental and health problems. For instance, because streams and rivers have been considered a convenient means of clearing and carrying wastes away from the discharge points, most rivers in urban areas are highly loaded with urban and industrial wastes (Smith and Wohlaman, 1987; Garric *et al.*, 1993). According to the Pan American Health Organisation (PAHO), less than 10% of the municipalities in developing countries treat sewage adequately before emptying it into natural water sources, and waste treatment sewers for industrial effluents are often not working or nonexistent (Black, 1994).

Pollution prevention, recycling and chemical safety programmes are also scarce or entirely lacking. As a result of these practices, poor education and apathy, most developing nations pollute more fresh water on a per capita basis than Europe (Black, 1994). The untreated wastewater dumped into the rivers in many cases becomes part of the water source downstream.

Nigeria being an oil producing and developing country is faced with the problem of environmental degradation caused by oil pollution of the environment through accident blowouts, oil pipeline leaks, failure of storage tanks and effluents from refinery operations (Orisakwe *et al.*, 2001).

Abuja being the new Federal Capital Territory of Nigeria could be faced with serious emerging environmental problems. Increased population, which is always accompanied by increase in the generation of domestic, municipal and industrial wastes, is already emerging which if not checked, could pose an environmental hazard in the city. Other wastes, such as, agricultural wastes emanating from farm activities, air pollution from automobiles, water and soil contamination from different sources, also, interference with top soil integrity due to the various construction activities in the city, are of serious environmental concern; and most of them, pose a potential hazard to humans and to the ecosystem.

Presently, there is no documented evaluation available of the state of environment in Abuja Municipal, although the accompanying environmental problems characteristics of heavily populated cities are beginning to manifest. Water pollution and soil contamination particularly by hazardous substances could be an emerging problem in Abuja with important implications for public health and agriculture.

This study, therefore, attempts to establish the baseline contamination pattern of water, soil and some foodstuffs with the view of making appropriate useful recommendations to prevent or reduce the pollution level in Abuja municipal.

1.2 LITERATURE REVIEW

1.3 ENVIRONMENTAL POLLUTION

The environment, which is simply our immediate vicinity in the universe that we influence or influences man, can be classified into atmosphere, hydrosphere, lithosphere and biosphere (Kendal and Lacher, 1994). These various part of the earth crust are quite related, such that alteration in the normal constituent of one is reflected by changes in another. Humans and other living organisms are dependent on the environment for their survival. For example, man depends on the atmosphere for oxygen, hydrosphere for water and lithosphere for food. Hence, ecotoxicological hazards caused by waste or pollution on the environment can affect the environment and threaten the existence of living organisms in the world (Hoffman *et al.*, 1995).

Environmental pollution is the contamination of Earth's environment with materials that interfere with human health, the quality of life, or the natural functioning of ecosystems (living organisms and their physical surroundings). Although some environmental pollution is a result of natural causes such as volcanic eruptions, most is caused by human activities.

There are two main categories of polluting materials, or pollutants. Biodegradable pollutants are materials, such as sewage, that rapidly decompose by natural processes. These pollutants become a problem when added to the environment faster than they can decompose (see Sewage Disposal). Non-degradable pollutants are materials that either do not decompose or decompose slowly in the natural environment. Once contamination occurs, it is difficult or impossible to remove these pollutants from the environment.

Non-degradable compounds such as dichlorodiphenyltrichloroethane (DDT), dioxins, polychlorinated biphenyls (PCBs), and radioactive materials can reach dangerous levels of accumulation as they are passed up the food chain into the bodies of progressively larger animals. For example, molecules of toxic compounds may collect on the surface of aquatic plants without doing much damage to the plants. A small fish that grazes on these plants accumulates a high concentration of the toxin. Larger fish or other carnivores that eat the small fish will accumulate even greater, and possibly life-threatening, concentrations of the compound. This process is known as bioaccumulation.

Pollution of the environment, which can be in the form of liquid, solid or gases, is on the basis of their physical state. To characterise chemical behaviour, it is necessary to measure the chemical in different environmental compartments (e.g.; soil, water and biological systems) and to understand the movements and transportation of the chemical within and among these compartments (Tinsley, 1979).

Different types of wastes are generated by humans, which can pollute the environment at various levels as postulated by Kendell and Lacher, (1994). Domestic wastes generated from the household activities, which are many and include materials in various stages of decay; industrial wastes whose variety and volume depend on the type of industries and the level of industrialisation of the district; agricultural waste emanating from farm activities; chemical wastes usually in the form of acids, gases and heavy metals. All these contribute one way or the other to cause contamination of the environment. Some of these wastes pose a potential hazard to human health and microorganisms at large, because such wastes are usually non putrescible or non biodegradable, non combustible, lethal or persistent in nature, which can cause detrimental cumulative effect (Black, 1994).

Black, (1994) reported that over the last few decades, there has been an unprecedented rise in the production of wastes, which has lead to environmental pollution. Pollution occur when the environment is being defiled by any material, substance, chemical or organism that brings about any undesirable change in the physical and biological characteristics of air, water and soil due to addition to the environment, of material or energy in quantities and at rates which are harmful to living organisms (Connell and Miller, 1984; Hoffman *et al.*, 1995).

The pollution of the environment has many sources: air pollution which include particulate matter; monoxide, sulphur oxides, nitrogen oxides and lead from gasoline combustion and a myriad of other compounds considered under the category of hazardous air pollutants (Miller and Miller, 1993). Water pollution arise from a wide range of substances ranging from waste originating from humans to heavy metals washed by rain to the rivers. Soil pollutants such as plastics, tyres, demolition debris, solid waste from industries, leaks from oil pipe line, failure of storage tanks and effluents, seepage from agricultural activities or runoffs and urban runoffs; all these, contribute to the pollution of soil with hazardous environmental effects (Thibodeaux, 1979; Atkins, 1982). The mechanisms of operation of these pollutants as they affect living organisms are varied in their nature.

Wastewater from industries and other sources has adverse effects on water and environment. This is hazardous to public health and safety. Danger to public health as a result of environmental pollution may not only come from one source but many – sources. Plants that humans are dependent on for food are dependent on polluted soil and water for their growth and development. Many poisonous substances that pollute the environment are absorbed by plants from the contaminated soil and water, such that the consumption of these plant materials may be quite disastrous (Fytianos and Zarogiannis, 1999). Organic waste under the influence of bacterial action deplete the dissolved oxygen by consuming it in biochemical oxidation reaction, this may reduce the biochemical oxygen demand of the water concerned (Orisakwe *et al.*, 1999).

1.4 TYPES OF ENVIRONMENTAL POLLUTION

Pollution exists in many forms and affects many different aspects of Earth's environment. Point-source pollution comes from specific, localized, and identifiable sources, such as sewage pipelines or industrial smokestacks. Non-point-source pollution comes from dispersed or uncontained sources, such as contaminated water runoff from urban areas or automobile emissions (Engelking, 2004).

The effects of these pollutants may be immediate or delayed. Primary effects of pollution occur immediately after contamination occurs, such as the death of marine plants and wildlife after an oil spill at sea. Secondary effects may be delayed or may persist in the environment into the future, perhaps going unnoticed for many years. DDT, a non-degradable compound, seldom poisons birds immediately, but gradually accumulates in their bodies. Birds with high concentrations of this pesticide lay thin-shelled eggs that fail to hatch or produce deformed offspring. These secondary effects, publicized by Rachel Carson in her 1962 book, Silent Spring, threatened the survival of species such as the bald eagle and peregrine falcon, and aroused public concern over the hidden effects of non-degradable chemical compounds (Engelking, 2004).

1.4.1 Air Pollution

Smog is caused by industrial and automobile pollution. It is compounded by temperature inversions, which cause the air pollution to be kept in a particular area for extended periods. Continued exposure to smog can result in respiratory problems, eye irritation, and even death (Engelking, 2004).

Human contamination of Earth's atmosphere can take many forms and has existed since humans first began to use fire for agriculture, heating, and cooking. During the Industrial Revolution of the 18th and 19th centuries, however, air pollution became a major problem (Hart, 2004).

Urban air pollution is commonly known as smog. Smog is generally a smoky mixture of carbon monoxide and organic compounds from incomplete combustion (burning) of fossil fuels such as coal, and sulphur dioxide from impurities in the fuels. As the smog ages and reacts with oxygen, organic and sulphuric acids condense as droplets, increasing the haze. Smog developed into a major health hazard by the 20th century. In 1948, 19 people died and thousands were sickened by smog in the small U.S. steel-mill town of Donora, Pennsylvania. In 1952, about 4,000 Londoners died of its effects (Hart, 2004).

A second type of smog, photochemical smog, began reducing air quality over large cities like Los Angeles in the 1930s. This smog is caused by combustion in car, truck, and airplane engines, which produce nitrogen oxides and release hydrocarbons from unburned fuels. Sunlight causes the nitrogen oxides and hydrocarbons to combine and turn oxygen into ozone, a chemical agent that attacks rubber, injures plants, and irritates lungs. The hydrocarbons are oxidized into materials that condense and form a visible, pungent haze (Engelking, 2004).

Eventually most pollutants are washed out of the air by rain, snow, fog, or mist, but only after travelling large distances, sometimes across continents. As pollutants build up in the atmosphere, sulphur and nitrogen oxides are converted into acids that mix with rain. This acid rain falls in lakes and on forests, where it can lead to the death of fish and plants, and damage entire ecosystems. Eventually the contaminated lakes and forests may become lifeless. Regions that are downwind of heavily industrialized areas, such as Europe and the eastern United States and Canada, are the hardest hit by acid rain. Acid rain can also affect human health and man-made objects; it is slowly dissolving historic stone statues and building facades in London, Athens, and Rome (Hart, 2004).

One of the greatest challenges caused by air pollution is global warming, an increase in Earth's temperature due to the build-up of certain atmospheric gases such as carbon dioxide. With the heavy use of fossil fuels in the 20th century, atmospheric concentrations of carbon dioxide have risen dramatically. Carbon dioxide and other gases, known as greenhouse gases, reduce the escape of heat from the planet without blocking radiation coming from the Sun. Because of this greenhouse effect, average global temperatures are expected to rise 1.4 to 5.8 Celsius degrees (2.5 to 10.4 Fahrenheit degrees) by the year 2100. Although this trend appears to be a small change, the increase would make the Earth warmer than it has been in the last 125,000 years, possibly changing climate patterns, affecting crop production, disrupting wildlife distributions, and raising the sea level (Hart, 2004).

Air pollution can also damage the upper atmospheric region known as the stratosphere. Excessive production of chlorine-containing compounds such as chlorofluorocarbons (CFCs) (compounds formerly used in refrigerators, air conditioners, and in the manufacture of polystyrene products) has depleted the stratospheric ozone layer, creating a hole above Antarctica that lasts for several weeks each year. As a result, exposure to the Sun's harmful rays has damaged aquatic and terrestrial wildlife and threatens human health in high-latitude regions of the northern and southern hemispheres (Hart, 2004).

1.4.2 Water Pollution

The pollution of rivers and streams with chemical contaminants has become one of the most critical environmental problems of the 20th century. Waterborne chemical pollution entering rivers and streams comes from two major sources: point pollution and non-point pollution. Point pollution involves those pollution sources from which distinct chemicals can be identified, such as factories, refineries or outfall pipes. Non-point pollution involves pollution from sources that cannot be precisely identified; such as runoff from agricultural or mining operations or seepage from septic tanks or sewage drain fields. It is estimated that each year 10 million people die worldwide from drinking contaminated water (Hart, 2004).

The demand for fresh water rises continuously as the world's population grows. From 1940 to 1990 withdrawals of fresh water from rivers, lakes, reservoirs, and other sources increased fourfold. Of the water consumed in the United States in 1995, 39 percent was used for irrigation, 39 percent was used for electric power generation, and 12 percent was used for other utilities; industry and mining used 7 percent, and the rest was used for agricultural livestock and commercial purposes (Hart, 2004).

Sewage, industrial wastes, and agricultural chemicals such as fertilizers and pesticides are the main causes of water pollution. The U.S. Environmental Protection Agency (U.S. EPA, 2002) reports that about 37 percent of the country's lakes and estuaries, and 36 percent of its rivers, are too polluted for basic uses such as fishing or swimming during all or part of the year. In developing nations, more than 95 percent of urban sewage is discharged untreated into rivers and bays, creating a major human health hazard (Hart, 2004).

Water runoff, a non-point source of pollution, carries fertilizing chemicals such as phosphates and nitrates from agricultural fields and yards into lakes, streams, and rivers. These combine with the phosphates and nitrates from sewage to speed the growth of algae, a type of plant-like organism. The water body may then become choked with decaying algae, which severely depletes the oxygen supply. This process, called eutrophication can cause the death of fish and other aquatic life. Agricultural runoff may be to blame for the growth of a toxic form of algae called *Pfiesteria piscicida,* which was responsible for killing large amounts of fish in bodies of water from the Delaware Bay to the Gulf of Mexico in the late 1990s. Runoff also carries toxic pesticides and urban and industrial wastes into lakes and streams (Hart, 2004).

Chemicals used to kill unwanted animals and plants, for instance on farms or in suburban yards, may be collected by rainwater runoff and carried into streams, especially if these substances are applied too lavishly. Some of these chemicals are biodegradable and quickly decay into harmless or less harmful forms, while others are nonbiodegradable and remain dangerous for a long time.

Fertilizers and other nutrients used to promote plant growth on farms and in gardens may find their way into water. At first, these nutrients encourage the growth of plants and algae in water. However, when the plant matter and algae die and settle underwater, microorganisms decompose them. In the process of decomposition, these microorganisms consume oxygen that is dissolved in the water. Oxygen levels in the water may drop to such dangerously low levels that oxygen-dependent animals in the water, such as fish, die. This process of depleting oxygen to deadly levels is called eutrophication

When animals consume plants that have been treated with certain nonbiodegradable chemicals, such as chlordane and dichlorodiphenyltrichloroethane (DDT), these chemicals are absorbed into the tissues or organs of the animals. When other animals feed on these contaminated animals, the chemicals are passed up the food chain. With each step up the food chain, the concentration of the pollutant increases. In one study, DDT levels in ospreys (a family of fish-eating birds) were found to be 10 to 50 times higher than in the fish that they ate, 600 times the level in the plankton that the fish ate, and 10 million times higher than in the water. Animals at the top of food chains may, as a result of these chemical concentrations, suffer cancers, reproductive problems, and death.

Many drinking water supplies are contaminated with pesticides from widespread agricultural use. More than 14 million Americans drink water contaminated with pesticides, and the Environmental Protection Agency (EPA) estimates that 10 percent of wells contain pesticides. Nitrates, a pollutant often derived from fertilizer runoff, can cause methemoglobinemia in infants, a potentially lethal form of anaemia that is also called blue baby syndrome.

Heavy metals, such as copper, lead, mercury, and selenium, get into water from many sources, including industries, automobile exhaust, mines, and even natural soil. Like pesticides, heavy metals become more concentrated as animals feed on plants and are consumed in turn by other animals. When they reach high levels in the body, heavy metals can be immediately poisonous, or can result in long-term health problems similar to those caused by pesticides and herbicides. For example, cadmium in fertilizer derived from sewage sludge can be absorbed by crops. If these crops are eaten by humans in sufficient amounts, the metal can cause diarrhoea and, over time, liver and kidney damage. Lead can get into water from lead pipes and solder in older water systems; children exposed to lead in water can suffer mental retardation.

Erosion, the wearing away of topsoil by wind and rain, also contributes to water pollution. Soil and silt (a fine sediment) washed from logged hillsides, ploughed fields, or construction sites, can clog waterways and kill aquatic vegetation. Even small amounts of silt can eliminate desirable fish species. For example, when logging removes the protective plant cover from hillsides, rain may wash soil and silt into streams, covering the gravel beds that trout or salmon use for spawning (Hart, 2004).

The marine fisheries supported by ocean ecosystems are an essential source of protein, particularly for people in developing countries. Yet pollution in coastal bays, estuaries, and wetlands threatens fish stocks already depleted by over-fishing. In 1989, 260,000 barrels of oil was spilled from the oil tanker Exxon Valdez into Alaska's Prince William Sound, a pristine and rich fishing ground. In 1999 there were 8,539 reported spills in and around U.S. waters, involving 4.4 billion litres (1.2 billion gallons) of oil (Engelking, 2004).

1. 4.3 Soil Pollution

Engelking 2004, extensively reviewed issues on soil pollution as follows; Soil is a mixture of mineral, plant, and animal materials that forms during a long process that may take thousands of years. It is necessary for most plant growth and is essential for all agricultural production. Soil pollution is a build-up of toxic chemical compounds, salts, pathogens (disease-causing organisms), or radioactive materials that can affect plant and animal life.

Unhealthy soil management methods have seriously degraded soil quality, caused soil pollution, and enhanced erosion. Treating the soil with chemical fertilizers, pesticides, and fungicides interferes with the natural processes occurring within the soil and destroys useful organisms such as bacteria, fungi, and other microorganisms. For instance, strawberry farmers in California fumigate the soil with methyl bromide to destroy organisms that may harm young strawberry plants. This process indiscriminately kills even beneficial microorganisms and leaves the soil sterile and dependent upon fertilizer to support plant growth. This results in heavy fertilizer use and increases polluted runoff into lakes and streams (Engelking, 2004).

Improper irrigation practices in areas with poorly drained soil may result in salt deposits that inhibit plant growth and may lead to crop failure. In 2000 BC, the ancient Sumerian cities of the southern Tigris-Euphrates Valley in Mesopotamia depended on thriving agriculture. By 1500 BC, these cities had collapsed largely because of crop failure due to high soil salinity. The same soil pollution problem exists today in the Indus Valley in Pakistan, the Nile Valley in Egypt, and the Imperial Valley in California (Engelking, 2004).

1.4.4 Solid Waste

Components of Municipal Solid Waste A person living in an industrialized nation produces a great variety of solid waste, often a mix of potentially reusable or recyclable items (such as paper and yard waste) and largely non-recyclable material (such as food waste and many types of plastic). Of the municipal solid waste (the waste collected from residences and businesses) produced in the United States in 2000, about two-fifths of the paper, metal, and yard waste was recycled, and about one-quarter of the glass was recycled (Huang, 2004).

Solid wastes are unwanted solid materials such as garbage, paper, plastics and other synthetic materials, metals, and wood. Billions of tons of solid waste are thrown out annually. The United States alone produces about 200 million metric tons of municipal solid waste each year (see Solid Waste Disposal). A typical American generates an average of 2 kg (4 lb) of solid waste each day. Cities in economically developed countries produce far more solid waste per capita than those in developing countries. Moreover, waste from developed countries typically contains a high percentage of synthetic materials that take longer to decompose than the primarily biodegradable waste materials of developing countries (Huang, 2004).

Overflowing Landfill An average city dweller may produce a ton of refuse in a year, a volume that rapidly overflows local dumps. Cities running out of space for landfill often turn to incinerating their waste or transporting it to other areas, although up to 90 percent of the material might have been recycled (Huang, 2004).

Areas where wastes are buried, called landfills, are the cheapest and most common disposal method for solid wastes worldwide. But landfills quickly become overfilled and may contaminate air, soil, and water. Incineration, or burning, of waste reduces the volume of solid waste but produces dense ashen wastes (some of which become airborne) that often contain dangerous concentrations of hazardous materials such as heavy metals and toxic compounds. Composting, using natural biological processes to speed the decomposition of organic wastes, is an effective strategy for dealing with organic garbage and produces a material that can be used as a natural fertilizer. Recycling, extracting and reusing certain waste materials, has become an important part of municipal solid waste strategies in developed countries. According to the EPA, more than one-fourth of the municipal solid waste produced in the United States is now recycled or composted. Recycling also plays a significant, informal role in solid waste management for many Asian countries, such as India, where organized waste-pickers comb streets and dumps for items such as plastics, which they use or resell (Huang, 2004).

Expanding recycling programs worldwide can help reduce solid waste pollution, but the key to solving severe solid waste problems lies in reducing the amount of waste generated. Waste prevention, or source reduction, such as altering the way products are designed or manufactured to make them easier to reuse, reduces the high costs associated with environmental pollution (Huang, 2004).

1.4.5 **Hazardous Waste**

Hazardous wastes are solid, liquid, or gas wastes that may be deadly or harmful to people or the environment and tend to be persistent or non-degradable in nature. Such wastes include toxic chemicals and flammable or radioactive substances, including industrial wastes from chemical plants or nuclear reactors, agricultural wastes such as pesticides and fertilizers, medical wastes, and household hazardous wastes such as toxic paints and solvents (Engelking, 2004).

About 400 million metric tons of hazardous wastes are generated each year. The United States alone produces about 250 million metric tons—70 percent from the chemical industry. The use, storage, transportation, and disposal of these substances pose serious environmental and health risks. Even brief exposure to some of these materials can cause cancer, birth defects, nervous system disorders, and death. Large-scale releases of hazardous materials may cause thousands of deaths and contaminate air, water, and soil for many years. The world's worst nuclear reactor accident took place near Chernobyl', Ukraine, in 1986 (see Chernobyl' Accident). The accident killed at least 31 people, forced the evacuation and relocation of more than 200,000 more, and sent a plume of radioactive material into the atmosphere that contaminated areas as far away as Norway and the United Kingdom (Engelking, 2004).

Until the Minamata Bay contamination was discovered in Japan in the 1960s and 1970s, most hazardous wastes were legally dumped in solid waste landfills, buried, or dumped into lakes, rivers, and oceans. Legal regulations now restrict how such materials may be used or disposed, but such laws are difficult to enforce and often contested by industry. It is not uncommon for industrial firms in developed countries to pay poorer countries to accept shipments of solid and hazardous wastes, a practice that has become known as the waste trade. Moreover, cleaning up the careless dumping of the mid-20th century is costing billions of dollars and progressing very slowly, if at all. The United States has an estimated 217,000 hazardous waste dumps that need immediate action. Cleaning them up could take more than 30 years and cost $187 billion (Engelking, 2004).

Hazardous wastes of particular concern are the radioactive wastes from the nuclear power and weapons industries. To date there is no safe method for permanent disposal of old fuel elements from nuclear reactors. Most are kept in storage facilities at the original reactor sites where they were generated. With the end of the Cold War, nuclear warheads that are decommissioned, or no longer in use, also pose storage and disposal problems (Engelking, 2004).

1.4.6 Noise Pollution

Sound Intensities Sound intensities are measured in decibels (dB). For example, the intensity at the threshold of hearing is 0 dB, the intensity of whispering is typically about 10 dB, and the intensity of rustling leaves reaches almost 20 dB. Sound intensities are arranged on a logarithmic scale, which means that an increase of 10 dB corresponds to an increase in intensity by a factor of 10. Thus, rustling leaves are about 10 times louder than whispering (Engelking, 2004).

Unwanted sound, or noise, such as that produced by airplanes, traffic, or industrial machinery, is considered a form of pollution. Noise pollution is at its worst in densely populated areas. It can cause hearing loss, stress, high blood pressure, sleep loss, distraction, and lost productivity (Engelking, 2004).

Sounds are produced by objects that vibrate at a rate that the ear can detect. This rate is called frequency and is measured in hertz, or vibrations per second. Most humans can hear sounds between 20 and 20,000 hertz, while dogs can hear high-pitched sounds up to 50,000 hertz. While high-frequency sounds tend to be more hazardous and more annoying to hearing than low-frequency sounds, most noise pollution damage is related to the intensity of the sound, or the amount of energy it has. Measured in decibels, noise intensity can range from zero, the quietest sound the human ear can detect, to over 160 decibels. Conversation takes place at around 40 decibels, a subway train is about 80 decibels, and a rock concert is from 80 to 100 decibels. The intensity of a nearby jet taking off is about 110 decibels. The threshold for pain, tissue damage, and potential hearing loss in humans is 120 decibels. Long-lasting, high-intensity sounds are the most damaging to hearing and produce the most stress in humans (Engelking, 2004).

Solutions to noise pollution include adding insulation and sound-proofing to doors, walls, and ceilings; using ear protection, particularly in industrial working areas; planting vegetation to absorb and screen out noise pollution; and zoning urban areas to maintain a separation between residential areas and zones of excessive noise (Engelking, 2004).

1.5 IMPACTS OF POLLUTION

Air Pollution and Acid Rain Rainwater once was the purest form of water available but now is often contaminated by pollutants in the air. Acid rain is caused when industrial emissions mix with atmospheric moisture. Pollutants may be carried in clouds for long distances before falling, which mean that forests and lakes far away from factories may be damaged by acid rain. In the near vicinity of the factories, additional damage is caused by deposition, a kind of dry rain in which the larger pollutant particles fall to the ground. Air pollution has been increasing since the Industrial Revolution but only recently have side effects such as acid rain become severe and widespread enough to evoke international concern (Engelking, 2004).

Because humans are at the top of the food chain, they are particularly vulnerable to the effects of non-degradable pollutants. This was clearly illustrated in the 1950s and 1960s when residents living near Minamata Bay, Japan, developed nervous disorders, tremors, and paralysis in a mysterious epidemic. More than 400 people died before authorities discovered that a local industry had released mercury into Minamata Bay. This highly toxic element accumulated in the bodies of local fish and eventually in the bodies of people who consumed the fish. More recently research has revealed that many chemical pollutants, such as DDT and PCBs, mimic sex hormones and interfere with the human body's reproductive and developmental functions. These substances are known as endocrine disrupters (Engelking, 2004).

Pollution also has a dramatic effect on natural resources. Ecosystems such as forests, wetlands, coral reefs, and rivers perform many important services for Earth's environment. They enhance water and air quality, provide habitat for plants and animals, and provide food and medicines. Any or all of these ecosystem functions may be impaired or destroyed by pollution. Moreover, because of the complex relationships among the many types of organisms and ecosystems, environmental contamination may have far-reaching consequences that are not immediately obvious or that are difficult to predict. For instance, scientists can only speculate on some of the potential impacts of the depletion of the ozone layer, the protective layer in the atmosphere that shields Earth from the Sun's harmful ultraviolet rays (Engelking, 2004).

Another major effect of pollution is the tremendous cost of pollution cleanup and prevention. The global effort to control emissions of carbon dioxide, a gas produced from the combustion of fossil fuels such as coal or oil, or of other organic materials like wood, is one such example. The cost of maintaining annual national carbon dioxide emissions at 1990 levels is estimated to be 2 percent of the gross domestic product for developed countries. Expenditures to reduce pollution in the United States in 1993 totalled $109 billion: $105.4 billion on reduction, $1.9 billion on regulation, and $1.7 billion on research and development. Twenty-nine percent of the total cost went toward air pollution, 36 percent to water pollution, and 36 percent to solid waste management (Engelking, 2004).

In addition to its effects on the economy, health, and natural resources, pollution has social implications. Research has shown that low-income populations and minorities do not receive the same protection from environmental contamination, as do higher-income communities. Toxic waste incinerators, chemical plants, and solid waste dumps are often located in low-income communities because of a lack of organized, informed community involvement in municipal decision-making processes (Engelking, 2004).

1.6 Behaviour of Environmental Chemicals

The study of the behaviour of chemicals in the environment is no trivial matter (Tinsley, 1979). To characterise chemical behaviour, it is necessary to measure the chemical in different environmental compartments (soil, water, biological systems) and to understand the movement and transportation of the chemical within and among these compartments. During the past half-century, intensive effort has been directed towards developing analytical techniques to detect and quantify minute concentrations of chemicals in environmental matrices (Murray, 1993; Blaser *et al.*, 1995).

Understanding chemical movement in the environment is necessary to ultimately characterise chemical concentrations as speciation in different environmental compartments. A likely scenario for a chemical released into the environment has been postulated as follows: a chemical is released into one environmental compartment; it is partitioned among environmental compartments; it is involved in movement and reactions within each compartment; it is partitioned between each compartment and the biota that reside in that compartment; it reaches an active site in an organism at a high enough concentration for long enough to induce an effect (Thibodeaux, 1979; Mackay, 1991).

Chemical transport in and among environmental matrices, and the persistence of chemical in the environment, are complex interdisciplinary subjects (Thibodeaux, 1979). Once a man-made chemical enters the environment, it is acted upon primarily by natural forces. Models are used to predict the effects of natural forces on the movement of chemical in the environment. This requires the incorporation of abiotic variables into valid models. These variables include temperature, wind and water flow directions and velocities, incident solar radiation, atmospheric pressure and humidity and the concentration of the chemical in one of four matrices. These matrices are those that have mobile phases – atmosphere (air) and hydrosphere (water) – and those that contain stationary phases – lithosphere (soil) and biosphere organisms. Chemical transport in the environment is thus divided into intraphase and interphase movements (Atkins, 1982). Concentration gradients result in movement within the medium. Contaminant persistence is a function of the stability of that chemical in a phase and its transport within that phase. Howard *et al.*, (1991) reported that stability of a chemical in the environment is a function of the physiochemical properties of that particular chemical and the kinetics of its degradation in the phase; these vary widely in and between classes of chemicals.

The primary routes of entry of contaminants into the atmosphere are through evaporation and stack emissions. Significant amounts of contaminant enter the atmosphere through transport from other matrices. Contaminant transport in air is similar to that in the hydrosphere but generally occurs much more rapidly, as air has lower viscosity. Contaminant transport in air occurs primarily by diffusional process or advection. The contaminant diffusivity in air depends on its molecular weight compared to air, air temperature, the molecular separation at collision, the energy, and molecular interaction (Atkins, 1982). Wind currents transport air borne contaminants much more rapidly than does diffusion (Wark and Warner, 1981).

Contaminants enter the hydrosphere by direct application, spills, wet and dry deposition, and interphase movement. In addition, chemicals enter the hydrosphere by direct dissolution of lighter-than-water spills in the form of slicks or from pools on the bottom of channels, rivers, or other waterways. Chemical movement in the hydrosphere occurs through diffusion, dispersion, and bulk flow of the water.

Willard *et al.*, (1988) reported that chemicals enter the lithosphere by processes similar to those for the hydrosphere. Soils have varying porosities, but pores are invariably filled with either gas or fluids. Chemical movement in the soil occurs by diffusion in these fluids or by the movement of water through the voids between soil particles. The direction of diffusion will be from areas of high to areas of low concentration. The chemical diffusion rate in soil depends on molecular weight, soil temperature, the length of the path, and the magnitude of the concentration gradient among other issues. Contaminants leave the soil by interphase transport or decomposition (Shounard *et al.*, 1993).

A chemical, once released, can enter any of the four matrices: the atmosphere by evaporation, the lithosphere by adsorption, the hydrosphere by dissolution, or the biosphere by absorption, inhalation or ingestion (depending on the species). Once in a matrice, the contaminant can enter another matrix by interphase transport (Mackay, 1991).

Chemical bioavailability in various environmental compartments ultimately dictates toxicity. Important considerations include oxidation state, whether organic or inorganic, as well as physical and chemical characteristics e.g.; acid concentrations, pH, conductivity, salinity, alkalinity, dissolved solids, chemical oxygen demands etc. Considerations of the above are taken into account as markers of environmental pollution (Tinsley, 1979).

Traditionally, environmental risk has been assessed by chemical residue determination in samples of the environment from affected sites. This approach, although it yielded useful information, has several limitations. First, the determination of chemical residues in environmental matrices is not simple and may require extensive sample cleanup (U.S. EPA, 1986b). Moreover, the cost per sample may be high for certain classes of chemicals. Secondly, the availability of the chemicals from the environmental matrix to the biological receptor (bioavailability) cannot be quantified by this approach. To overcome this problem, chemical analysis of tissues from the biological receptor may be performed (Agency for Toxic Substances and Disease Registry, ATSDR, 1994). However, this approach is often more difficult and more expensive than the cost of the analysis of environmental matrices. In addition, the toxicokinetics and toxicodynamics of a contaminant in a particular species determine whether an exposure is capable of an adverse response. A biomarker – based approach resolves many of these difficulties by providing a direct measure of toxicant effects in the affected species (Dickerson *et al.*, 1994). A biomarker or biological marker is a chemically induced alteration in cellular or biochemical components or processes, structures, or functions that is measurable in a biological system or sample. Therefore, biomarkers can be broadly categorised as markers of exposure and effects (ATSDR, 1994; Henderson *et al.*, 1989).

1.7 Toxicity Profile of Environmental Pollutants

Metals differ from other toxic substances in that they are neither created nor destroyed by humans. Nevertheless, their utilisation by humans influences the potential for health effects in at least two major ways: first, by environmental transportation, that is by human or anthropogenic contributions to air, water, soil, and food, and second, by altering the speciation or biochemical form of the element (Beijer and Jernelov, 1986).

Metals are probably the oldest toxins known to humans. Lead usage may have begun prior to 2000 B.C. when abundant supplies were obtained from ores as a by-product of smelting silver. Hippocrates is credited in 370 B.C. with the first description of abdominal colic in a man who extracted metals. Arsenic and mercury are cited by Theophrastus of Erebus (370 – 287 B.C.) and Pliny the Elder (A.D. 23 – 79). Arsenic was obtained during the melting of copper and tin, and an early use was for decoration in Egyptian tombs. In contrast, many of the metals of toxicologic concern today are only recently known to humans. Cadmium was first recognised in ores containing zinc carbonate in 1817(Goyer, 1984).

Metals are redistributed naturally in the environment by both geologic and biologic activities. Rainwater dissolves rocks and ores and physically transports material to streams and rivers, depositing and stripping materials from adjacent soil, and eventually transporting these substances to the ocean to be precipitated as sediment or taken up in rainwater to be relocated elsewhere on earth. The biological cycles include bioconcentration by plants and animals and incorporation into food cycles. These natural cycles may exceed the anthropogenic activity, as is the case for mercury. Human industrial activity, however, may greatly shorten the residence time of metals in ore, may form new compounds, and may greatly enhance worldwide distribution. The role of human activity in the redistribution of metals is demonstrated by the 200-fold increase in lead content of Greenland ice beginning with a "natural" low level (about 800. B.C.) and a gradual rise in lead content of ice through the evolution of the industrial age, followed by a rise in lead corresponding to the period when lead was added to gasoline in the 1920s (Ng and Patterson, 1981). Metal contamination of the environment therefore reflects both natural sources and a contribution from industrial activity (Goyer, 1984).

1.7.1 Cadmium

Cadmium is a toxic metal. It was only discovered as an element in 1817. Cadmium is a soft, silver – white metal, often found in association with zinc and obtained primarily as a by-product of zinc preparation (Belilies, 1994). It is primarily used in the production of nickel – cadmium batteries, but also for metal plating, pigments, plastics and synthetics, and other miscellaneous uses (ATSDR, 1993). Cadmium may be electrolytically deposited as a coating on metals, chiefly iron or steel, on which it forms a chemically resistant coating. Cadmium lowers the melting point of metals with which it is alloyed; it is used with lead, tin, and bismuth in the manufacture of fusible metals for automatic sprinkler systems, fire alarms, and electric fuses. An alloy of cadmium with lead and zinc is used as a solder for iron. Cadmium salts are used in photography and in the manufacture of fireworks, rubber, fluorescent paints, glass, and porcelain. Cadmium has been used as a control or shielding material in atomic energy plants because of its high absorption of low-energy neutrons. Cadmium sulphide is employed in a type of photovoltaic cell (see Solar Energy), and nickel-cadmium batteries are in common use for specialized purposes

The toxicity of cadmium has been widely investigated, and cadmium has been shown to affect nearly every organ system if the dose is high enough (Beton *et al.*, 1966; Friberg *et al.*, 1986; WHO, 1992).

Friberg and Lerner, (1986) stated that airborne cadmium in the present-day workplace environment is generally 0.05μg/m^3 or less. Air from uncontaminated areas contains less than 0.1μg/m^3. Meat, fish, and fruit contain 1 to 50μg/kg, grain contains 10-150μg/kg and the greatest concentrations are in the liver and kidney of animals. Shellfish, such as mussels, scallops, and oysters, may be a major source of dietary cadmium and contain 100- 1000μg/kg. Shellfish accumulate cadmium from the water and then bind to cadmium – binding peptides. Total daily intake from food, water and air in North America and Europe varies considerably but is estimated to be about 10 to 40μg per day (Friberg and Lerner, 1986).

Cadmium is more readily taken up by plants than other metals, such as lead. Factors contributing to cadmium's presence in soil are fallout from the air, cadmium-containing water used for irrigation, and cadmium added to fertilizers. Commercial phosphate fertilizers usually contains less than 20mg/kg. Another source of concern about potential sources of cadmium toxicity is the use of commercial sludge to fertilize agricultural fields. Commercial sludge may contain up to 1500mg of cadmium per kilogram of dry material (Anderson and Hahlin, 1981).

Respiratory absorption of cadmium is about 15 to 30 percent (WHO, 1992). Workplace exposure to cadmium fumes or airborne cadmium is the major source of respitory disease caused by cadmium. Most airborne cadmium is respirable. A major non-occupational source of respirable cadmium is cigarettes. One cigarette contains 1 to 2μg cadmium and 100% of the cadmium is inhaled (0.1 to 0.2μg). Smoking more packs of cigarette a day may double the daily absorbed burden to cadmium (Blanc and Boushey, 1993).

Gastrointestinal absorption of cadmium is less than respiratory absorption and is about 5 to 8 percent. Absorption is enhanced by dietary deficiencies of calcium and iron and by diets low in protein (Flanagan *et al.*, 1978; Friberg, 1984). Cadmium is transported in blood by binding to red blood cells and large molecular weight proteins in plasma, particularly albumin. Blood cadmium level in adults without excessive exposure is usually less than 1μg/dl. Human breast milk and cow's milk are low in cadmium, with less than 1μg/kg of milk (Friberg *et al.*, 1986). About 50 to 57 percent of the body burden of cadmium is in the liver and kidneys; its half-life in the body is not known exactly, but it is many years and may be as long as 30 years (Friberg *et al.*, 1986). Because of the potential for accumulation in the kidneys, there is considerable concern about the levels of dietary cadmium intake for the general population. Studies from Sweden have shown a slow but steady increase in the cadmium content of vegetables over the years (Friberg *et al.*, 1986). The increase in body burden has been determined from an historic autopsy study (Friberg *et al.*, 1986).

Acute toxicity may result from the ingestion of relatively high concentration of cadmium, as may occur in contaminated beverages or food. Norberg (1972) relates an instance in which nausea, vomiting, and abdominal pain occurred from consumption of drinks containing approximately 16mg per litre of cadmium, recovery was rapid without apparent long-term effects. Inhalation of cadmium fumes or other heated cadmium containing materials may produce an acute chemical pneumonitis and pulmonary oedema. The principal long-term effects of low-level exposure to cadmium are chronic obstructive pulmonary disease and emphysema and chronic renal tubular disease. There may also be effects on the cardiovascular and skeletal systems (Friberg *et al.*, 1986). Toxicity to the respiratory system is proportional to the time and level of exposure. Obstructive lung disease results from chronic bronchitis, progressive fibrosis of the lower airways, and accompanying alveola damage leading to emphysema (Lauwerys *et al.*, 1979).

Cadmium affects proximal renal tubular function and is manifested by increased cadmium in the urine, proteinuria, aminoaciduria, glucosuria, and decreased renal tubular reasbsorption of phosphate. Renal toxicity of cadmium has been extensively reviewed (Skerfving *et al.*, 1987; Ellis *et al.*, 1984; WHO, 1992; Roels *et al.*, 1989; Kido *et al.*, 1988; Ellis, 1985; Wang *et al.*, 1993; Chan *et al.*, 1993; Dorian *et al.*, 1995; Thun *et el.*, 1989; Nogawa *et el.*, 1989).

1.7.2 Lead

If we were to judge of the interest excited by any medical subject by the number of writings to which it has given birth, we could not but regard the poisoning by lead as the most important to be known of all those that have been treated of, up to the present time. Lead is the most ubiquitous toxic metal and is detectable in practically all phases of the inert environment and in all biological systems. Because it is toxic to most living things at high exposures and there is no demonstrated biological need for it, the major issue regarding lead is determining the dose at which it becomes toxic. Specific concerns vary with the age and circumstances of the host, and the major risk is toxicity to the nervous system. The most susceptible populations are children, particularly toddlers, infants in the neonatal period, and the foetus. Several reviews and multi-authored books on the toxicology of lead are available (Goyer and Rhyne, 1973; Mahaffey, 1985; EPA, 1986, 1989a; Goyer, 1993; NRC, 1993; ATSDR, 1993).

Lead is a heavy, bluish-grey metal and, although it serves no biological purpose, is the most widely used non-ferrous metal (Fischbein, 1992; ATSDR, 1993). Lead and/or lead compounds have been used in many industrial applications, including batteries, ammunition, paints and vanishes, gasoline, pigments, radiation shields, medical equipment, solder, glass, and ceramic glazes (ATSDR, 1993).

The principal routes of exposure for people in the general population are ingestion and inhalation. Sources that produce excess exposure and toxic effects are usually environmental and presumably controllable. These sources as reported by Hipkins *et al.*, (1998) include lead-based indoor paint in old dwellings, lead in dust from environmental sources, lead in contaminated drinking water, lead in air from combustion of lead-containing industrial emissions, hand-to-mouth activities of young children living in polluted environments, lead-glazed pottery and, less commonly, lead dust brought home by industrial workers on their clothes and shoes.

Lead is used in enormous quantities in storage batteries and in sheathing electric cables. Large quantities are used in industry for lining pipes, tanks, and X-ray apparatus. Because of its high density and nuclear properties, lead is used extensively as protective shielding for radioactive material. Among numerous alloys containing a high percentage of lead are solder, type metal, and various bearing metals. A considerable amount of lead is consumed in the form of its compounds, particularly in paints and pigments.

EPA 1986, reported that dietary intake of lead has decreased since the 1940s when estimates of intake were 400 – 500μg per day for U.S. populations to present levels of under 20μg per day. One factor reducing the lead content of food has been a reduction in the use of lead – soldered cans for food and beverages (EPA, 1986).

Most municipal water supplies measured at the tap contain less than 0.05μg/ml, so that daily intake from water is usually about 10μg, and it is unlikely to be more than 20μg. Corrosive water (pH 6.4) will leach lead from soldered joints and lead containing brass fittings (NRC, 1993).

Adults absorb 5 to 15 percent of ingested lead and usually retain less than 5 percent of what is absorbed. Children are known to have a greater absorption of lead than adults (Caprio *et al.,* 1974; Lanphear *et al.,* 1998; Hayes *et al.,* 1994). Concentrations of lead in air vary due to point source emissions but are usually less than 1.0ug/m3. Since the introduction of lead-free gasoline in the U.S., airborne lead is only a minor component of total daily leads exposure (EPA, 1986). Lead in the atmosphere exists either in solid forms, dust or particulates of lead dioxide, or in the form of vapours. Lead absorption by the lungs also depends on a number of factors in addition to concentration. These include volume of air respired per day, whether the lead is in particle or vapour form, and size distribution of lead-containing particles. Absorption of retained lead through alveoli is relatively efficient and complete (Hipkins *et al.*, 1998; Fishbein, 1992). More than 90 percent of the lead in blood is in red blood cells.

The total body burden of lead is found in the bones and the soft tissues, with a half-life of more than 20 years. Mobilisation of lead from maternal bone is of particular concern during pregnancy and lactation and may be mobilised in later years in persons with osteoporosis (Silbergeld *et al.,* 1988). The fraction of lead in bone increases with age from about 70 percent of body lead in childhood to as much as 95 percent of the body burden with advancing years. The total lifetime accumulation of lead may be as much as 200mg to over 500mg for a worker with heavy occupational exposure (Leggeth, 1993).

Lead taken internally in any of its forms is highly toxic; the effects are usually felt after it has accumulated in the body over a period of time. The symptoms of lead poisoning are anaemia, weakness, constipation, colic, palsy, and often a paralysis of the wrists and ankles. Flaking lead-based paints and toys made from lead compounds are considered serious hazards for children. Children are especially at hazard from lead, even at levels once thought safe. Lead can reduce intelligence, delay motor development, impair memory, and cause hearing problems and troubles in balance. In adults, one lead hazard at levels once thought safe is that of increased blood pressure. Present-day treatment of lead poisoning includes the administration of calcium disodium ethylenediaminetetraacetic acid, or EDTA, a chelating agent; lead is removed from the body by displacing the calcium in EDTA and forming a stable complex that is excreted in the urine.

Lead in the central nervous system tends to concentrate in grey matter and certain nuclei. Renal excretion of lead is usually with glomerular filtrate with some renal tubular resorption. Lead crosses the placenta, so that cord blood lead levels generally correlate with maternal blood lead levels but are slightly lower. Lead accumulation in foetal tissues, including brain, is proportional to maternal blood lead levels (Goyer, 1990b).

The toxic effects from lead form a continuum from clinical or overt effects to subtle or biochemical effects (Goyer, 1990a). These effects involve several organ systems and biochemical activities. The critical effects of most sensitive effects in infants and children involve the nervous system (EPA, 1989b; Needleman *et al.*, 1990; NRC, 1993; Graziano, 1994; Henze *et al.*, 1998; Diouf *et al.*, 1995). For adults with excess occupational exposure, or even accidental exposure, the concerns are peripheral neuropathy and/or chronic nephropathy. However, the critical effect or most sensitive effect for adults in the general population may be hypertension (U.S.E.P.A, 1986; Harlan, 1988; Hu *et al.*, 1996). Effects on the haeme system provide biochemical indicators of lead exposure in the absence of chemically detectable effects, but anaemia due to lead exposure is uncommon without other detectable effects or other synergistic factors. Other target organs are the gastrointestinal and reproductive systems. Morphological alterations and decreases in sperm count, density, and motility have all been reported in heavily exposed males (Blood lead levels>40μg/dl) (Apostoli *et al.*, 1998; Assennato *et al.*, 1987; Lerds, 1992).

Nearly, all environmental exposure to lead is to inorganic compounds, even lead in food. Lead from mining wastes added to diets of experimental animals is less bioavailable than lead acetate (Freeman *et al.*, 1994). Organo-lead exposures, including tetraethyl lead; have unique toxicologic patterns (Grandjean and Grandjean, 1984).

1.7.3 Copper

Copper is widely distributed in nature and is an essential element. It occurs naturally as the free metal and occurs in compounds in +1 or +2 valence state (*ATSDR*, 1990). Because of its many desirable properties, such as its conductivity of electricity and heat, its resistance to corrosion, its malleability and ductility, and its beauty, copper has long been used in a wide variety of applications. The principal uses are electrical, because of copper's extremely high conductivity, which is second only to that of silver. Because copper is very ductile, it can be drawn into wires of any diameter from about 0.025 mm (about 0.001 in) upward. The tensile strength of drawn copper wire is about 4200kg/sq cm (about 60,000 lb/sq in); it can be used in outdoor power lines and cables, as well as in house wiring, lamp cords, and electrical machinery such as generators, motors, controllers, signalling devices, electromagnets, and communications equipment.

Copper has been used for coins throughout recorded history and has also been fashioned into cooking utensils, vats, and ornamental objects. Copper was at one time used extensively for sheathing the bottom of wooden ships to prevent fouling. Copper can easily be electroplated, alone or as a base for other metals. Large amounts are used for this purpose, particularly in making electrotypes, reproductions of type for printing.

Copper deficiency causes anaemia, neutropenia, and impaired growth, particularly in children (NRC, 1989). Copper sulphate is used medicinally as an emetic. It has also been used for its astringent and caustic action and as an anthelmintic. Copper sulphate mixed with lime has been used as a fungicide. The potential health effects associated with copper are reviewed by U.S EPA, (1987c).

The ingestion of copper in foods is the primary source for copper intake. The intake from copper plumbing and unpolluted fresh water is not significant. The estimated safe and adequate daily dietary adult intake is 1.5 to 3.0mg/day (NRC, 1989). The U.S. EPA action level for copper in tap water is 1.3mg/l (CFR, 1997). Gastrointestinal absorption of copper is normally regulated by body stores (Sarkar *et al.*, 1983). Copper is readily absorbed following oral ingestion, but homeostatic mechanisms limit further intake once requirements are met. Copper is either active or in transit with little or no excess copper being normally stored (Linder and Hazegh, 1996).

Acute poisoning resulting from ingestion of excessive amounts of oral copper salts, most frequently copper sulphate, and may produce death. The symptoms are vomiting, sometimes with a blue-green colour observed in the vomitus, haematemesis, hypotension, melena, coma, and jaundice. Autopsy findings have revealed centrilobular hepatic necrosis (Chuttani *et al.*, 1965). Industrial exposure may occur to copper fumes resulting in metal fume fever with dyspnoea, chills, headache, and nausea (Beliles, 1994). Copper can be dermally absorbed from copper – containing topical products (Landsdown, 1995; Pirot *et al.*, 1996). Dermal irritation and contact allergic dermatitis have been associated with copper jewellery, intrauterine contraceptive devices, and through occupational exposure to electroplating and copper containing agricultural products (Landsdown, 1995). Copper poisoning producing haemolytic anaemia has also been reported as the result of using copper-containing dialysis equipment (Manzer and Schreiner, 1970). Individuals with glucose-6-phosphate deficiency may be at increased risk to the hematologic effects of copper, but there is uncertainty to the magnitude of the risk (Goldstein *et al.*, 1985).

Copper in relation to other disease conditions have been extensively reviewed; Wilson's disease, a rare hereditary disease caused by a defect in the body's ability to metabolize copper. If the disease is untreated, the accumulation of copper in the body can lead to liver failure and brain damage. The disease is treated with daily doses of penicillamine, a drug known as a chelating agent, that removes the metal from the bloodstream. (Valencia and Gamboa, 1993; Sarkar *et al.*, 1983; Chan *et al.*, 1983; Walshe, 1964 and 1983); and Menke's disease, (Riordan, 1983).

1.7.4 Zinc

Zinc is a nutritionally essential metal, and a deficiency result in severe health consequences. At the other extreme, excessive exposure to zinc is relatively uncommon and requires heavy exposure. Zinc does not accumulate with continued exposure but body content is modulated by homeostatic and liver levels (Bertholf, 1986; Walshe *et al.*, 1994).

Zinc is a bluish-white; soft metal extracted from ore and is used in alloys, for galvanising iron to prevent corrosion and oxidation, and in numerous compounds including use in cosmetics, pharmaceuticals, and dry-cell batteries (Fisher, 1992). Zinc is ubiquitous in the environment so that it is present in most foodstuffs, water, and air. Content of substances in contact with galvanised copper or plastic pipes may be increased. Sea-foods, meats, whole grains, dairy products, nuts and legumes are high in zinc content, while vegetables are lower, although zinc applied to soil is taken up by growing vegetables. Atmospheric zinc levels are higher in industrial areas. The average daily intake for Americans is approximately 12 to 15mg, mostly from food (ACGIH, 1996).

According to the American Conference of Governmental and Industrial Hygienist (ACGIH), (1996), zinc toxicity from excessive ingestion is uncommon, but gastrointestinal distress and diarrhoea have been reported following ingestion of beverages standing in galvanised cans or from use of galvanised utensils. However, evidence of haematological, or renal toxicity has not been observed in individual ingestion of as much as 12g of elemental zinc over a 2-day period (Fisher, 1992).

With regard to industrial exposure, ACGIH (1996) reported that metal fume fever resulting from inhalation of freshly formed fumes of zinc presents the most significant effect. This disorder has been most commonly associated with inhalation of zinc oxide fumes, but it may be seen after inhalation of the fumes or other metals, particularly magnesium, iron, and copper. Attacks usually begin after 4 to 8hours of exposure. Chills and fever, profuse sweating, and weakness are the commonest signs. Attacks usually last only 24 to 48 hours and are most common on Mondays or after holidays (ACGIH, 1996). Other aspects of zinc toxicity are not well established. Experimental animals have been given 100 times their dietary requirements without discernible effects (Goyer *et al.*, 1979). Testicular tumours have been produced by direct intra-testicular injection in rats and chickens. This effect is probably related to the concentration of zinc normally in the gonads and may be hormonally dependent. Zinc has not produced carcinogenic effects when administered to animals by other routes (Furst, 1981). The National Research Council (NRC), (1989) reported that long term oral intakes of zinc at levels of 18.5 – 25mg/day can interfere with copper absorption, and intakes of 10-30 times the recommended dietary allowances (RDA) can impair immune responses and decrease serum high-density lipoprotein.

1.7.5 Manganese

Manganese is a silver-grey soft metal and occurs in ores mainly as oxides (Beliles, 1994). Manganese and its compounds are used in numerous products and application including iron and steel alloys, dry cell batteries, paints, inks, fertilizers, and fungicides (Gilmore *et al.*, 1992). Manganese is used principally in the form of alloys with iron, obtained by treating pyrolusite in a blast furnace with iron ore and carbon. The most important of these alloys, which are used in steelmaking, are ferromanganese, containing about 78 percent manganese, and spiegeleisen, containing from 12 to 33 percent manganese. Small amounts of manganese are added to steel as a deoxidizer; large amounts are used to produce a very tough alloy, resistant to wear. Safes, for example, are made of manganese steel containing about 12 percent manganese. Nonferrous manganese alloys include manganese bronze (composed of manganese, copper, tin, and zinc), which resists corrosion from seawater and is used for propeller blades on boats and torpedoes, and manganin (containing manganese, copper, and nickel), used in the form of wire for accurate electrical measurements because its electrical conductivity does not vary appreciably with temperature (Beliles, 1994).

Manganese is an essential element and is a co-factor for a number of enzymatic reactions, particularly those involved in phosphorylation, cholesterol, and fatty acids synthesis. Manganese is present in all living organisms, while it is present in urban air and in most water supplies; the principal portion of the intake is derived from food. Vegetables, the germinal portions of grains, fruits, nuts, tea, and some spices are rich in manganese (Underwood, 1977; Keen and Leach, 1988). Manganese is a silver-grey soft metal and occurs in ores mainly as oxides (Beliles, 1994). Manganese and its compounds are used in numerous products and application including iron and steel alloys, dry cell batteries, paints, inks, fertilizers, and fungicides (Gilmore *et al.*, 1992). Although outright manganese deficiency has not been observed in the human population, suboptimal manganese intake may be a concern (U.S.E.P.A., 1998). In animals, manganese deficiency can cause impaired growth, skeletal abnormalities, and alter metabolism of carbohydrates and lipids (ATSDR, 1998). NRC (1989) reported that the estimated safe and adequate daily dietary intake for manganese is set equal to current U.S.

dietary intakes, based on a lack of evidence for human manganese deficiency, yielding a range of 2.5mg/day. The U.S.E.P.A. has reviewed numerous human and animal studies and related information and concluded that an appropriate chronic oral reference dose for manganese is 10mg/day (0.14mg/kg/day) (U.S.E.P.A., 1998). Only between 3 and 10 percent of dietary manganese is absorbed in normal adults, and total body stores are controlled by a complex homeostatic mechanism regulating absorption and excretion. Calcium, iron deficiencies, age, and other factors increase manganese absorption (ATSDR, 1998; U.S.E.P.A., 1998).

Occupational inhalation exposure is the primary route for manganese toxicity. The primary toxic effect of occupational inhalation exposure is neurological damage (Roels *et al.*, 1987); however, inhalation exposure to manganese can also affect the lung directly, causing metal fume fever, pneumonitis, chronic obstructive lung disease, and pneumonia (ATSDR, 1998; Nemery, 1990). Occupational exposure to manganese at levels of about 1mg/m^3 has been reported to decrease male fertility (Gennart *et al.*, 1992; Lauwerys *et al.*, 1985).

Victims of chronic manganese poisoning tend to recover slowly, even when removed from the excessive exposure. Little evidence exists to suggest that manganese has carcinogenic potential. A 2-year bioassay of manganese sulphate monohydrate in the diet found no evidence of carcinogenicity to rats and equivocal evidence of carcinogenicity to mice (ATSDR, 1998). The U.S. EPA has classified manganese as a group D carcinogen (not classifiable as to human carcinogenicity), based on inadequate evidence in humans and animals (U.S.E.P.A., 1998).

1.7.6 Iron

The major scientific and medicinal interest in iron is as an essential metal, but toxicological considerations are important in terms of accidental acute exposures and chronic iron overload, due to idiopathic haemochromatosis or as a consequence of excess dietary iron of frequent blood transfusions. The complex metabolism of iron and mechanisms of toxicity are detailed by Jacops and Worwood (1981) and Spivey- Fox and Rader, (1988).

Iron is a silver-white solid metal found mainly in combination with other elements as oxides, carbonates, sulphides, and silicates (Beliles *et al.*, 1994). It exist in two stable oxidation states, oxidised ferric (Fe^{3+}) and reduced ferrous (Fe^{2+}), which accounts for its essentiality as a trace element and its crucial role in the oxygen and electron transport reactions of all living cells. Dietary iron is available as either haeme or non-haeme (Allen, 1996). Pure iron, prepared by the electrolysis of ferrous sulphate solution, has limited use. Commercial iron invariably contains small amounts of carbon and other impurities that alter its physical properties, which are considerably improved by the further addition of carbon and other alloying elements.

By far the greatest amount of iron is used in processed forms, such as wrought iron, cast iron, and steel. Commercially pure iron is used for the production of galvanized sheet metal and of electromagnets. Iron compounds are employed for medicinal purposes in the treatment of anaemia, when the amount of haemoglobin or the number of red blood corpuscles in the blood is lowered. Iron is also used in tonics.

Acute iron toxicity is nearly always accidental ingestion of iron-containing medicines and most often occurs in children (Litovitz *et al.*, 1992; Weiss *et al.*, 1993). Despite supplements being packaged in child-resistant packages and carrying warning labels, the public perception of their potential danger is low (Huott and Storrow, 1997) and fatalities in children have recently increased (Anderson, 1997; Berkovitch *et al.*, 1994; Weiss *et al.*, 1993).

Free iron is an oxygen-reactive substance, highly toxic to cells, and will enhance the formation of free radicals and peroxidation of membrane lipids (Bacon and Britton, 1990; Bacon *et al.*, 1983; Ryan and Aust, 1992). Humans are unable to eliminate excess iron and regulate body iron stores by limiting absorption (McCance and Widdowson, 1937).

Iron poisoning in humans has extensively been reviewed (Ellenhorn and Barceloux, 1988; Greengard, 1975; McGuigan, 1996). Gastrointestinal symptoms typically occur following the ingestion of 20mg elemental iron/kg body weight, and doses greater than 60mg/kg are often lethal. Treatment involves stabilising vital functions, removing unabsorbed iron from the gastrointestinal tract, and intravenous administration of deferoxamine if symptoms are severe (Anderson, 1997; McGuigan, 1996; Mills and Curry, 1994). The FDA recently issued regulations requiring all iron-containing products to carry a label stating the dangers of iron overdosage and unit-dose packaging for products containing 30mg or more per dosage units (U.S. FDA, 1997). The U.S. EPA has not derived any toxicity values for iron (U.S.E.PA, 1998); the ACGIH has adopted Threshold

Limit Values (TLV)-TWA values for iron of 5mgFe/m^3 for iron oxide dust and fume and 1mgFe/m^3 for soluble iron salts (ACGIH, 2000).

1.7.7 Nitrates

Nitrates are wide spread in soil, and are present in small amounts in plant and animal tissues. Water and food containing high nitrate concentrations are potentially harmful to infants and young children (Gbodi *et al.*, 2001). Bacteria in the gut can reduce nitrate which when absorbed into the blood stream oxidizes haemoglobin to methaemoglobin (Baron, 1982) which cannot carry oxygen for respiration and therefore cyanosis and anoxia set in. Although methaemoglobinaemia occurs occasionally in babies causing illness and deaths of infants, it constitutes a frequent major health problem in cattle (Ridder *et al.*, 1974). Calabrese (1978) reported that infants are at considerable risk for nitrate related toxicity, as compared to adults. He revealed that levels of nitrate beyond 20mg/l resulted in a marked up – shift in the frequency of methaemoglobinemia in infants but not in adults. Nitrates can be reduced endogenously by microbial systems to nitrites, which then oxidise the haemoglobin to methaemoglobin (haeme iron from ferrous to ferric state). Methaemoglobin, being unable to combine with oxygen, following accumulation in sufficient quantities, can lead to anoxia. The use of water with high (> 30mg/l) nitrate content (from soils, ponds, fertilizers, etc) in making baby formula and foods, spinach with high nitrate content, and occasionally meats with high levels of added nitrates and nitrites have resulted in life- threatening methaemoglobinemia in humans, especially children (Derks *et al.*, 1997; Fytianos and Zarogiannis, 1999). Consequently, a standard of

10mg/l is principally designed to prevent the occurrence of elevated levels of methaemoglobin in infants. Concentrations twice as great would still protect adults.

Despite the fact that most nitrate health hazards come from polluted water (Gbodi and Atawodi, 1986), water planners and managers in developing countries lay emphasis only on water quantity and neglect water quality. Thus water supplies in most rural and urban areas in Nigeria are supplied to the people without proper treatment. Borehole water is never treated and is supplied to homes directly. Gbodi *et al.*, (2001) reported a significantly higher mean nitrate concentrations in both tap and well water during the rainy seasons as compared to levels obtained during the dry season in a study of tap and well water nitrate levels in Bosso, Minna, Nigeria. Water borne diseases of epidemic and endemic proportions occur periodically in parts of the country especially during the early rains. Above all, water quality guidelines for various physical, chemical, and biological parameters are yet to be established in Nigeria (Gbodi *et al.*, 2001). In this situation, nitrate – nitrite problem becomes an unfortunate non-priority event but because of its hazardous nature it cannot be ignored.

Of the total daily dietary intake of nitrates, of 10 – 150mg/day, leafy vegetables contribute 99 percent. In developed countries nitrates are used to treat meats (to give characteristic flavour and pink colour, to prevent rancidity, and to prevent growth of spores of *clostridium botulinum*) contributes < 0.1mg / day (Derks *et al.*, 1997). If there are excessive quantities of nitrates, they percolate into the groundwater supplies, flow into streams and rivers and eventually reach the sea or lakes where they become concentrated. Nitrates may also be concentrated in groundwater, which tends to be a very long-lived effect because of the slow turnover of groundwater reservoirs. This may have detrimental effects on aquatic and marine ecosystem, and may lead to public health problems when drinking water is contaminated. Natural fertilisers or manure also produce large quantities of nitrates. In addition, animal husbandry produces huge amounts of excrement, which contains some quantity of nitrates that are added to the environment (Fytianos and Zarogiannis, 1999).

1.8 CONTROLLING POLLUTION

1.8.1 Source Reduction

The best way to eliminate hazardous wastes is not to generate them in the first place. For example, improvements have been made in the production of integrated circuits: The toxic chlorinated hydrocarbons commonly used in the 1970s were replaced in the 1980s by less toxic glycol ethers and in the 1990s by low-toxicity esters and alcohols (Engelging, 2004).

Air Pollution is controlled in two ways: with end-of-the-pipe devices that capture pollutants already created and by limiting the quantity of pollutants produced in the first place (Hart, 2004). End-of-the-pipe devices include catalytic converters in automobiles and various kinds of filters and scrubbers in industrial plants. In a catalytic converter, exhaust gases pass over small beads coated with metals that promote reactions changing harmful substances into less harmful ones (Hart, 2004). When end-of-the-pipe devices first began to be used, they dramatically reduced pollution at a relatively low cost. As air pollution standards become stricter, it becomes more and more expensive to further clean the air. In order to lower pollution overall, industrial polluters are sometimes allowed to make cooperative deals. For instance, a power company may fulfil its pollution control requirements by investing in pollution control at another plant or factory, where more effective pollution control can be accomplished at a lower cost (Hart, 2004).

End-of-the-pipe controls, however sophisticated, can only do so much. As pollution efforts evolve, keeping the air clean will depend much more on preventing pollution than on curing it. Gasoline, for instance, has been reformulated several times to achieve cleaner burning. Various manufacturing processes have been redesigned so that less waste is produced. Car manufacturers are experimenting with automobiles that run on electricity or on cleaner-burning fuels. Buildings are being designed to take advantage of sun in winter and shade and breezes in summer to reduce the need for artificial heating and cooling, which are usually powered by the burning of fossil fuels (Hart, 2004).

The choices people make in their daily lives can have a significant impact on the state of the air. Using public transportation instead of driving, for instance, reduces pollution by limiting the number of pollution-emitting automobiles on the road. During periods of particularly intense smog, pollution control authorities often urge people to avoid trips by car. To encourage transit use during bad-air periods, authorities in Paris, France, make bus and subway travel temporarily free (Hart, 2004).

1.8.2 Recycling

Recycling is the recovery or reuse of usable materials from waste. About 5 percent of hazardous waste in the United States is recycled as solvents; a similar amount is recovered as metals. (Engelging, 2004).

For example, approximately 15 percent of sulphuric acid is recycled in chemical manufacturing. In the past, most sulphur used for sulphuric acid production was mined; now the amount of sulphur recovered from smelters (facilities that remove metals from ores), refineries (facilities that purify substances), and manufacturers is more than double that produced by mining.

In the United States, the practice of using industrial wastes, which often contain hazardous wastes, as ingredients in commercial fertilizers is encouraged as a means of recycling hazardous wastes. The safety of this practice has recently been called into question, however, and some states are starting to regulate it (Engelking, 2004).

1.8.3 Treatment

Wastes may be made less hazardous by physical, chemical, or biological treatment. Nearly 10 percent of hazardous waste in the United States is treated with water; another 11 percent undergoes other treatment. For example, sodium hydroxide has been used to treat acid wastes at integrated-circuit plants. Some newer plants now treat hydrofluoric acid wastes with lime, producing relatively harmless calcium fluoride, the mineral fluorite. Sulphuric acid wastes, if not recycled, can be treated with ammonia wastes from the same plant, forming ammonium sulphate, a fertilizer.

Incineration has been used since human beings learned to control fire. It is the preferred method of handling infectious medical wastes. However, it should not be used for wastes that contain toxic heavy metals or chlorinated hydrocarbons: When burned, old painted surfaces can release lead or arsenic into the air, whereas chlorinated hydrocarbons produce hydrochloric acid and dioxins. Solids left over from incineration may have to be disposed of as hazardous waste. About 6 percent of hazardous waste in the United States is incinerated, and another 11 percent is burned along with fuel (Engelking, 2004).

Solidification of wastes involves melting them and mixing them with a binder, a substance that eventually hardens the mix into an impenetrable mass. One suggested treatment of radioactive waste involves turning it into a glass through a process known as vitrification (Engelking, 2004).

Approximately 8 percent of hazardous waste in the United States is stabilized—kept from moving through groundwater and air. Sometimes waste can be stabilized on-site; simple remedies such as covering the waste may be sufficient. Other stabilization methods involve building a barrier around the waste. This barrier can be of plastic, steel, concrete, clay, or even glass (Engelking, 2004).

1.8.4 Disposal

Surface impoundment (placing liquid or semi-liquid wastes in unlined pits) keeps waste in long-term storage, but it is not considered a method of final disposal. About 8 percent of hazardous waste is injected into deep wells; 21 percent enters landfills (large, unlined pits into which solid wastes are placed) as its ultimate resting place (Engelking, 2004).

Abandoned and particularly serious waste sites may qualify as "Superfund" sites, eligible for cleanup with government funding under legislation passed in 1980. In 1993, of about 38,000 hazardous-waste sites inventoried by the Environmental Protection Agency (EPA), 1407 sites were listed on or proposed for the National Priority List (NPL) for waste cleanup. In 1995 the EPA estimated that 73 million people lived within 4 miles of a Superfund site in the United States. Before 1995, 3300 emergency removals—urgent cleanups of hazardous wastes because of the immediate hazard they present—were conducted (Engelking, 2004).

The serious problem of underground plumes of hazardous materials leaving the original disposal sites has only partial solutions at this time. The typical method of handling this problem is the drilling of wells around a plume's perimeter. Hazardous materials are then removed from some wells, and water may be injected into other wells to produce a barrier to the plume's motion. Drilling wells and monitoring holes near a toxic site carries risks; a plume originally confined between strata (horizontal layers of rock) may penetrate vertically through a drilled hole and escape confinement. (Engelking, 2004).

A recent method of treatment for shallow plumes of chlorinated solvents depends on their chemical reactivity. A trench is dug around the leaking waste site and filled with a mixture of soil and powdered iron. The iron then reacts with the chlorinated solvents, turning them into simple hydrocarbons, which are less hazardous (Engelking, 2004).

Because of the many environmental tragedies of the mid-20th century, many nations instituted comprehensive regulations designed to repair the past damage of uncontrolled pollution and prevent future environmental contamination. In the United States, the Clean Air Act (1970) and its amendments significantly reduced certain types of air pollution, such as sulphur dioxide emissions. The Clean Water Act (1977) and Safe Drinking Water Act (1974) regulated pollution discharges and set water quality standards. The Toxic Substances Control Act (1976) and the Resource Conservation and Recovery Act (1976) provided for the testing and control of toxic and hazardous wastes. In 1980 Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, to provide funds to clean up the most severely contaminated hazardous waste sites. These and several other federal and state laws helped limit uncontrolled pollution, but progress has been slow and many severe contamination problems remain due to lack of funds for cleanup and enforcement (Engelking, 2004).

International agreements have also played a role in reducing global pollution. The Montréal Protocol oh Substances that Deplete the Ozone Layer (1987) set international target dates for reducing the manufacture and emissions of the chemicals, such as CFCs, known to deplete the ozone layer. The Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and Their Disposal (1989) serves as a framework for the international regulation of hazardous waste transport and disposal (Engelking, 2004).

Since 1992 representatives from more than 160 nations have met regularly to discuss methods to reduce greenhouse gas emissions. In 1997 the Kyoto Protocol was devised, calling for industrialized countries to reduce their gas emissions by 2012 to an average 5 percent below 1990 levels. At the end of 2000 the Kyoto Protocol had not yet been ratified; negotiators were still working to find consensus on the rules, methods, and penalties that should be used to enforce the treaty (Engelking, 2004).

Regulations and legislation have led to considerable progress in cleaning up air and water pollution in developed countries. Vehicles in the 1990s emit fewer nitrogen oxides than those in the 1970s did; power plants now burn low-sulphur fuels; industrial stacks have scrubbers to reduce emissions; and lead has been removed from gasoline. Developing countries, however, continue to struggle with pollution control because they lack clean technologies and desperately need to improve economic strength, often at the cost of environmental quality. The problem is compounded by developing countries attracting foreign investment and industry by offering cheaper labour, cheaper raw materials, and fewer environmental restrictions. The maquiladoras, assembly plants along the Mexican side of the Mexico-U.S. border, provide jobs and industry for Mexico but are generally owned by non-Mexican corporations attracted to the cheap labour and lack of pollution regulation. As a result, this border region, including the Río Grande, is one of the most heavily polluted zones in North America. To avoid ecological disaster and increased poverty, developing countries will require aid and technology from outside nations and corporations, community participation in development initiatives, and strong environmental regulations (Engelking, 2004).

Nongovernmental citizen groups have formed at the local, national, and international level to combat pollution problems worldwide. Many of these organizations provide information and support for people or organizations traditionally not involved in the decision-making process. The Pesticide Action Network provides technical information about the effects of pesticides on farm workers. The Citizen's Clearinghouse for Hazardous Waste, established by veterans of the Love Canal controversy, provides support for communities targeted for hazardous waste installations. A well-organized, grassroots, environmental justice movement has arisen to advocate equitable environmental protections. *Greenpeace* is an activist organization that focuses international attention on industries and governments known to contaminate land, sea, or atmosphere with toxic or solid wastes. Friends of the Earth International is a federation of international organizations that fight environmental pollution around the world (Engelking, 2004).

1.9 Objectives of the present study

Changes in the environment caused by the influence of modern society are increasingly experienced as unintended or unwanted. Most of the populace live in cities and towns, and it is in these urban settings that many environmental problems are found. Cities and towns are increasing in size and spreading over the landscape, sometimes eliminating valuable farmland and natural areas. Life on our planet is characterised by complex relationships among living things, the atmosphere, the water, and the land. Human activity has begun to change the environment on a global scale in ways harmful to people and other living things.

Disease is often due to an imbalance resulting from a poor adjustment between the individual and the environment. However, disease seldom has a one-cause one-effect relationship with the environment. Rather the incidence of a disease depends on several factors, including physical environment, biological environment, and life-style. Linkages between these factors are often related to other factors, such as local customs and the degree of industrialisation. For instance, the more primitive societies that live directly off the local environment are usually plagued by a different variety of environmental health problems than is our urban society. Industrial societies have nearly eliminated environmental disease, such as cholera, dysentery, and typhoid. However, they are more likely to suffer from chronic and acute diseases, such as respiratory problems and cancer from industrialisation. If the environment is not seriously looked into, pollution and other environmental hazards will emanate with dare consequences to public health and development.

In order to facilitate harmony between industrial and commercial activities and the quality of urban environments, this study was conducted in Abuja Municipal with the following objectives:

1. To provide basis for the need for regular monitoring programmes for the environment in Abuja Municipal and the Federal Capital Territory as a whole.
2. To determine the baseline values of soil, water and food contamination pattern in the city (if any) with a view to its relationship to public health.
3. To investigate the effect of industrial effluents (if any) in soil, water and food.
4. To determine the biological integrity of soil and water in the municipal; and
5. To educate and recommend preventive processes and solutions to a possible environmental problems.

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1 Sample collection

Samples of tap water were collected in polythene bottles from Garki, Maitama and Wuse districts of Abuja Municipal. The polythene bottles were acid washed first then rinsed with de-ionised water, oven dried, before used for sample collection. River water samples were also collected from Garki River (near Garki General Hospital), Maitama river (between the Federal Secretariat and Hilton Hotel) and Wuse river (between Julius Berger Junction and Federal Ministry of Finance Housing Estate). Tap water samples were collected from different locations within the municipal. Foodstuff samples (cassava, sugarcane and spinach) were collected from gardens at Garki, Maitama and Wuse areas of the Municipal. Two samples each of soil; water and foodstuff were collected during the dry season (February) and the rainy season (July) from each area. Samples collected were immediately transported to the laboratory for processing. Water samples that were not immediately analysed were refrigerated at 4°C till processed. A total of six samples each for soil, water and foodstuffs were collected during the dry season and another six during the rainy season. For water samples, surface water and deep water were collected, and for soil, surface soils and another soil from about 30-cm depth referred to as deep soil were collected. Foodstuff samples were collected at a distance of about 75-200m from each other. The samples were analysed at the UNDP assisted quality control laboratory of the Niger State Ministry for Environment and at the chemistry laboratory of University of Abuja, Gwagwalada. At each sampling site, the presence of macro-organisms (insects, ants, etc) was recorded by direct observation and by catching them with a net (diameter of mesh 0.2mm).

The choice of sampling sites was not based on any criteria other than the fact that Abuja Municipal is divided into three major districts of Garki, Maitama and Wuse with each having a river passing through it. All sampling stations were located far away from any industrial discharge point.

2.2 Extraction of juice from foodstuff samples.

100g each of samples of cassava, sugarcane and spinach were homogenized (blended) separately using Hach® 120 blender (Hach Company, Loveland, Colorado USA). 100ml of distilled water was then added to the mixture, which was then sieved, using a plastic sieve (0.01 diameter of mesh) and the extract was then used for analysis as described by Jones *et al.*, 1990 and adopted by Orisakwe *et al.*, 2001.

2.3 Extraction of heavy and trace metals from soil samples

Soil digestion method as described by Piper (1994) and adopted by Orisakwe *et al.,* 2001 was used. Soil samples were digested by adding 5g of soil to 15ml of concentrated nitric acid and hydrochloric acid at the ratio of 1:1 and allowed to stand for one hour. This was then heated on a hot plate for one and half (1½) hours until the acid turned colourless. The mixture was allowed to cool then filtered into a conical flask using Whatman N<u>o</u> 44 filter paper; the filtrate was made up to 100ml with de-ionized water and poured into a clean, labelled plastic container. The filtrate was used for the determination of heavy metal composition using atomic absorption spectrophotometer.

2.4 Extraction of nitrates from soil

50g soil sample, free from coarse stone was mixed with 100ml of 0.025mol/l calcium chloride solution in a glass bottle. A spatula – tipfull of charcoal activated for soil test was added and the closed bottle placed on a shaking machine for 1 hour. The suspension was allowed to settle then filtered with Whatman no.42 filter paper. The filtrate was made up to 100ml with deionised water, and then used for nitrate analysis using a UV Spectrophotometer (Spec M330, Unicam LTD., York Street, Cambridge CB 12 PX, London) at 220nm wavelength (Gbodi *et al.*, 2001).

2.5 Determination of pH of soil, water and foodstuff samples

The Hach one® EC 10 portable pH meter (Hach Company, Box 389, Loveland, Colorado, USA) responds to the hydrogen ion concentration (activity) by developing an electrical potential at the glass/liquid interface. Water or foodstuff extract samples were filtered and standardized with 0.1M KCl, then poured into a beaker and kept on a flat metal plate. Soil samples were mixed with distilled water in a 1:1 ratio. To determine the pH, the dispenser button was pressed once, which oozes a gel like substance from the tube; the electrode was then placed in the sample. Care was taken to ensure that the entire sensing end was submerged and there were no air bubbles in the beaker. pH value was then read from the display screen when it became stable (U.S.EPA, 1986).

2.6 Determination of conductivity in water and foodstuff samples

Water and foodstuff extracts were poured in a beaker each for the measurement of conductivity using the Hach® C0150 conductivity meter (Hach Company HQ, Box 389, Loveland, Colorado, USA). Electrolytic conductivity is the capacity of ions in a solution to carry electrical current and is the reciprocal of the solution resistivity. Inorganic dissolved solids and cations carry current. Measuring conductivity is done by measuring the resistance occurring in an area of the test solution defined by the probe's physical design. Voltage is applied between the two electrodes immersed in the solution, and the voltage drop caused by the resistance of the solution is used to calculate conductivity per centimetre. The Hach CO 150 conductivity meter was prepared for operation and automatically it selects the appropriate range. The Hach CO 150 probe was immersed in a beaker containing the sample. The probe was moved up and down and tapped on the beaker to free bubbles from the electrode area. With the meter at the conductivity mode, the values were read on the display screen (U.S.EPA, 1986).

2.7 Determination of salinity in water and foodstuff samples

The same procedure is followed as with conductivity above. Only in this determination the Hach CO 150 is prepared for operation with the selection for salinity. The probe is placed in the beaker containing the sample, with the meter at the salinity mode; the values were read on the display screen (U.S.EPA, 1986).

2.8 Determination of phenolphthalein (total) acidity in water and foodstuff samples

100ml of each sample was measured and poured into a clean 250-ml Erlenmeyer flask. Four (4) drops of phenolphthalein indicator were added and Hach TitraStir® was used to stir the mixture. This was then titrated with sodium hydroxide from a colourless to a light pink colour using the Hach digital titrator. The delivery tube tip of the titrator was placed into the solution and the flask swirled while titrating. The number of digits required was recorded. Titration to pH 8.3 includes both strong mineral acidity as well as weaker acid species, this represents the total acidity, and the results are expressed in mg/l as calcium carbonate at pH 8.3 (U.S.EPA, 1986).

2.9 Determination of total alkalinity in water and foodstuff samples

The procedure is the same with total acidity above only that in place of sodium hydroxide, sulphuric acid was used. Four drops of phenolphthalein indicator was used, the solution was colourless before titrating with sulphuric acid. Titration was continued with sulphuric acid until a light violet grey (pH 4.5) colour was obtained. The results were recorded and analysed. Phenolphthalein alkalinity was determined by titration to a pH between 3.7 and 5.1, and includes all carbonate, bicarbonate and hydroxide. Results were expressed at mg/l $CaCo_3$ total alkalinity (U.S.EPA, 1986).

2.10 Determination of suspended solids in water samples

The photometric method (non filterable residue) was used. This method of determining suspended solids is a simpler, direct measurement that does not require the filtration or ignition and weighing steps that gravimetric procedures do. The Hach® DREL/2010 spectrophotometer was dialled to display 810nm wavelength. 500ml of each sample was blended at high speed for two (2) minutes. The homogenized (blended) sample was poured into a 600-ml beaker and then stirred. 25ml of the homogenized (blended) samples were poured into a sample cell, with an equivalent 25ml deionised water in another cell (blank). The prepared sample cell was swirled to remove any gas bubble and uniformly suspended any residue. The sample cell was then placed in the cell holder with the light shield closed. The result was read and recorded from the display screen. The result was expressed in mg/l suspended solid. (Adapted from U.S. sewage and industrial waste. U.S.E.P.A. 1986).

2.11 Determination of total hardness in water samples

25ml each of the sample was measured into a 250ml Erlenmeyer flask. This was diluted to about the 100ml mark with deionised water. 2ml of buffer solution was added and the flask swirled to mix the solution. Four drops of Hach Man Ver® hardness indicator solution was added. The deliver tube of the digital titrator, which contains the EDTA, was then placed into the solution, and while swirling the flask, the titration with EDTA was done using Hach Digital Titrator until the solution changed from red to pure blue. The concentration was then recorded and the result calculated. EDTA titrant reacts first with the free calcium and magnesium ions, then with those bound to the indicator causing it to change to a blue colour at the end point. Results were expressed as mg/l total hardness (as $CaCo_3$) (Adapted from U.S. sewage and industrial waste. U.S.E.P.A. 1986).

2.12 Determination of dissolved oxygen in water samples

100ml each of the samples were treated with manganeous sulphate and alkaline iodide – azide reagent to form an orange-brown precipitate. Upon acidification of the sample, this floc reacts with iodide to produce free iodine as tri-iodide in proportion to the oxygen concentration. The iodine is titrated with sodium thiosulate to a colourless end point using Hach Digital Titrator. The results were expressed as mg/l dissolved oxygen (Adapted from U.S. sewage and industrial waste. U.S.E.P.A. 1986).

2.13 Determination of nitrate levels in water, soil and food samples

All samples were filtered through acid washed Whatman 42 filter paper and absorbance read at 220nm. The UV-Spectrophotometric method outlined in CAM SPEC M330 spectrophotometric manual (Cam Spec Ltd., Yorkshire, England). The procedure involved the preparation of a calibration curve using a range of standards of potassium nitrate. Correction for organic constituents was made by reading filtered samples at 275nm. Nitrate concentration were extrapolated from the calibration curve by using the absorbance values calculated as follows: $A = A_{220} - 4A_{275}$ Internal standards were run to check for the accuracy of the method (Allen, 1974).

2.14 Determination of biological integrity

The presence of macro-organisms (insects, ants, etc.) dead or alive was recorded by direct observation capturing them with a net (diameter of the mesh 0.2mm), and by soaking the soil samples in water and recording the presence of macro-organisms dead or alive (Herkovits *et al.*, 1996).

2.15 Determination of soil and water micro-biology

A serial dilution with distilled water was prepared, 0.02g of soil samples were added to each of the dilution plates containing nutrient agar prepared for bacterial counts; some of the plates containing Sabourand dextrose agar (SDA) prepared for fungal counts. Water samples were also incubated for 24 hours and the growth recorded, as described by Postgate, (1969).

2.16 Determination of trace and heavy metals in water, soil and foodstuff samples

The atomic absorption spectrophotometer (Unican Spectrophotometric Manual (UNICAM Ltd., York Street Cambridge CB 12 PX, England) was used to determine trace and heavy metals. Atomic absorption spectrophotometer (AAS) is a valuable analytical tool for determining trace amounts of metals in biological samples. AAS depends on the absorption by atoms of a quantum of energy of characteristic wavelength, when going from a ground state to an exited. It uses this fact to achieve a high specificity for many other elements and low level interference from other elements.

A typical AAS has an energy source (the hollow cathode lamp), an atomising device (usually a flame), a monochromator, a photo multiplier and amplifier, and a recording device. The samples were aspirated and mixed as an aerosol with combustible gases (acetylene and air). The mixture was then ignited in a flame of temperature of 2300 degrees celcius. During combustion, atoms of the elements of interest in the sample are reduced to the atomic state. A light beam from a lamp whose cathode is made of the element being determined is passed through the flame into a monochronometer and detector. Free, unexcited ground state atoms of the element absorb light at characteristic wavelengths; this reduction of the light energy at the analytical wavelength is the measure of the amount of the element in the sample. The

Cathode lamp for the element to be quantified was inserted in the lamp holder inside the AAS and the AAS switched on. The required wavelength was set. The gas supply was turned on and the air supply turned on and flame ignited. The air pressure was regulated to the required pressure. The AAS was allowed to warm up for about 10mins. The AAS was set on the absorbance mode and distilled deionised water was aspirated into the AAS to zero it, this was followed by using the blank solution and the standard solutions to calibrate and the absorbance were read. The absorbance of sample solution were then read, the standard was used to check the calibration after 4-5 sample readings. The sample concentration was obtained from the curves plotted for each standard. The results of the analysis were recorded and printed out via a printer. The absorbance of the metals was determined at the following wavelengths; cadmium 228.8nm; lead 217nm; copper

334.8nm; Zinc 213.9nm; Manganese 279.5nm; Iron 248.3nm; silica 251.6nm. The concentration for each element was obtained from the prepared calibration curves of each element

(U.S.E.P.A., 1983).

2.17 Statistical Analysis

Results are expressed as mean ± standard deviations. Analysis of variance (ANOVA) and student's t - test was computed using SPSS software version 6 on a V570 Compaq Computer. The statistical level of significance was set at 95% ($p<0.05$).

CHAPTER THREE

3.0 RESULTS

3.1 Physico – electrochemical content of water samples

The result of the physico-electro-chemical content (pH, conductivity, salinity, acidity, and alkalinity) analysed in both dry and rainy season water samples of Abuja Municipal are shown on Table 1. No seasonal, locational, significant difference ($p>0.05$) was seen in all parameters tap water samples analysed, probably because they were from the same source. Statistically significant differences ($p<0.05$) were seen in all river water parameters measured, when compared to that of tap water samples. Higher and significant values were obtained for; conductivity, acidity and alkalinity in all river samples when compared to values for tap water samples. However, the differences observed in pH and salinity were not significant ($p>0.05$) except for Wuse rainy season river sample that was found to be the lowest (6.1) in all samples analysed. Wuse river samples had a significantly ($p<0.05$) higher conductivity, acidity and alkalinity levels for both dry and rainy season samples when compared with Maitama and Garki river samples; Maitama river had the lowest conductivity, acidity and alkalinity levels when compared to Garki and Wuse samples (Table 1). There was a significantly ($P<0.05$) higher increase in conductivity, acidity and alkalinity levels in all rainy season river samples when compared to dry season samples.

TABLE 1: Physico-electro-chemical properties of dry and rainy season water samples of Abuja Municipal

	PH		Conductivity (µs)		Salinity (%)		Acidity (mg/l)		Alkalinity (mg/l)	
Sample	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	RAINY SEASON
Garki Tap Water	6.9±0.01	6.9±0.01	96.1±0.03	96.3±0.07	0	0	10.2±0.05	10.4±0.01	60.1±0.02	60.5±0.02
Garki River Water	6.3±1.03	6.5±0.01	184.2±6.33	192.6±3.09	0.1±0.06	0.1±0.04	256.4±8.03	262.7±7.12	84.8±5.13	86.9±3.51
Maitama Tap Water	6.0±0.02	6.9±0.01	96.1±0.03	96.3±1.06	0	0	10.1±0.60	10.3±0.95	60.2±0.09	60.6±0.02
Maitama River	6.7±4.02	6.4±7.13	140.6±3.06	170.9±4.62	0.1±0.01	0.1±0.02	252.9±6.16	259.8±3.72	84.8±6.82	85.6±4.65
Wuse Tap Water	6.9±0.06	6.9±0.02	96.2±0.01	96.3±0.02	0	0	10.2±0.04	10.3±0.02	60.2±0.03	60.4±0.02
Wuse River	6.6±2.06	6.1±1.03	288.7±5.01*	292.1±3.41*	0.1±0.01	0.1±0.03	259.3±3.65*	267.2±2.25*	103.6±5.09*	109.7±3.51*

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t-test) when compared with other corresponding values $p<0.05$

3.2 Analysis of suspended solids, total dissolved solids, and total hardness in Water

The results of suspended solids, total dissolved solids, and total hardness in both dry and rainy season water samples of Abuja Municipal are shown on Table 2. The results indicate that no significant ($p>0.05$) seasonal difference was seen in all tap water samples analysed from all the districts for both dry and rainy season samples. Suspended solids were not detected in all tap water samples. All river samples showed a significantly ($p<0.05$) higher level of both total dissolved solids and total hardness in dry and rainy seasons samples when compared with tap water. Maitama river showed a significantly ($p<0.05$) low level of suspended solids, total dissolved solids and total hardness for both dry and rainy season samples when compared to river Garki and river Wuse, while River Wuse showed significantly ($p<0.05$) higher levels of these parameters. There was a statistically significant ($p<0.05$) increase in suspended solids and total dissolved solids in rainy season river samples when compared to dry season samples. However, a decrease in total hardness of all river samples was seen, but was not statistically significant ($p>0.05$).

TABLE 2: Physico-chemical contents of dry and rainy season water samples of Abuja Municipal.

	Suspended Solids (mg/l)		Total Dissolved Solids (mg/l)		Total Hardness (mg/l)	
Sample	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
Garki Tap Water	0.0	0.0	43.5±0.12	45.9±0.09	0.036±0.11	0.038±0.02
Garki River Water	20.9±3.02	27.6±2.90	91.3±3.74	163.5±2.95	45.6±3.34	40.7±2.16
Maitama Tap Water	0.0	0.0	43.6±0.09	45.7±0.11	0.036±0.09	0.038±0.07
Maitama River	16.3±2.71	19.6±3.02	88.2±3.11	116.9±3.07	43.5±2.60	38.9±3.11
Wuse Tap Water	0.0	0.0	42.9±0.14	44.9±0.17	0.035±0.13	0.038±0.10
Wuse River	26.7±0.91*	34.3±1.12*	130.9±3.01*	190.2±5.13*	48.8±2.10*	45.2±1.33*

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$

3.3 Analysis of Dissolved Oxygen, Biological Oxygen demand and Nitrates in water

Table 3 shows the result of the analysis of dissolved oxygen [$D0_2$], biological oxygen demand [BOD], and nitrates in both dry and rainy season water samples of Abuja Municipal. Significantly ($p<0.05$) higher levels of $D0_2$ were seen in tap water samples for both dry and rainy seasons in comparison to river samples. Wuse River had a significantly ($p<0.05$) low levels of $D0_2$ when compared to Garki and Maitama rivers. BOD was significantly ($p<0.05$) low in both dry and rainy season tap water samples when compared to river samples. A significantly ($p<0.05$) high BOD level was seen in both dry and rainy season Wuse River samples. With the exception of Wuse river, all the nitrate levels seen in all samples were below the World Health Organisation (WHO) recommended maximum safe level (45ppm) for human consumption (WHO, 1983). Significant ($p<0.05$) increases in rainy season nitrate levels were seen in all river samples when compared with dry season samples. Wuse rainy season river samples had the highest nitrate level (49.7 ± 3.37), which is above the maximum safe limit of 45ppm.

TABLE 3: Oxygen and Nitrate contents of in dry and rainy season water samples of Abuja Municipal.

	Dissolved Oxygen (mg/l)		Biological Oxygen Demand [BOD] (mg/l)		Nitrate (mg/l)	
Sample	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
Garki Tap Water	176.5±0.02*	175.6±0.04*	0.01±0.01	0.01±0.01	22.4±0.78	23.4±0.09
Garki River Water	146.9±3.12	140.3±2.92	21.4±2.09	18.9±2.71	42.7±2.36*	44.8±3.39*
Maitama Tap Water	176.4±0.06*	176.2±0.09*	0.01±0.01	0.01±0.01	22.3±0.62	22.5±0.17
Maitama River	153.7±2.16	150.6±2.35	15.3±2.02	14.8±2.67	33.9±3.53	37.3±2.01
Wuse Tap Water	175.9±0.01*	176.3±0.02*	0.01±0.01	0.01±0.01	22.4±0.35	23.2±0.07
Wuse River	123.5±4.32	118.9±3.71	26.7±3.07*	29.6±3.77*	46.4±3.63*	49.7±3.57*

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$

3.4 Heavy and Trace metals content of water samples

Heavy and trace metals contents of water samples in dry and rainy season water samples of Abuja Municipal is shown on Table 4. Cadmium was not detected in all tap water samples and the levels were low in both dry and rainy season river water samples with a range of 0.005–0.017ppm. An increase in the Wuse rainy season Cd levels was seen (0.017) in comparison to that of Garki and Wuse rivers, however, this was not statistically significant (p>0.05). Pb was detected in all water samples with significantly higher levels in both dry and rainy season Wuse river samples. Lower levels of Pb were seen in tap water samples when compared to the river samples. Also lower levels of Pb were seen in dry season river samples in comparison to the rainy season samples; with the exception of Wuse water samples, these lower levels were not statistically significant (p>0.05). All water samples tested showed some contamination of Cu, Zn, Mn and Fe. The level of these metals in tap water was low when compared to the river samples. An increase in the contamination pattern of these metals was seen in rainy water samples when compared to dry season samples; this increase was not significant (p>0.05).

TABLE 4: Heavy and trace metal levels in dry and rainy season water samples of Abuja Municipal

	Cadmium		Lead		Copper		Zinc		Manganese		Iron	
Sample	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
Garki tap water	ND	ND	0.039 ±0.06	0.041 ±0.03	0.019 ±0.07	0.026 ±0.01	0.048 ±0.12	0.086 ±0.06	0.045 ±0.04	0.035 ±0.09	0.027 ±0.03	0.041 ±0.09
Garki river water	0.009 ±0.03	0.009 ±0.07	2.107 ±1.08	2.340 ±0.92	0.861 ±0.13	0.925 ±1.30	0.356 ±0.13	0.513 ±0.09	2.531 ±0.19	2.668 ±1.34	3.015 ±1.45	3.513 ±1.72
Maitama tap water	ND	ND	0.038 ±0.09	0.043 ±0.05	0.017 ±0.13	0.027 ±0.92	0.047 ±1.02	0.089 ±0.76	0.047 ±0.19	0.035 ±0.08	0.025 ±0.12	0.043 ±0.09
Maitama river	0.006 ±0.16	0.007 ±0.13	1.923 ±0.62	2.051 ±1.31	0.671 ±0.05	0.855 ±0.13	0.291 ±1.10	0.362 ±0.16	1.691 ±0.12	1.930 ±1.07	2.315 ±0.81	2.506 ±0.70
Wuse tap water	ND	ND	0.038 ±0.19	0.043 ±1.02	0.018 ±0.02	0.029 ±1.11	0.047 ±0.16	0.088 ±1.03	0.046 ±1.03	0.035 ±0.08	0.026 0.16	0.042 ±0.10
Wuse river	0.012 ±0.18	0.017 ±0.017	3.029 ±1.02*	4.316 ±1.95*	0.923 ±0.95	0.987 ±1.07	0.561 ±1.12	0.723 ±0.84	3.011 ±1.13*	3.412 ±0.95*	3.513 ±1.02*	3.792 ±0.72*

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$. Values expressed in ppm. ND = Not detected

3.5 pH, Nitrates and microbial load of soil samples

Table 5 shows the pH, nitrates level and microbiological (bacterial and fungal counts) of dry and rainy season soil samples of Abuja Municipal. The pH of the soil samples ranged from 5.4–6.5, for both dry and rainy seasons; there was no significant ($p>0.05$) change in pH levels in all samples. The highest level of nitrates was seen in Garki and Wuse rainy season soil samples. The levels were above the WHO safe limit of 45ppm. Significant ($p<0.05$) increase in the number of bacterial and fungal colonies was recorded in all rainy season soil samples when compared with dry season soil samples. Wuse soil samples had the highest levels of bacterial and fungal colonies for both dry and rainy season samples; these levels were significantly ($p<0.05$) higher when compared to Garki and Maitama samples.

TABLE 5: The pH, nitrates level and microbial load of dry and rainy season soil samples for Abuja Municipal.

	pH		Nitrate (ppm)		Bacterial Colonies (Total Counts Per Litre)		Fungal Colonies (Total Counts Per Litre)	
Sample	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
Garki soil	6.3±0.37	6.2±0.09	43.2±1.30	46.7±1.07*	30.0±0.0	35.5±0.12*	4.60±0.05	6.50±0.01
Maitama soil	6.4±0.52	6.5±0.12	36.7±1.62	40.2±1.35	20.5±0.02	27.5±0.01	3.30±0.09	5.0±0.0
Wuse soil	6.1±0.53	5.4±0.16	45.4±1.60	48.1±1.81*	40.6±0.07	45.4±0.03*	14.3±0.71*	18.7±0.95*

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$. Results expressed in ppm.

3.6 Heavy and Trace Metal Content of Soil

The results of analysis of heavy and trace metals in dry and rainy season soil samples of Abuja Municipal are shown on Table 5. Lead was detected in significantly ($p<0.05$) higher levels in Garki and Wuse dry and rainy season soil samples when compared to all the other metals, there was also a significant ($p<0.05$) increase in lead levels in Wuse and Garki samples for both dry and rainy season soil, when compared to that of Maitama soil samples. With the exception of lead, low levels of all the other metals analysed were seen in the soil samples.

TABLE 6: Heavy and trace metal content of dry and rainy season soil samples of Abuja Municipal

	Cadmium		Lead		Copper		Zinc		manganese		Iron	
Samples	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
Garki soil	0.004	0.003	3.600	3.405	0.015	0.012	0.012	0.011	0.004	0.005	0.015	0.015
	±0.01	±0.02	±0.12*	±0.16*	±0.07	±0.01	±0.03	±0.09	±0.05	±0.02	±0.06	±0.07
Maitama soil	0.003	0.003	1.425	1.305	0.012	0.011	0.012	0.009	0.003	0.003	0.014	0.013
	±0.01	±0.04	±0.17	±0.12	±0.11	±0.04	±0.01	±0.32	±0.01	±0.02	±0.14	±0.03
Wuse soil	0.006	0.004	4.010	3.500	0.017	0.014	0.017	0.015	0.005	0.004	0.016	0.014
	±0.05	±0.09	±1.06*	±1.02*	±0.07	±0.13	±0.10	±0.13	±0.07	±0.12	±0.09	±0.17

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$. Values expressed in ppm

3.7 – 3.9 Physico-electrchemical properties and Nitrate content of foodstuff samples

The physico-electrochemical properties and nitrate content of water extracts of dry and rainy season cassava, sugarcane and spinach samples of Abuja Municipal are shown in Tables 7 - 9. pH range for cassava was 4.2 – 5.4 for all samples. The range of conductivity for all samples was 60 – 80 μs with the highest levels seen in Garki rainy season cassava samples. Differences in the levels of acidity and alkalinity were seen for all samples without any statistical significance ($p>0.05$). Highest levels of nitrates were recorded in Wuse cassava sample (23.6±1.07) with the range of nitrates level at 15.9±1.82 – 23.6±1.07. The level of nitrates in Wuse rainy season cassava sample was significantly ($p<0.05$) higher than that of Maitama sample. pH range for sugarcane was 7.2 – 7.8; the range for conductivity was 49.7 – 56.6μs for both dry and rainy season samples. The highest (20.10ppm) levels of nitrates were seen in rainy season sugarcane samples. This level is significantly ($P<0.05$) higher than all nitrate levels detected from other districts.

pH range for spinach extract was 7.6±0.03 – 8.1±1.02, the range for conductivity was 42 – 48μs while acidity and alkalinity had 38 – 42mg/l and 61 – 65mg/l respectively. No significant ($P>0.05$) differences were seen in pH, conductivity, acidity and alkalinity samples from different districts. A significant ($P<0.05$) increase in rainy season spinach nitrates (28.7±1.35) was obtained when compared with other nitrate levels. Maitama had the lowest nitrate level when compared to Garki and Wuse, though these levels were not statistically significant ($P>0.05$). Nitrates levels in all food samples were not up to the WHO acceptable safe limit of 45ppm.

TABLE 7-9 **Physico-electrchemical properties and Nitrate content of foodstuff samples**

Sample	PH		Conductivity (μs)		Acidity (mg/l)		Alkalinity (mg/l)		Nitrates (ppm)	
	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
Garki cassava	4.9±0.05	5.2±0.01	62.5±0.07	68.7±0.09	235.5±1.72	204.3±1.09	69.9±0.73	75.1±1.61	17.8±2.01	18.2±1.13
Maitama cassava	5.1±0.07	5.2±0.06	60.7±1.75	62.9±1.35	229.1±3.10	211.3±2.04	65.2±0.71	69.4±1.09	15.9±1.82	16.6±1.01
Wuse cassava	4.2±0.03	5.1±0.04	60.4±1.23	62.7±0.83	239.1±0.16	225.6±1.32	67.7±1.90	70.5±1.07	20.0±0*	23.6±1.07*
Table 8 FOR SUGARCANE										
Garki s/cane	7.4±0.03	7.8±0.08	54.5±0.03	56.6±0.07	56.2±1.30	47.2±1.30	87.8±0.07	89.2±0.09	14.7±1.03	15.9±0.72
Maitama sugarcane	7.5±0.06	7.4±0.08	50.2±0.16	49.7±0.01	50.6±0.23	48.0±0	86.6±1.07	87.7±0.92	14.2±1.73	14.7±1.03
Wuse s/cane	7.2±0.01	7.3±0.03	51.1±0.04	53.3±0.17	54.4±1.03	45.1±1.00	88.7±0.71	85.5±1.75	15.7±1.02	20.1±1.79*
TABLE 9 FOR SPINACH										
Garki spinach	7.9±0.01	7.6±0.03	45.1±0.10	42.3±0.03	42.7±0.02	39.3±0.04	63.6±0.14	65.1±0.03	21.3±0.16	23.5±0.07
Maitama spinach	7.7±0.13	7.8±0.16	48±0.07	44.2±0.13	40.3±0.01	40.3±0.17	61.4±0.12	62.3±0.08	19.2±0.01	18.1±0.05
Wuse spinach	7.9±0.11	8.1±1.02	46.7±0.16	45.3±0.07	38.8±1.06	40.5±0.03	62.6±1.01	64.0±0	22.3±0.19	28.7±1.35*

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$

3.10 – 3.12 Heavy and Trace metal content of foodstuff

Heavy and Trace metal analysis in cassava extract for both dry and rainy season samples of Abuja Municipal are shown on Table 10. Higher levels (1.250±0.16) of lead were seen in Wuse dry season cassava in comparison to Garki (0.625±0.06) and Maitama (0.400±0). The levels were not significant ($p>0.05$). Zinc was also high in comparison to other metals; the levels of zinc were significantly ($p<0.05$) higher when compared to other metals for both dry and rainy season samples. There was no significant ($p>0.05$) difference between zinc levels in the various districts. Lower levels of heavy metals analysed were observed in all samples with the exception of lead and zinc (Table 10).

Copper was not detected in sugarcane sample (Table 11). Iron was also not detected in rainy season sugarcane samples at Garki district. In general, all the levels of metals detected in all the samples were quite low.

The levels of zinc in both dry and rainy season spinach (Table 12) were significantly higher for all samples when compared to other metals however, there was no significant ($p>0.05$) difference for zinc levels between districts. Dry season lead levels in Wuse spinach samples were found to be higher but not significant ($p>0.05$) when compared with Garki and Maitama districts. Manganese levels ranged from 1.205±0.15 – 1.605±0.07. All other samples were found in low quantity as shown in Table 12.

TABLE 10: Heavy and Trace metal content of dry and rainy season cassava of Abuja Municipal

	Cadmium		Lead		Copper		Zinc		Manganese		Iron	
Sample	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
Garki cassava	0.005 ±0.02	0.004 ±0.01	0.625 ±0.06	0.450 ±0.09	0.019 ±0.13	0.014 ±0.06	2.086 ±1.02*	2.135 ±1.09*	0.002 ±0.03	0.002 ±0.007	0.017 ±0.12	0.015 ±0.01
Maitama cassava	0.003 ±0.06	0.003 ±0.12	0.400 ±0	0.350 ±0.07	0.016 ±0.02	0.012 ±0.04	2.012 ±0.06*	2.001 ±0.03*	0.002 ±0.06	0.001 ±0.01	0.019 ±0.05	0.016 ±0.02
Wuse cassava	0.004 ±0.03	0.003 ±0.02	1.250 ±0.16	0.860 ±0.12	0.019 ±0.09	0.015 ±0.10	2.930 ±0.14*	2.803 ±0.19*	0.003 ±0.004	0.002 ±0.06	0.105 ±0.07	0.095 ±0.02

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$

Table 11. Heavy and Trace metal content of dry and rainy season sugarcane of Abuja Municipal

	Cadmium		Lead		Copper		Zinc		Manganese		Iron	
Sample	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season
Garki	0.002	0.001	0.065	0.040	ND	ND	0.002	0.001	0.001	0.001	0.001	ND
sugarcane	±0.01	±0.01	±0.02	±0.03			±0.01	±0.01	±0.01	±0.01	±0.01	
Maitama	0.001	0.001	0.050	0.020	ND	ND	0.003	0.002	0.001	0.001	0.001	0.001
sugarcane	±0.01	±0.01	±0.04	±0.05			±0.02	±0.01	±0.02	±0.01	±0.01	±0.01
Wuse	0.003	0.002	0.090	0.060	ND	ND	0.004	0.002	0.002	0.002	0.001	0.001
sugarcane	±0.02	±0.03	±0.10	±0.01			±0.01	±0.01	±0.01	±0.02	±0.01	±0.01

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$

ND: Not Detected. Results Expressed as ppm

Table 12. Heavy and Trace metal content of dry and rainy season spinach of Abuja Municipal

	Cadmium		Lead		Copper		Zinc		Manganese		Iron	
Sample	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season	Dry Season	Rainy Season
Garki	0.012	0.011	0.201	0.169	0.012	0.009	2.013	2.500	1.605	1.205	0.135	0.161
spinach	±0.03	±0.01	±0.02	±0.01	±0.03	±0.01	±0.12	±0.01	±0.07	±0.15	±0.02	±0.11
Maitama	0.011	0.009	0.200	0.142	0.008	0.005	2.109	2.151	1.500	1.391	0.153	0.113
spinach	±0.02	±0.01	±0. 03	±0.13	±0.07	±0.01	±0.05	±0.12	±0.01	±0.10	±0.06	±0.03
Wuse	0.016	0.013	0.923	0.565	0.014	0.011	2.312	2.611	1.601	1.517	0.251	0.320
spinach	±0.04	±0.02	±0.03	±0.11	±0.05	±0.02	±0.09	±0.01	±0.01	±0.06	±0.15	±0.04

Values are expressed as mean ± standard deviations of two samples. Values marked with asterisk differ significantly (Student's t – test) when compared with other corresponding values $p<0.05$

Results expressed as ppm

CHAPTER FOUR

4.0 DISCUSSION

4.1 Soil and Water Integrity

The biological integrity of the Abuja Municipal soil and water collected from the different sampling sites was evaluated for the presence of macro-organisms (insects, ants, etc). The presence of live macro-organisms was observed at all sites. These observations indicate a low degradation of the water and soil quality in this ecosystem. Orisakwe et al., (1999) in a similar study at Nnewi (Anambra State), observed a total absence of living macro-organisms at all sampling sites, there finding was in agreement with other studies documenting the poor chemical, physical and biological integrity of rivers in industrialised areas elsewhere (Herkovits *et al.*, 1996). However, Abuja Municipal being mainly an administrative city for now is yet to experience pollution due to rapid industrialization.

4.2 Ecotoxicological profile of Water

The normal pH value of water ranges from less than 6 to more than 8, while that of soil ranges from 4 to 8. The pH range of all water samples for both dry and rainy seasons was found to be 6.1 – 6.7 (Table 1A). This pH is capable of sustaining aquatic life both in the dry and rainy seasons. The pH of an aquatic environment can be upset by added acid or alkali form wastewater. To maintain a good fish population in a marine environment for instance, it is necessary to keep the pH of the water in the range of 6.7 – 8.6. Only a few fishes can survive outside this range and a medium with extremely high pH (>10) or low pH (<4.0) cannot support fish at all (Terzwell; 1957). pH is also known to influence the toxicity of inorganic pollutants such as ammonia, cyanide and hydrogen sulphide to fishes. The toxicity of ammonia is enhanced by high pH, while the toxicity of cyanide and sulphide is enhanced at low pH (Orisakwe *et al.*, 2001). pH is a measure of how acidic or basic a water sample is. Most life forms generally tolerate pH in water between 6.5 to 8, but outside of these ranges many problems begin to occur, especially if the change in pH is sudden. Lower pH extremes can result in the death of many aquatic organisms and can also result in mobilisation of toxic heavy metals. Higher pH and extremes can result in precipitation reactions and can also kill aquatic organisms. Mining and industry wastes and land clearing activities are also known to have contributed to pH disturbances in many areas. The observed elevated increase in conductivity, acidity and alkalinity level seen in all rainy season river samples when compared to dry season samples, might be attributed to the fact that during rainy season, a lot of waste products and other pollutant substances are washed down into the rivers; increase in seepage of fluid and water from organic matter sources into rivers is seen during the rainy season.

The acceptable range for total dissolved solid in any water sample is 500 – 1500mg /l. The observation that all the water samples in the municipal contain low dissolved solids in this study requires a reinvestigation probably using different methods. Suspended solids were not detected in all tap water samples. River Wuse had the highest (34±1.12) level of SS during the rainy season due to the reasons earlier mentioned; while dry season Maitama River had the lowest SS (16.3±2.71) observed. SS is a measure of total amount of particle material in a water sample. It includes all types of sediments (silt, clay, sand), precipitates, colloids, and inorganic and organic matter larger than 0.45μm. High levels of SS can make the water more turbid and may indicate erosion problems in the catchment. Fine particulate matter can also provide a means of transport for nitrogen, phosphorous, toxic heavy metals, pesticides, bacteria and may be and irritant for some fish. Longer-term impacts of high SS include alteration of in-stream dynamics and receiving water-bodies (e.g. blocking channels and filling river pools), potential flooding problems and loss of aquatic flora and fauna habitat.

Regarding water hardness, there are no distinctly defined levels of what constitutes a hard or soft water supply. A generally accepted classification is that water less than 75mg /l of $CaCO_3$ is soft; 75 – 150mg / l is moderately hard and above 150mg/l of $CaCO_3$ is hard (Yang *et al.*, 1996). Two theories have been offered concerning causative agent for the relationship between death from cardiovascular disease and water hardness. Soft water is more corrosive than hard water, and promotes the dissolution of cadmium, lead and other toxic substances from the plumbing system into the drinking water (Nishijo *et al.*, 1995; Schwartz, 1995). Another theory is the protective effect of magnesium from the water (Karppanen, 1986; Marier, 1986). All the water samples analysed for both tap and river can be considered soft, so that overall hardness of its drinking water cannot be seen as a main etiologic factor in cardiovascular disease in the Abuja municipal if it exist. However, the relationship between hardness of water and cardiovascular disease in Abuja is a subject of further research work, which is beyond the scope of this work.

As stated earlier, Wuse river flows out of the city and collects waste from organic and inorganic matter along with it, also Garki and Maitama rivers empty themselves into Wuse river may add to the waste burden in Wuse river. In addition, Wuse District of Abuja seem densely populated, being the first part of the city to be inhabited, it also houses many low / middle income earners when compared to Garki and Maitama Districts. Biological oxygen demand (BOD) in all river samples ranged from 14 – 29 for both dry and rainy seasons. This level can sufficiently sustain microbial activity. A stream without oxygen is a dead stream for fish and for many organisms, a stream with an inadequate oxygen level is considered polluted for those organisms that require dissolved oxygen above existing level. Wuse River had the lowest levels of dissolved oxygen (118.9 ± 3.71) compared to other river water samples analysed. Dissolved oxygen is a measure of the amount of oxygen gas dissolved in a water sample. Oxygen is essential for most aquatic organisms to live. Diffusion of oxygen from the atmosphere into the water is extremely slow and is dependent on atmospheric conditions, water temperature, turbulence and mixing of the water column. Hypoxic conditions (low O_2) may be due to stagnant waters, high rates of plant and animals' respiration or bacterial decomposition of organic matter. Fish kills and nutrient release from sediments are common under these conditions. Hyperoxic conditions (supersaturated O_2) can be associated with temperature increases, turbulent water flow or by high rates of phytoplankton photosynthesis. These conditions can also lead to fish deaths. The presence of macro and micro-organisms in the rivers analysed, coupled with the level of dissolved oxygen which is acceptable for the survival of aquatic organisms (Orisakwe *et al.*, 1999), and the low levels of BOD is an indication that the rivers are still viable for the sustenance of aquatic life and as such, cannot be said to be polluted for now based on the present findings.

With the exception of Wuse river, all the nitrate levels obtained in all the samples analysed fall below the WHO recommended maximum safe level for human consumption (45mg / L) (WHO, 1985). The increase of nitrate contents of water and soil during the rainy season can be considered an indication of increased pollution of water and soil from organic sources and increased in agricultural activities during this period. Significant sources of these organic matter and nitrate are, chemical fertilizers from cultivated land, drainage from sewage, livestock feeds, domestic and industrial waste water. The level of industrialization in Abuja is low; as such, pollution of water and soil from industrial wastewater is not expected. In most urban and rural areas in Nigeria, human wastes are poorly handled and in many cases not safely disposed of. In rural areas, some people construct pit latrines while majority of the people use open bush for toilet purposes. The pit latrines are usually in close proximity with artesian wells. In urban areas, wastes are either disposed of on open fields or when treated, the resulting effluents are pumped directly into nearby water drainages, streams, rivers or lagoons that become continuously polluted. It is also common practice in many parts of Nigeria to rear livestock at home. The dung and feed waste are used as manure and are therefore kept at a site within the household before use. These activities act as available sources of nitrate inputs around the house (Gbodi *et al.*, 2001). During the rains, increased percolation and seepage of fluid from close pit latrines and water run of from livestock and sewage disposed site into aquifers might account for elevation of nitrate content of the river samples analysed during the rainy season. The result obtained in this study is in agreement with that of a similar study conducted by Gbodi *et al.*, (2001) in Bosso, Niger State, Nigeria.

Another primary source of contamination of rivers or land by nitrate is agricultural fertilizers and these are applied in a reckless and widespread manner as the rural dwellers and amateur farmers are encouraged by government to use fertilizers extensively in order to produce more food for the teeming Nigerian population. Many households maintain gardens and small farms around the compound and on these residential farms nitrogenous fertilizer and manure are applied. It is believed that most of the applied fertilizers used by ignorant farmers are washed away to pollute shallow and deep waters during the rains when agricultural activities are at their peak. (Gbodi and Atawodi, 1986; Gbodi *et al.*, 2001). Although most of the farmlands in Abuja are rapidly giving way for construction of offices and residential accommodation, reasonable farmlands are still cultivated with the use of artificial fertilisers within and outside the city, which can contribute to the nitrate burden on the soil and the rivers.

The pollution peaks are sustained in the rainy season because sludge deposits with high ammonia content become suspended in water and are washed into various water bodies including wells and waterworks reservoirs (Suess, 1986; Gbodi *et al.*, 2001). Death and decay of plants, animals and other organisms contribute to soil organic matter, which, in turn, is washed into water bodies particularly during the rains (Doe, 1982; Gbodi *et al.*, 2001).

Although the original master plan of the city of Abuja was made in such a way as to accommodate civil servants and other business entrepreneurs and to handle waste generated by human activities, the present situation on the ground is that many low income people are in the city, the houses are not enough to accommodate all the people; and as such, many have resorted to building make-shift tents for accommodation with the attendant generation of domestic waste and attendant pollution problems.

The low levels of nitrates (and indeed other parameters) in tap water was expected because unlike rivers, tap water is natural water that has undergone purification at the municipal water treatment plant before being supplied. This observation also agreed well with other similar studies (Gbodi *et al.*, 2001). Abuja has a water treatment plant located at the Lower Usuma Dam. The principal processes of improvement of water at such plants include, clarification or sedimentation, decolourisation, deironing, disinfection and chlorination (Nikoladze *et al.,* 1989). Solid organic waste that would have been decomposed to nitrates and nitrites by microorganisms in polluted water are removed during the sedimentation process of water purification. Similarly, disinfection of water by chlorination annihilates pathogenic bacteria and viruses including nitrifying bacteria that would have otherwise generated nitrates – nitrites from organic wastes in untreated water. These purification processes including demineralisation would no doubt reduce the concentration of nitrates and other pollutant substances from tap water (Gbodi *et al.*, 2001).

A high nitrate intake had been associated with stomach cancer (Boeing, 1991). A nitrate concentration above the safe level causes cyanotic effect particularly in infants when contaminated water is used in preparation of their food formula (Ridder *et al.*, 1974; Derks *et al.*, 1997; Gbodi *et al.*, 2001).

4.3 Ecotoxicological Profile of Soil

The pH range from both dry and rainy season soil samples was found to be 5.4 – 6.5 (Table 2A) this pH, is favourable for agriculture (Terzwell; 1957). This present study did not agree with the study conducted by Orisakwe *et al.*, (2001); where soil pH (range 3.5 – 5.5) from 3 industrial sites at Nnewi (Anambra State), were found to be acidic and not favourable for agriculture. Abuja however, as mentioned earlier is not industrialized and as such, pollution from industries is not being expected for now.

During the rainy season the soil medium is more conducive for microbial activity, this may explain the increase of microorganisms during the rains in this study. Soil pollution due to micro organisms at Wuse district is on the rise due to the increase in the generation of domestic waste that are not promptly cleared by the appropriate authorities. Soil pollution by micro organisms at the Garki and Maitama districts can be said to be low based on the findings of this study, but this could also be expected to rise rapidly due to the increase in the generation of waste and the attendant increase in the activity of micro organisms that are known to multiply rapidly once there is enough nutrient. Three key aspects, of this problem are usually, the lack of sewage lines, increase in domestic and industrial discharge beyond the capacity of the city and the physical expansion of the city faster than the physical expansion of the sewage system (Orisakwe *et al.*, 1999). A good sewage system is in place in Abuja Municipal, but presently due to the rapid physical expansion of the city, faster than the expansion of the sewage system coupled with the lack of proper maintenance of the existing system and the increase in domestic discharge, can actually increase microbial pollution in the city in the near future if not checked.

4.4 Toxicity Profile of Foodstuff

The levels of acidity observed in cassava samples may not pose any danger to the populace who consume the processed cassava, but may in part be responsible for a lot of other health problems especially in the form of peptic ulcers and increase in epigastric pains when cassava is consumed raw, which is a practice in the northern part of Nigeria. However, the relationship between peptic ulcer and the consumption of raw cassava needs to be investigated.

All food samples contained various levels of nitrates, the highest levels of nitrates seen in Wuse food samples were below the WHO recommended intake of 45ppm and the results obtained in this study agree with other studies (Fytianos and Zaragianis, 1999). Green leafy vegetables have been shown to contain high nitrates levels and to contribute about 99 percent of total daily dietary intake (Derks et al., 1997; Fytianos and Zarogiannis, 1999).

4.5 Heavy and Trace metal profile of River, Soil and Foodstuff

The presence of cadmium (Cd) in all river, soil and food samples is noteworthy. There was an uneven distribution of Cd in all samples with the highest level obtained in Wuse rainy season river sample (0.017). Increase in Cd level during the rainy season may be as a result of agricultural activities. Commercial phosphate fertilisers usually contain about 20mg/kg of Cd, and the use of fertilisers in Abuja for farming is a common occurrence as with other parts of the country. The levels of Cd observed in this study are too low to produce toxicity, and if the primary contamination of soil and water in Abuja were from agricultural activity, then levels would be expected to still be low because most of the farmlands within and around the city are rapidly being converted for residential purposes. If however, the source of contamination is not from fertilisers, then probably the levels of Cd may be expected to rise to a significant level in the future if it is not checked; this should however, be further investigated and monitored. Total daily intake of Cd from food, water and air in North America and Europe varies considerably but is estimated to be about 10 – 40 μg per day (Friberg *et al.*, 1986). As previously stated, Cd is highly toxic, accumulating in the body and eventually causing effects such as tubular dysfunction, and disturbances of calcium homeostasis and metabolism (WHO, 1992). The results obtained in this study agreed well with a similar study conducted in the eastern part of the country where low contamination pattern of Cd was observed (Orisakwe *et al.*, 2001). Cd was not detected in all tap water samples probably because of the processes drinking water undergoes before being supplied to the public.

The presence of lead (Pb) in all samples analysed is also noteworthy. Wuse river and soil samples for both dry and rainy season showed a significantly higher Pb levels when compared with other samples. These levels are relatively high when compared with the acceptable value of 0.2ppm in the body (Hicks; 1992). As earlier mentioned, Wuse district of Abuja is highly populated with people from all works of life, (including automobile mechanics) followed by the Garki district, where by physical estimation can be said to be over populated. Also, Wuse River is the major river that carries most waste products out of the city. Therefore, for Pb levels to be high in Wuse and in Garki districts could be attributed to the increase in activities that can lead to increase in contamination with Pb. These high levels could probably also be due to the presence of several automobiles in the city with resultant Pb emissions from combustion of leaded petrol, which is presently used in Nigeria.

Hipkins *et al.*, (1998) reported that sources for Pb contamination and exposure include, among other things, Pb – based indoor paints in old dwellings, Pb in dust from environmental sources, Pb in contaminated drinking water and Pb in air from combustion of Pb-containing industrial emissions. In Nigeria, as in many developing countries, the density of traffic is becoming important in urban centres particularly in Abuja where more than 60% of vehicles use leaded petrol. For economic reasons, the number of old cars on the roads are daily on the increase adding to traffic density and air pollution.

Previous studies have showed correlation between high traffic density, especially with leaded petrol and high Pb concentrations in the air and soil measured in certain urban cities of the world (Caprio *et al.*, 1974; Graziano, 1994; Cheng *et al.,* 1998; Heinze *et al.*, 1998; Lanphear *et al.*, 1998). These studies postulated that petrol is likely to be the main origin of lead exposure in the areas studied. Since there are no Pb acid manufacturing plants in Abuja and neither are there Pb smelting industries, we can infer that, the increase in the amount of lead seen in river water and soil could be due to increase traffic density with Pb emissions from combustion of petrol. This then, could be expected to be on the increase as long as leaded petrol is used to run motorcars.

The presence of Pb in tap water may not pose an immediate danger because the levels obtained were less than 0.05-ppm, and daily intake from water is usually about 10ppm (NRC, 1993). Pb poisoning, though rare arise from accumulative inhalation of dust and consumption of organolead compounds, resulting in headaches, dizziness and insomnia. Among the population exposed to Pb, children are the most vulnerable and sensitive. Despite its preventability, Pb toxicity remains a common paediatric problem (Landrigan, 1992; Mushak, 1992). Not only can intoxicated children have impaired intelligence, but also they are aggressive, more distractible, disorganised and less able to follow directions (Needleman, 1993; 1994). Even at low blood Pb (BPb) concentrations, adverse effects of Pb on the neuropsychological development of children have been observed. With Pb levels over 800ppm, children generally show symptoms of an acute clinical Pb intoxication with irreversible encephalopathy (Diouf *et al.*, 1995). Man's daily intake of Pb from food and drink normally range from

200 – 400 ppm, of which only about 10% is absorbed (NRC, 1993). BPb concentrations in both children and adults in Abuja municipal need to be investigated and monitored This, however, is for further research.

This study found low and uneven distribution in the levels of Cu, Zn, Mn, and Fe. Acute poisoning resulting from ingestion of excessive amounts of oral copper salts, (most frequently copper sulphate), may produce death from centrilobular hepatic necrosis (Chuttani *et al.*, 1965). Industrial exposure may occur in copper fumes resulting in metal fume fever with dyspnoea, chills, headache, and nausea (Beliles, 1994).

Zn is generally considered a relatively non-toxic metal (NAS, 1986), but some Zn salts such as chloride, in sufficient concentrations can injure tissues. Inhalation, exposure of skin, or ingestion can produce local pathological effects. In the present study, significant levels of Zn were observed in food samples when compared to water and soil samples. These levels are however, not up to the recommended daily allowances of 8 – 15 ppm in humans.

Mn is an essential element and is a co-factor for a number of enzymatic reactions. Occupational inhalation exposure is the primary route for Mn toxicity. The primary toxic effect of occupational inhalation exposure is neurological damage (Roels *et al.*, 1987); however, inhalation exposure to Mn can also affect the lung directly, causing metal fume fever, pneumonitis, chronic obstructive lung diseases, and pneumonia (ATSDR, 1998; Nemery, 1990).

Acute iron toxicity is nearly always accidental ingestion of iron-containing medicines and most often occurs in children (Litovitz *et al.*, 1992; Weiss *et al.*, 1993). Despite supplements being packaged in child – resistant packages and carrying warning labels, the public perception of their potential danger is low (Huott and Storrow, 1997) and fatalities in children have recently increased (Weiss *et al.*, 1993; Berkovitch *et al.*, 1994; Anderson; 1997).

The levels of Cu, Zn, Mn and Fe observed in this study may not pose an immediate threat to the populace and the ecosystem. However, the likelihood of increase in their concentration and accumulation occurring in the near future, leading to harmful effects should not be over looked.

4.6 SUMMARY

The ecotoxicological profile of Abuja Municipal was investigated with a view to determine the base line values of water, soil an food contamination pattern in the city and to provide a basis for the need for regular monitoring programmes for the environment.

The biological integrity of both water and soil in the city has not been affected yet by pollutant substance based on the finding of this study. The presence of macro-organisms was observed at all sampling sites. The pH of both water and soil for all samples analysed was within acceptable range. This is an indication that agricultural activity can still be sustained by the soil in the city, and aquatic life can still be preserved at least for now. The biochemical oxygen demand and the total dissolved oxygen observed for both seasons in this study can sufficiently sustain microbial activity, since sufficient oxygen was present in all river samples analysed.

The range of total hardness for all water and food samples both during the rainy and dry seasons was found to be low, which is considered soft and as such cannot be seen as a main etiological factor in cardiovascular disease associated with water hardness if it is prevalent in Abuja. This however calls for further investigation. The low dissolved solids observed in this study for all samples calls for a reinvestigation, probably using a different analytical method. The level of nitrates observed in this study could be as a result of agricultural and domestic activities in the city. Soil microbiology revealed a moderate activity of microbial life in the soil, at least microbial pollution was not observed in this study, however this should be monitored.

Levels of heavy metals contaminated varied at different sampling sites and with different samples analysed. However, heavy metal contamination can be said to be low in the city presently, however, accumulation can occur both in the environment and in body organs more especially in the children.

Since elevated lead levels were seen in river and soil in Wuse and Garki districts, it is recommended that a control measure to reduce lead exposure within the city and to the adjoining communities should be put in place immediately. A public awareness programme has to be instituted to alert the populace and the communities of a possible rise in environmental contamination by lead. There is also a need for a follow-up study by research toxicologists of the blood lead levels of children and adults. Aquatic life toxicity needs also to be researched into.

4.7 RECOMMENDATIONS

Nigeria as a developing nation with leaded petrol still being used has difficulty enforcing waste laws, and years of neglect and accumulations may pose problems that will be expensive to solve. With the downturn in the economy, it is clear that expensive high-tech solutions for clean up are unrealistic. Therefore, it is important that relatively inexpensive ways be found to deal with old accumulations and that waste minimisation strategies be developed to alleviate the problem of wastes generated in the future. Lead concentration in petrol should be completely removed or reduced to the barest minimum. The Environmental Protection Board should be well funded to be able to dispose of waste generated appropriately and to be able to cope with future population expansion. Mechanics should be given a certain part of the city where they can carry out their operations outside the city. In the advent of industries coming to Abuja, a certain area far away from the populace should be assigned to them for their factories, also regulatory bodies should be put in place to ensure safety standards are maintained by the industries. The public must be enlightened and encouraged to know about the importance of recycling, and to practice it. Severe penalties should be put in place to punish offenders who violate rules bothering on environment. All stakeholders must come together to fight environmental degradation and pollution.

There is need to put in place a regulatory body to regulate the importation of fairly used automobiles and to reduce or minimize the level of such importation. On this scale however, the Ministry of Science and Technology need to be encouraged to stimulate stakeholders to manufacture environment friendly automobiles for use in Nigeria.

The Ministry of Petroleum resources need to be enlightened on the dangers involved in the use of leaded petrol. Measures should be put in place to remove lead from the petrol that is used in the country, or at least be reduced to the barest minimum.

Evaluations of the environmental impact of human activities as well as strategies for river conservation should be considered a main priority for environmental and human health. The idea that rivers are convenient means of clearing and carrying pollution away from the discharge point should be urgently and properly reconsidered in order to protect water quality, the ecosystem and human health.

The control of illegal discharges into the municipal sewage system should be considered a high priority. Short-term structural actions to improve environmental enforcement must be taken by the Federal Environmental Protection Agency (FEPA). One of these actions could be to map and designate certain location(s) as industrial estate and to ensure that industries are only sited at these areas so as to require such areas to collect and recycle waste from their plants. This would improve water management in the city and at the same time would reduce the number of potential illegal discharges into the municipal sewage system.

4.8 CONCLUSION

Even though the presence of pollutant substances were observed in the city of Abuja Municipal in this study, the contamination pattern at the present level is low and may not constitute an immediate problem to public health and the ecosystem if controlled. However, the ecosystem needs o be monitored and checked regularly to forestall danger due to increase in pollutant substances and accumulation of such substances.

4.9 SUGGESSTION FOR FURTHER STUDY

1. Regular monitoring and evaluation of environmental impact of human activities and public health.
2. Blood lead levels in children should be investigated
3. Relationship between blood lead levels and cardiovascular disorders/stress should be investigated and monitored in adults.
4. Pollution level should be investigated in aquatic animals.
5. Study relationship between industries, environment and public health.
6. Study contamination pattern of nitrates in soil and water.

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