ASSESSMENT OF THE EFFECTS OF THE INDUSTRIAL EFFLUENTS OF THE KADUNA REFINING AND PETROCHEMICAL COMPANY LIMITED ON THE QUALITY OF ROMI RIVER, KADUNA, NIGERIA

BY

JIMOH, ABDULWASIU ADEBISI

M.TECH/SSSE/2007/1814

DEPARTMENT OF GEOGRAPHY

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA.

AUGUST, 2010

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AUGUST, 2010.

DECLARATION

ЛOH ABDULWASIU ADEBISI, declare that this thesis work was written by me has not been presented either in whole or part, for the award of any post duate degree anywhere else. All literatures cited have been duly acknowledged in reference.

ЛOH, ABDULWASIU ADEBISI	31/08/2010 **DATE:**

CERTIFICATION

This thesis titled "Assessment of the effects of the industrials effluents of the Kaduna Refining and Petrochemical Company limited on the quality of Romi River, Kaduna Nigeria". Carried out by Jimoh Abdulwasiu Adebisi (M.Tech/SSSE/2007/1814) meets the regulations governing the award of the Degree of Master of Technology (M.Tech.) of the Federal University of Technology Minna and is approved for its contribution to scientific knowledge and literary presentation.

Dr. A.A. Jigam
Name of Supervisor

03/09/10
Signature & Date

Dr. A.S. Abubakar
Name of Head of Department

18/10/2010
Signature & Date

Prof. M. Galadima
Name of Dean,
School of Science & Science Education

22/10/2010
Signature & Date

Prof. S.L Lamai
Name of Dean, Postgraduate School

2/2/2011
Signature & Date

DEDICATION

This Research Work Is Dedicated To My Lovely Family For Their Love And Support.

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I express my gratitude to Almighty God for wisdom and inspiration toward writing this research work. Creating this piece of work to knowledge has been a team effort. I have been fortunate to have the assistance of a very talented person, an educator and Head of Department in person of Dr. A. A. Jigam my humble project supervisor who skillfully crafted significant portions of the manuscript, drawing on both his considerable knowledge and notable literary skill to complement my abilities beautifully, God bless you Sir. With due respect, I acknowledge the former Head of Geography Department Dr. Akinyeye whose fatherly advice is immeasurable and the present Head of Department Dr. A. S. Abubakar. This work would be lacking if Mal. Saidu Salihu the Geography Department Postgraduate Coordinator is not recognized for being there for us whenever we need his support. In fact, he is our moral booster and prime mover. My profound gratitude goes to all my course mates, especially pollution and waste management course mates. Big thanks to Grannyconnections.

ABSTRACT

Kaduna Refining and Petrochemical Company use vast amount of water for several purposes, the source of which is Romi River flows. The company also discharges vast amount of Effluents (waste water) in polluted forms into this River flows. However, since the demand for zero discharge is rather idealistic, it can only be attempted to abate the consequent pollution by converting it to a less noxious form. This water pollution affects the live of many people, especially those living in the vicinity of the industries. The people who live along the banks of the river complain of foul smelling water. The research is aimed at ascertaining the level of pollution of Romi River flows and the consequences of improper Effluents treatment of Kaduna Refining and Petrochemical Company in Sabon area of Kaduna State. Since they have no other source of water for domestic use, it is imperative that steps are taken to ensure that the Effluents (Waste Water) is pre-treated properly and tested to conform to standard before discharge in Romi River flows. The study was hence carried out to determine the nature of the Effluents discharge into Romi River by KRPC and to see the effects on water quality and conformity with Federal Environmental Protection Agency (FEPA) standards. During the assessment, few litres of Effluents waste water from the retention tank in the Refinery Site, Romi Upstream and Downstream River flows were collected during the dry and rainy season as samples for most Physical, Chemical and Heavy Metals parameters analysis. A separate volume of each was collected in clean empty plastic bottles and was examined thoroughly with the use of series of computerized systems, equipments, machines and also with the use of individual apparatus. The Physical and Chemical Parameters of Kaduna Refining and Petrochemical Company for Effluent, Romi River Upstream and Downstream were highly concentrated above Federal Environmental Protection Agency. But for Heavy Metal parameters which were within the stipulated standard. The Industrial Effluent of KRPC contained some hazardous chemical which could cause kidney damage, corrosion, stain in cloths, liver destroy, etc. and which is capable of rendering the water unsuitable for aquatic and human use. It is paramount that actions should be taken drastically to step up the Effluents treatment properly and efficiently before being discharge into Romi River flows. The Refinery should build modern and standard laboratory rooms in order to carry out all the analysis at all time. There should be regular and constant records keeping of data and results of analyses on Effluents (wastewater) for Waste management committee, so as to enhance reliable inference to draw on easily.

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LIST OF ABBREVIATIONS

FEPA Federal Environmental Protection Agency

NIS Nigeria Industrial Standard

WHO World Health Organization

^oC Degree Celsius

NTU Neu Turbidity Unit

Mg/l milligram/litre

BOD Biological Oxygen Demand

COD Chemical Oxygen Demand

DO_2 Dissolved Oxygen

KRPC Kaduna Refining and Petrochemical Company

TDS Total Dissolved Solid

TSS Total Suspended Solid

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The era of technological awakening is one of the contents of measuring civilization in this contemporary time and it is also a yardstick for basic necessity of life. Water portability is top most priority on the world developmental agenda list. The growth in global population and it's most increasing need for energy has so much stressed man's relationship with his environment that it depict gloomy picture when viewed. This is made all the more glaring when it is realized that man spoilt earth not because of ignorance but because he did not just care.

Recent developments have indicated that of many of the problems facing mankind e.g. conflicts, social upheavals, disease, and hunger etc. environmental pollution is the most serious and its consequences the most far reaching. In fact, (Ferguson, 2002) predicted that future wars will be fought not over land or minerals, but over the control of water which is a vital environmental resources. The past few years have however seen the desirability of positive actions to be taken to restore the quality of the environment and to protect it from all forms of pollution.

Water is the elixir of life. Every living depends on water for survival. So the importance of environmentally safe water cannot be over emphasized.

Water is said to be polluted when and because of man's actions in adding or causing the addition of matter to water or altering its temperatures, the physical chemical or biological characteristics of water are changed to such extents, that its utility for any reasonable purpose or its environmental value is demonstrately depreciated.

1.2 Statement of the Problem.

The Effluents (Waste water) from Kaduna Refining and Petrochemical Company processes is constantly discharged into the Romi River. The people who live along the banks of the Romi River usually complain of foul smelling of their only source of water. The fish farmers gradually reduce in their practices due to dead of fish species and also frequent suffering of cholera diseases. Since they have no other source of water for their domestic uses, it is imperative that steps are taken to ensure that the water is pre-treated properly before discharge into Romi River.

1.3 Purpose and Significance of the Study

Industries use vast amounts of water for several purposes, the sources of which are nearly streams, rivers and lakes. These water bodies are normally locate in area adjacent to human settlements. They also discharge vest amounts of waste water in polluted forms into these water bodies. However, since the demand for zero discharge is rather idealistic, it can only be attempted to abate the consequent pollution by converting it to a less noxious form. Water pollution affects the lives of many people throughout the world especially those living in industrial areas of developing countries. Moreover the organic and inorganic load in natural water continues to increase. Among the causes of this are the large volumes of waste water often subject to little or no control originating from highly populated cities, the discharge of untreated effluents from industrial plants and the use of chemical fertilizers and pesticides in agriculture (Coje, 2002), Waste constituents that present pollution problems are those that deplete oxygen in the receiving water bodies and those that encourage excessive aquatic growth, those that are toxic to aquatic life and those that damage its aquatic appeal.

The consequences of polluted water include harm to animal and plant life, unpleasant odours, reduced water clarity, property and reduction in the recreational quality of coastal and inland beaches.

1.4 Scope and Limitation of the Study

This research focuses on Assessment of the effects of the industrials effluents of the Kaduna Refining and Petrochemical Company limited on the quality of Romi water in Sabon area. It takes into account only the Effluents (Waste Water), Romi Upstream and Downstream only

The findings of the study will be based primarily on data collected from experimental analysis of sample of water available at various Sampling points in Sabon area of Kaduna State. This study seeks to verify whether the discharged effluents waste water conforms to acceptable standards suit by the regulatory authorities (The Federal Ministry of Environment and World Health Organization)

1.5 Aim and Objectives of the Study

The Research is aimed at ascertaining the level of pollution of Romi River Flows and the consequences of improper Effluents treatment of Kaduna Refining and Petrochemical Company in Sabon area of Kaduna State.

The objectives are;

i. Determining the components of the waste water effluents discharged into the adjacent Romi River by the refinery.

ii. Identifying and assessing those components of the effluents that pose environmental hazards.

iii. Comparing the discharged effluents with standards set by the regulatory authorities to determine whether the environment is being short-changed by the operations of the refinery.

1.6 Description of the Study Area

Kaduna refinery was commissioned in 1980 and is located in the southern part of Kaduna state metropolis. It has two plants: the refinery and the petrochemical complex. Some of the products include premium motor spirit, domestic kerosene, and aviation fuel, cooking gas, lube, oils and feedstock for the manufacture of plastic. The many processes and operations carried out by the treatment plant where it is treated before being discharged as effluent into the nearby Romi River. The Romi River flows through various settlements before emptying into the River Kaduna. If the effluents are not properly treated, it will have a direct negative consequence on the livelihood of those living along its course and also on the aquatic life. This study seeks to verify whether the discharged effluents waste water conforms to acceptable standards suit by the regulatory authorities (The Federal Ministry of Environment and World Health Organization).

1.7 Justification of the Study

The scattered settlements along the Romi River from the point it discharges of the waste have complained of foul smelling water fetched from wells nearby. In addition the people who complement their livelihoods by fishing from small tributaries that take their source from the river complain of gradually depleting fish stocks as compared to the past. This unwholesome development may be attributable to the presence of pollutants discharged in the river by the processes of the refinery. To be fair, the refinery has its elaborate and highly sophisticated waste water treatment plant, but the research seeks to find answers to the following question: Is the treatment plant doings its work?

1.8 Method and Scope of Study

In order to achieve the aims, sample of the discharged effluent will be taken at the source point of discharge and at the downstream and the following parameters will be assess and measured: pH, Temperature, Total Hardness, Titrate alkalinity, total suspended solids, total dissolved solids, conductivity phenols, oil content, biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity, phosphate, ammonia, iron, zinc, lead, chromium, cadmium. The samples will be collected over a two week period and the tests will be carried out in a suitable laboratory.

1.9 Sources of Oil Industry Wastewater (KRPC)

There are many processes and operations carried out at Kaduna refinery and petrochemical company (KRPC) which require the use of water for several purposes and hence, the production of waste water.

The waste water generated from the plants are channeled via drainages to the waste water treatment plant where they are treated before being discharged as effluents to the Romi River.

Some of the waste water generated include: -

1. Cooling Water: - An important part of the refinery operation, is the complex heat recovery system from process unit. For this, water is used as a coolant.
2. Process Oily Waste Water: - From the lube, fuel plant etc.
3. **Oily Drains: - From crude oil, oil tank, intermediate tanks to oily sewer etc.**
4. Chemical Wastage: - Alkaline and acidic water, drainage and flushing from equipments use chemical reagents and samples, water from the laboratory.
5. Oil Free Water: - Drain from boiler, Rain water from roof and terraces not contaminated with oil, surface drainages etc.
6. Sanitary Waste Water: - from septic tanks, water from administrative block buildings, medical centre and central rooms.

1.10 Water Pollution Control

Kaduna refinery and petrochemical company (KRPC) was mindful of the hazardous nature of their waste to both human, plant and aquatic life. In order to alleviate the problems, all the waste water generated from the refinery flows into the waste water treatment plant (units) through the drainages and sewer systems.

The waste water treatment involves appropriate physical, chemical and biological treatment methods. The treatments includes: Oil skimming, Oxidation, Biodegradation, Clarification, Chemical addition, Filtration and Evaporation.

The major equipments involved are separator, a biofilter, a clarifier, a high rate filter and a retention pond from where the treated water is sent to Romi River.

Sludge treatment on the other hand involves sludge thickening and dewatering with the resulting dewatered sludge coke disposed off the side with a dump truck or burnt along with refinery refuse waste such as paper, food wood and paint in the sludge Incinerator.

1.11 Chemical Contamination

Over the years, many types of chemicals have gotten into our waterways-and they continue to do so today. Chemical water pollution typically occurs because:

- The chemicals were dumped into the water intentionally;
- The chemicals seeped into groundwater, streams, or rivers because of failing pipes or storage tanks;
- "The chemicals catastrophically contaminated waterways because of industrial accidents;
- "The position' settled out of polluted air (or was precipitated out of polluted air); or Chemicals were leached out of contaminated soil.

The above types of chemical contamination are considered "point sources" of water pollution. Non-point-source chemical pollution also occurs via pesticide runoff from farm fields and 'homeovriers' lawns, as well as runoff of automotive t1uids and other chemicals from roads, parking lots, driveways, and other surfaces. It's beyond the scope of this particle to document the effect of every chemical that has ever polluted water, but it's easy enough to point out a few things:

- Severe chemical spills and leaks into surfaces waters usually have an immediate effect on aquatic life (fish kills, etc.).
- Chronic lower-level chemical pollution has more subtle effects, with

problems manifesting over a long period of time and sometimes being difficult picture of dead fish polluted' water to' tie directly to the water pollution.

The human effects of chemical pollution in water can generally be viewed the same as any other form of chemical contamination--water is just the delivery mechanism.

- **Pesticides can migrate via water into the food chain as well, ultimately being** consumed by humans or animals in food.

In the most infamous case of pesticide pollution, widespread use of the insecticide DOT polluted waterways, contaminating fish, and ultimately poisoning bald eagles (and other animals) that ate the fish. DDE, the principal breakdown product of DDT, built up in the fatty tissues of female eagles and prevented sufficient calcium being released to produce strong egg shells. The thin shells would break when the parents sat on the eggs to keep them warm. DOT affected many other species as well. The case against DDT and other pesticides was first introduced in the classic book by Rachel Carson, In terms of general human health effects, pesticides can affect and damage the nervous system:

- Cause liver damage;
- Damage DNA and cause a variety of cancers;
- Cause reproductive and endocrine damage;
- Cause other acutely toxic or chronic effects.

1.12 Oil and Petroleum Chemicals

When oil pollution gets in water, some of the components of are degraded and dispersed by evaporation, photochemical reactions, or bacterial degradation, while others are more resistant and may persist for many years, especially in shallow waters with muddy sediments.

Though much scientific work remains to be done on the effect that petroleum pollution has on plants and animals, we do know a few things:

- Deformed fish and other aquatic life have been found near Swedish pulp mills that use chlorine as a bleaching agent, a practice that results in discharges of dioxins and other highly toxic substances (Cote, 2004).

1.13 Other Chemicals

Tens of thousands of chemicals are used in industrial processes and are found in car maintenance products, household cleaners, toiletries, and many other consumer products. Our current regimes for controlling whether these chemicals get into the environment are not sufficient for keeping them out of the water, and the potential myriad effects are worrisome. It's well understood that many chemicals can have direct toxic effects on aquatic life.

Industrial spills into rivers invariable kill 11sh for miles downstream. During 2002 and 2003, in just four US states-Wisconsin, Iowa, Minnesota, and Missouri-pollution in rivers and streams killed 3.5 million fish. The number of US river miles on which people have been advised to restrict their consumption of fish rose from 2% in 1993 to 14% in 2001. Most states routinely issue advisories on consumption of fish from rivers and streams.

A newly emerging threat is the hormone-disrupting character of many chemicals. For instance, chemicals contained in sewage discharges into the waters off the Southern California coast are thought to be responsible for "interrex" fish. Similarly, chemicals in the water are also thought be responsible for egg-growing male fish in Maryland's Potomac River-possibly the effect of excreted birth-control chemicals (Sabuar, 2000).

More generally, the effects of hormone-disrupting chemicals include interrupted sexual development; thyroid system disorders; inability to breed; reduced immune response; and abnormal mating and parenting behavior. In humans, endocrine disruptors are thought to lead to degraded immune function, mental impairment, decreased fertility, and increases in some types of cancers (Maclean, 2001).

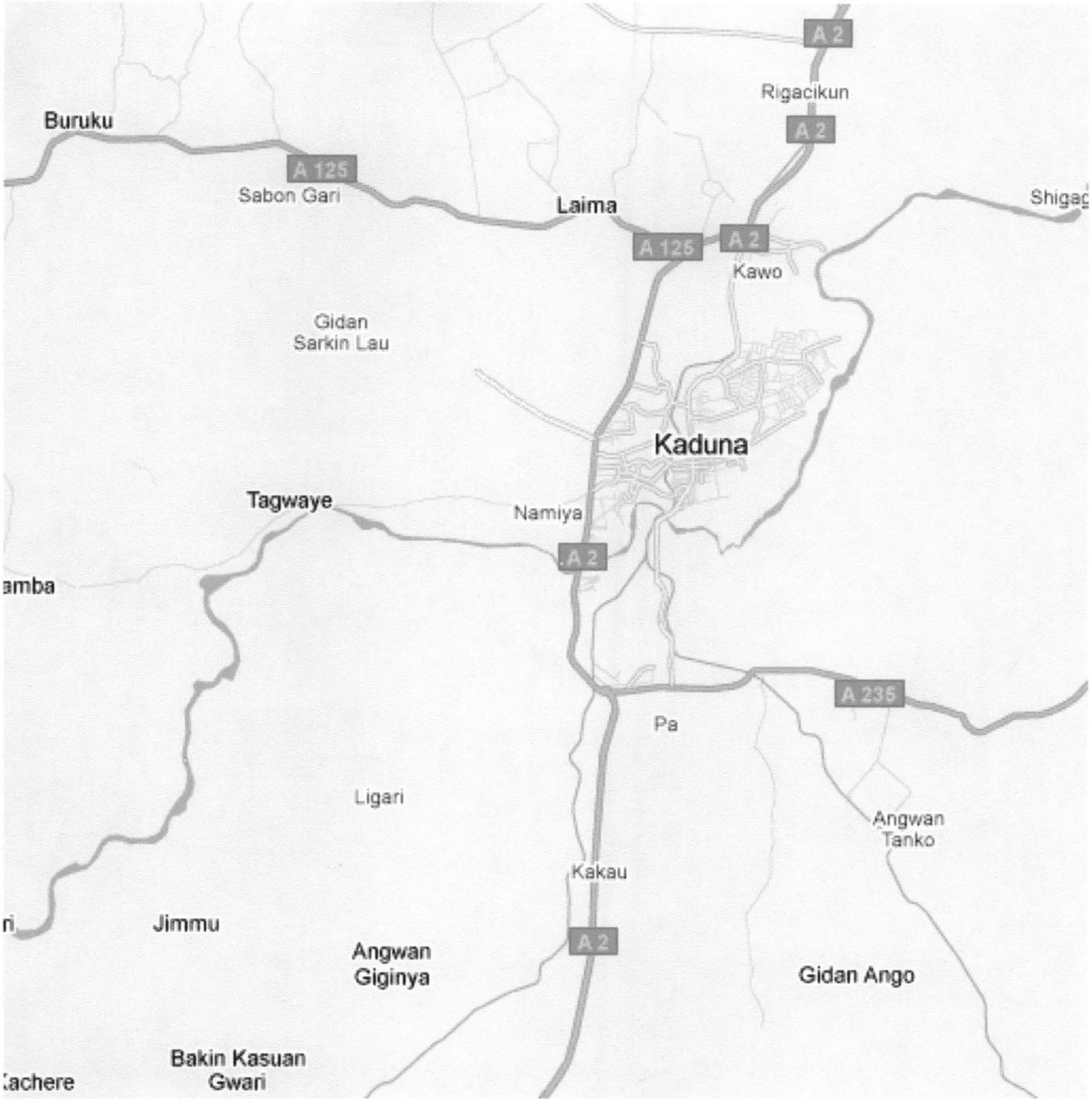

Fig. 1: Kaduna State Map showing Sabon LGA where the Kaduna Refining and Petrochemical Company Limited is located

Fig. 2: Kaduna Refining and Petrochemical Company Limited Site Area

Fig. 3: Romi River Flows in Sabon Area of Kaduna State where Effluents is being discharge into constantly

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Literature Review

Increasing demand on water resources all over the world has encouraged people concerned in the management to view its natural quality as of utmost importance, since water quality is a yardstick of its suitability for any beneficial use. In domestic water supply, it is a measure defined in terms of physiochemical, biological and biochemical requirement for water aquaculture species (Cote, 2004).

(Boyd, 2003) said water quality is determined by a myriad of biological, physical and chemical variables that affect the desirability of water for any particular use. Effluents waste water is known to have some chemical parameters that affect its desirability for use.

It was shown by Ran and Wooten (2001) that water quality impacts are changes in the value of its quality indicators resulting from a proposed action/project. For example, if a proposed project is expected to reduce average dissolved oxygen in a stream, then the project has a negative impact.

It has been reported (Cote, 2004), that effluents from petroleum refineries contain the following: oil, grease, cyanide, Sulphur, Nitrogen compounds, Ammonia, heavy metals suspended solids which accumulate in living organisms reaching concentrations which inhibit enzyme activity.

Rau and Wooten (2003) also showed that waste water flow and load information as of prime importance which assessing the impacts on the receiving water. Many of the compounds in refinery waste water are known to be potentially toxic thus affecting valuable resources (Sprague, 2001).

A survey by (Sabuar, 2000) indicated that waste water discharged from industries is known to be dangerous or hazardous to humans, animals or the environment entirely. The effect of persistent industrial chemicals on aquatic life can be particularly serious because instead of dissolving and thus existing in a dilute solution, they are concentrated at the surface of the river where they become harmful to aquatic life.

2.1 Assessing of Water Quality

The standards of water quality have been developed and raised based on changing water supply conditions and on advancing technology in treatment and analysis. The basic objectives of these are to make it safe for human consumption and be able to support life generally.

Water should be biological and chemically safe, anything less is unacceptable. Water that is appealing is clear, colourless, pleasant to the taste and odourless. It should be non-staining neither corrosive nor scale forming and reasonably soft. No matter the kind of use water is employed either for domestic, industrial or agricultural, it should posses the above qualities (Chanlett, 2001).

2.2 Characteristics of Refinery Waste Water Effluents

Generally the waste water effluents are divided into three main groups.

(i) Physical characteristics e.g. odour, electrical conductivity, suspended matter.

(ii) Chemical

(iii) Biological.

2.3.1 Water Quality Parameters

Knowledge of the pH of water is essential since it determines the acidity or alkalinity and it plays an important role in the choice of technique to be used in treatment. The pH value of a solution is defined as the negative logarithm of the solution hydrogen ion concentration:

$$pH = -Log\lfloor H^+ \rfloor$$

The pH measurement is an important consideration in determining the corrosive action of water.

Proper pH measurement and control consistent quality in numerous industrial and laboratory processes (Pavai, 2001).

2.3.2 Conductivity

This is the measure of the ability of water to conduct electricity. It is the reciprocal of resistance. It is determined by estimation of dissolved salts in natural and treated waters.

2.3.3 Turbidity

This is caused by the presence of suspended solids in the water that restricted their cleanliness (Chanlett, 2001). It is described as the reductions of the transparency of a sample because of the presence of water bodies are absolutely free of suspended matter. Industrial and domestic waste water that wash into receiving streams and excessive flooding conditions contribute to turbidity.

2.3.4 Dissolved Oxygen.

The dissolved oxygen content of water results from the photo synthetic and respiratory activities pf living organisms in the open water, the diffusion gradient at the air-water interphase and distribution by wind driven mixer (Ferguson, 2002).

2.3.5 Biological Oxygen Demand (BOD)

It is a measure of the oxygen required to oxidize organic matter by bacteria action. BOD test is widely applied in measuring waste loading to treatment that is to determine the pollution strength of waste water in terms of oxygen that they will require if discharged into natural water courses in which aerobic conditions exist.

2.3.6 Chemical Oxygen Demand (COD)

It gives the oxygen equivalent of the portion of organic matter in a sample that is susceptible to oxidation by a strong chemical oxidant.

2.3.7 Oil Content

This is the amount of grease released into the water body. The presence of oil on the surface of the water helps to raise the temperature of the water, and when grease is dark, it prevents light from penetrating the water and reducing the photosynthetic ability of aquatic plants (Cote, 2004).

2.3.8 Alkalinity

Alkalinity in waste water results from the presence of hydroxides, carbonates and bicarbonates of reactive metals like calcium and magnesium, the soil and waters are normally alkaline and they receive their alkalinity from the water supplied from the ground and material added during domestic and industrial use. Alkalinity is determined by titrating against standard acid and is expressed in terms of calcium carbonate.

2.3.9 Ammonia

In non-polluted well-oxygenated water, ammonia is normally present in low concentrations (less than 1 mg/l) but may reach between 5 to 10mg/L in the anaerobic hypolimnous of a Eutrophic lake. A high concentration of the compound is toxic (Chanlett, 2001).

2.3.10 Arsenic, Lead, Mercury, Cadmium

These are normally present in refinery waste water in relatively small amounts. The main effects of the ingestion of these metals in their toxic compound forms include dermatitis, ulcerations, kidney and liver damage, anaemia and among others.

2.3.10.1 Arsenic

Arsenic has no known biological function in animals and is highly toxic to them. It is a heavy metal which occurs naturally in the earth's crust. It is usually found combined with other elements such as oxygen, chlorine and Sulphur, which are known as inorganic compounds. In plants and animals it combines with carbon and hydrogen to form organic arsenic. Of the two forms, inorganic arsenic is usually more harmful. However, there arc great differences in the toxicity of different arsenic compounds. Arsenic is noted as a famous historical poison but acute arsenic poisoning is now rare in the UK .

Sources of arsenic include: pesticides, herbicides, fungicides, wood preservatives, ceramic enamels, paints, tobacco (there may be as much as 6 micrograms per pack), burning of fossil fuels as arsenic is a contaminant, from the diet as organic arsenic from fish and seafood. Occupational exposure can occur in: The smelting industry (arsenic is a by-product of ores containing lead, gold, zinc, cobalt and nickel), The microelectronics industry (as gallium arsenide), Coal power plants, Jobs involving the manufacturing of glass and fireworks, Jobs with contact with pesticides, Jobs with contact with wood treated with arsenic as a preservative.

The toxicity of the particular arsenic compound 'depends on its valence state which may be zero-, tri- or pent- valent, and the whether the compound is organic or inorganic, as well as on physical aspects such as absorption and elimination. Generally inorganic compounds are more toxic than organic compounds and trivalent compounds are more toxic than penta- or zero- valent compounds. Organic compounds are estimated to be 50-100 times more toxic (Mathew and Lawson, 1979).

After absorption of inorganic arsenic, the compound accumulates in the liver, spleen, kidneys, lungs and gastrointestinal tract. It is then rapidly cleared from these tissues but it leaves a residue in keratin-rich tissues such as skin, hair and nails. Ingested inorganic salts are well absorbed if they are soluble, and very soluble salts may also be able to enter the body through the skin and inhalation. The lethal dose of inorganic arsenic is estimated to be between 120 and 200mg. Some arsenic compounds notably arsenite (pentavalent, inorganic) are metabolized in the liver and this leads to the formation of compounds which are less toxic. Methyl groups are added to the arsenite which forms methylarsenic acid and dimethylarsenic acid. However this biomethylatation process can easily become saturated and this can lead to the excess inorganic arsenic being deposited in the soft tissues (Apostoli *et al,* 1998).

Arsenic compounds are directly toxic to body systems. Particularly in the trivalent form, they are able to bind to sulphydryl groups of enzymes in the pyruvate dehydrogenase system. They are also able to bind to enzymes in the Kreb's

(Tricarboxylic acid) cycle and they therefore can interfere with oxidative phosphorylation in cells. In the pentavalent form, they can also exert their toxicity by competitively substituting their ions for the body's phosphate ions. This can lead to the breaking down by hydrolysis of high energy bonds in compounds such as ATP. Organic arsenic compounds can also induce sensitization reactions (Goldwater and Clarkson, 1972).

The main clinical signs of arsenic poisoning are caused by capillary injury, which produces vasodilatation, transudation of plasma and shock. After ingestion, the main additional effect is inflammation and necrosis of the gastrointestinal Mucosa, which is manifest, is: Hemorrhagic gastroenteritis Fluid loss, Nausea, Vomiting, Abdominal pain. These symptoms occur between 1 and 12 hours after exposure. Other systems are also affected: Cardiovascular system (hypotension, tachycardia and circulatory collapse), Renal system (oliguria or anuria due to renal failure), Central nervous system (Headache, irritability, muscular weakness, convulsions and coma), Metabolic (severe fluid and electrolyte imbalance may occur leading to muscle cramps).

Acute inhalation of arsine gas leads to severe haemolysis within 3-4 hours of exposure and can lead to acute tubular necrosis and renal failure. There is also irritation of the nose, throat and exposed skin: Long term ingestion of 50-500micrograms per kg .of body weight will cause arsenic effects as well as skin lesions. The effects include inflammation of the respiratory mucosa, and sensory and motor polyneuritis, which may cause 'the patient to develop numbness, tingling and quadriplegia (these symptoms are not always reversible). Patients may also display "garlic breath", dermatitis and keratitis. Arsenic is a proven carcinogen in the lung and skin, if inhaled or ingested. It also suggested that it is carcinogenic in the bladder, kidney and colon (Matthew and Lawson, 1979).

The main treatment for arsenic intoxication is using the chelating agent dimercaprol. Penicillamine is also used but is less effective at promoting excretion. The new treatment DMPS has been successfully tried in some cases.

Patients may also need supportive treatment if they develop liver or renal failure and to correct electrolyte and t1uid imbalance.

2.3.10.2 Cadmium

Cadmium has no essential biological function and is extremely toxic to 'humans. In chronic exposure, it also accumulates in the body, particularly in the kidneys and the liver. These properties, along with its common usage make cadmium one of the commonest environmental metal poisonings. Acute poisoning from inhalation of fumes and ingestion of cadmium salts can also occur and at least one death has been reported from self-poisoning with cadmium chloride.

Cadmium has a wide variety of sources in the environment and from industry. One source is from ingestion of grown foodstuffs, especially grain and leafy vegetables, which readily absorb cadmium from the soil. The cadmium may occur naturally or as a contaminant and the contaminants include sewage sludge, fertilizers, polluted groundwater and mining effluents. Cadmium may also contaminate fish.

Cadmium is also a constituent of alloys, pigments, batteries, metal coatings for example protective coatings on steel, plastics and fertilizers. Occupational exposure may occur from the manufacture of these products and from welding, and smelting of lead, zinc and copper as these occur in mixed ores with cadmium.

Cadmium is also found in cigarette fumes (0.007 to 0.35.kg et cigarette) and fumes from vehicles. Residential sites may be contaminated by municipal waste or leaks from hazardous waste sites.

Humans have a daily intake of cadmium from ingestion and inhalation which is around 20 to 40*lg* per day, but only 5 to 10% of this is absorbed. After absorption, cadmium is transported in the blood bound to albumin. It is taken up by the liver, and, due to its similarity to zinc, causes this organ to induce the synthesis of the protein metallotheionin, to which it binds. The cadmium- rnetallotheionin complex then becomes transported to the kidneys, and it is filtered at the glomerulus, but is reabsorbed at the proximal tubule. Within the renal tubular cells, the cadmium-MT complex becomes degraded by digestive enzymes, which releases the cadmium. Renal tubular cells deal with the release of this toxic substance by synthesising MT to neutralise it, but eventually the kidneys loose their synthetic capacity for MT. At this point, the cadmium has accumulated to a high level in the renal tubular cells, and irreversible cell damage occurs (Bu, 1998). The renal cells do not have an effective elimination pathway for the cadmium complex, which means that the half life in the kidney is between 15 and 30 years.

The toxic effects of cadmium are due to its inhibition of various enzyme systems. Like similar heavy metals, it is able to inactivate enzymes containing sulphydryl groups and it can also produce uncoupling of oxidative phosphorylation in mitochondria. Cadmium may also compete with other metals such as zinc and selenium for inclusion into metallo-enzymes and it may compete with calcium for binding sites on regulatory proteins such as calmodulin (Assennato *et al,* 1987).

The organs most affected by cadmium exposure are the kidneys and the lungs. As mentioned above, cadmium poisoning may be acute by ingestion or inhalation or the poisoning may be chronic at lower levels, which can cause kidney damage by the mechanism described above. In chronic exposure, cadmium accumulates in the body, particularly the kidneys and liver (Baldwin and Marshall, 1999).

An acute intake of cadmium causes testicular damage. Within a few hours of exposure, there is necrosis and degeneration of the testes with complete loss of spermatozoa. This is thought to be due to an effect on the blood supply to these organs, reducing the blood flow. If the cadmium is inhaled, then severe lung irritation and damage (often called 'fume fever') occur. The patient displays pleuritic chest pain, dyspnoea, cyanosis, fever and tachycardia, and the pulmonary oedema which occurs may be life-threatening. Constitutional symptoms also occur such as diarrhoea and malaise. Acute ingestion of cadmium produces severe gastrointestinal irritation, which is manifest as severe nausea and vomiting, abdominal cramps and diarrhoea. A lethal dose of cadmium for ingestion is estimated to be between 350 and 8900 milligrams.

The chronic effects of cadmium are dose-dependent and also depend on the route by which the metal enters the body. Chronic inhalation causes emphysema and obstructive airways disease, and these occur before kidney damage is seen. However, 20 years exposure may be needed before these effects are seen. Long term ingestion causes kidney damage, which is first seen as proteinuria and B_2 microglobulinuria. In prolonged cadmium exposure, disorders of calcium metabolism occur, causing osteomalacia. This leads to painful fractures, hence the name given to the chronic exposure: disease in Japan: Itai-itai disease (literally "ouch!-ouch!" disease) Cadmium is also known to be carcinogenic, and in studies has been linked with cancers in the lungs and prostate (Hu, 1998).

At present, there is no effective treatment for cadmium intoxication, and patients are given supportive treatment according to their symptoms. However, it is thought that some of new chelating agents be effective.

2.3.10.3 Lead

Lead has also known biological function, and is highly toxic and accumulates in man. People have; known about the toxicity of lead for centuries, at least since 200BC, when Dioscorides wrote "lead makes the mind give way". Despite this, lead has been used extensively for both industrial and domestic applications for hundreds of years. As exposure to lead in workplaces and in the environment has become heavily regulated, there are now few cases of acute lead poisoning in the UK. However, in recent years there has been concern that low level chronic exposure to lead "may lead to intelligence loss and behavioral difficulties, but this link have not been proven (Mathew and Lawson, 1979).

Sources of lead may be natural, as it is found in the earth's crust and thus enters the food and water supply. It is absorbed by foodstuffs (particularly green leafy vegetables) growing on soil where lead is present; this may be due to contamination from vehicle exhausts or wastes, or it may be because the area is naturally high in lead (Apostoli et al, 1998). Previously, tetraethyl lead was an additive in petrol and lead was used in plumbing. In the UK, the use of leaded petrol is being phased out, and lead piping in households is gradually being replaced, due to health concerns. Lead also used to be used in paint, and some cases of lead poisoning are due to small children eating takes of this paint. Today, lead is still used in batteries and some insecticides, and is found in cigarette smoke, where there is between 0.017 and 0.98 micrograms per cigarette. Occupational exposure to lead may occur during the manufacture of the products above, but in addition to this lead is mined and smelted. Exposure to organic lead substances such as tetraethyl and tetramethyllead may occur in some industries. There may also be exposure in people who mine gold and zinc, as lead is a contaminant of the ore (Goldwater and Clarkson, 1972).

Elemental lead and inorganic lead compounds are absorbed by ingestion or inhalation, but organ\c lead compounds e.g. tetraethyl lead may also be absorbed by skin contact. Organic lead compounds are the most toxic. Absorption of lead from the lungs is very efficient, especially if the particles are less than 1 micrometre in diameter, as may happen for example with fumes from burning lead paint. Gastrointestinal absorption of lead varies with the age of the individual; children absorb around 50% of what they ingest, but adults only absorb 10-20% of what they ingest' (Timbrell, 1995). Lead is very similar chemically to calcium, so once in the body, it is handled as if it were calcium. The flow diagram below shows what happens in the body after an intake of lead.

Lead in the blood has a half-life of around 25 days and in tissue its half-life is about 40 days. Due to this, blood lead levels are not very useful as an indicator of how much lead exposure an individual has undergone, as they only show recent exposure. However, in non-labile bone lead has a half-life of 25 years or more, and it is possible to estimate past exposure to lead by X- ray. Lead is excreted from the body mainly in the urine but also in the faeces and &mall amounts also appear in hair, nails, sweat, saliva and breast milk (Timbrell, 1995). Lead is toxic as it has an affinity for cell membranes and mitochondria, and interferes with mitochondrial oxidative phosphorylation. It also affects sodium, potassium and calcium A TP-as pumps which maintain the cells' concentration gradients of these ions. The activity of calcium-dependent intracellular messengers, and in the bruin the enzyme protein kinase C are also impaired. Lead also stimulates the formulation of inclusion bodies in cells that may translocate the metal into the cell's nuclei and alter gene expression.

The clinical manifestations of lead toxicity are called plumbism. Acute lead poisoning may have effects on the following systems: Alimentary system causing nausea and vomiting, diarrhea, thirst and metallic taste, Central nervous system leading to parasthesia, muscle pain, fatigue convulsions and loss of consciousness, cardiovascular system causing hypotension and circulatory collapse, blood causing severe anaemia and renal system leading to oliguria. Severe poisonings are indicated by the presence of convulsions and coma, and death may result from generalised cerebral oedema or from renal failure. Young children are particularly affected by lead poisonings as they absorb greater amounts from the 01 tract (Apostoli *et al,* 1998).

The effects in the nervous system are thought to be due to the high sensitivity (particularly of the brain) to the toxicity of lead, particularly the damage to the energy production process. Capillary injury in the brain is also thought to help causes the oedema found in the brain in acute lead poisoning. In the peripheral nervous system, it is thought that lead produces degenerative changes in the supporting cells of the nerves, and secondarily in the myelin sheaths of the nerves. It is also thought to interact with calcium to interfere with impulse transmission along nerves. The anaemia that leads poisoning causes is due to the impairment of the synthesis of harm (the oxygen carrying component of hemoglobin) and an increased rate of destruction of red blood cells. Lead also acts on the kidneys particularly due to their excretory function and its effects are thought to be due to direct effects on the renal mitochondria, which decrease the energy production necessary for active transport of substances. This leads to generalised tubular dysfunction. Iron damages the mucosa in the 01 tract, as well as having the general effect of tissue desiccation. A diagnostic sign of lead poisoning is that purplish or "lack "lead lines" appear at the gingival border of the mouth. These appear as lead follows .the calcium pathways and becomes excreted with the saliva (Assennato et al, 1987).

Chronic lead poisoning in children at blood levels greater than 1.4 micromoles per litre causes mental retardation, and selective deficits in language, cognitive function, balance, behaviour and school performance. There are no other symptoms and affected children are often considered "slow", and the real reason for their difficulty is not recognised. As lead levels in the child's blood rise, more symptoms such as Hyper-excitability, Confusion, Delirium,' Convulsions, Progressive lethargy leading to a comatose state may appear. However, the last 4 symptoms are only seen in some cases. Chronic lead poisoning is also associated with kidney damage and interstitial nephritis, reproductive toxicity with adverse effects on sperm, anaemia, CNS defects, peripheral neuropathies, encephalopathic symptoms find effects on unbon1 children, including pre-term birth, reduced birth weight find reduced mental ability of the child (Hu, 1998).

It is unsure whether lead stored in the bone during childhood or adulthood to pose a threat in later life, particularly at times of increased bone reabsorption, such as in pregnancy, lactation, osteoporosis and hypothyroidism. However, elevation of the bone lead levels does seem to be a risk lactor or anaemia and hypertension. It is also thought that some people are more susceptible to lead poisoning than others due to genetic factors. 15% of Caucasians have a variant of a gene which codes for aminolevulinic acid dehydrogenase, a critical enzyme in the production of haem, which may make them more susceptible to toxicity from retained lead (Timbrell, 1995).

The treatment used for lead poisoning depends on the form of lead involved. Elemental and inorganic lead can be treated effectively with chelators, but in organic lead poisoning the compounds have already formed strong ligands with organic compounds in the body, and initial chelation is ineffective. At this stage, the patient is given supportive treatment. Eventually, the alkyl lead is converted to inorganic lead by the body, which can be treated with chelators.

The most important part of treatment for lead poisonings is to terminate the exposure. In an acute lead poisoning, if the lead was ingested, then gastric aspiration and lavage may be attempted. If the patient is found to have a normal blood lead level and is generally, no further calculation needed. However, if the patient has a raised blood lead level, then cheating agents are used for treatment of the patient is not acutely ill, only urgent call the *, and the new treatment DMSA is more effective than penicillamine. For more acutely ill patients, calcium EDTA is used, which is administered intravenously. Care must be taken during treatment, as the chelating agents cause the loss of much zinc as well as lead (Baldwin and Marshall, 1999).

2.3.10.4 Mercury

Mercury has no known biological function and is highly toxic to humans. Mercury can exist in 3 oxidation states (Elemental mercury, HgO Mercurous mercury, Hg, or Mercuric mercury, Hg^{2+}), and mercurous and mercuric 'mercury can combine with other elements to form either organic or inorganic mercury compounds. The distinction between elemental, inorganic and organic mercury is much more important than validation states in determining toxicity, as organic mercury compounds are the most toxic.

Organic mercury compounds, like the metal, are volatile at room temperature. Some of the compounds which have important industrial applications are the compounds in which the mercury is coupled with methyl or ethyl groups (alkyl mercury compounds), or a phenyl group (aryl mercury compounds). The alkyl mercury compounds are more toxic, particularly methyl mercury, than the aryl mercury compounds (Timbrell, 1995).

Mercury poisonings have been reported from ingestion of mercuric chloride (an inorganic compound which is used as a disinfectant), as well as from contaminated illegal drugs, for example amphetamines. Poisoning has also occurred from exposure to fungicides, some of which contain organic mercury compounds, and from industrial accidents in which mercury vapour was inhaled. Environmental discharges of mercury have also occurred, by discharge of industrial waste, which contaminated fish which were then eaten by humans. In recent years, there has been some concern that mercury contained in dental amalgalms adversely affects human health, produces illnesses including multiple sclerosis and Alzheimer's disease, but this conjecture has not been proven (Baldwin and Marshall, 1999).

Elemental mercury has many uses, including:

- As liquid contact material for electric switches
- In the manufacture of scientific instruments such as thermometers, barometers, direct current meters, hydrometers, and in the calibration of laboratory equipment.
- In the manufacture of amalgams e.g. amalgams of gold, copper and zinc used in dentistry for filling teeth and amalgamated zinc used in electric batteries.
- In the chemical industry for the preparation of mercury compounds, as the electrode material for the electrolysis of aqueous solutions or alkali halides for the manufacture of chlorine and sodium hydroxide, and as a catalyst for organic chemical reactions notably in the production of glacial acetic acid.
- As an electrical contact and seal, for example in electric switches and the manufacture of molybdenum wire.

Uses of inorganic mercury compounds include:

- In the paint and colour industry for the manufacture of pigments and anti-fouling marine paints (mercuric oxide) and vermillion (mercuric sulphide).
- In the pharmaceutical industry in the manufacture of drugs (mercurous chloride), disinfectants and antiseptic dressings (mercuric chloride) in timber preservation (mercuric chloride).

The use or organic mercury compounds has certainly declined greatly in the Great Britain, and is believed to have ceased entirely. The compounds were previously used in fungicides and in agents to control slime in paper mills, as well as in the manufacture of fulminate of mercury, which was used as a constituent of detonators in the manufacture of explosives.

Mercury exerts its toxicity by the metal or its ions binding to sulphydryl groups in the body. These groups may be part or some enzymes, and hence mercury and its compounds are potent inhibitors or some enzymes, Mercury also blocks the transport of potassium into cells and also blocks the transport of sugars, these effects are due to the binding of mercury to the S-H groups in or on the cell membrane. Once inside the cell, the metal may be sequestered in an inactive combination, or it may react with enzymes or other compounds to elicit other toxic effects (Timbrell, 1995).

Once inside the body, mercury undergoes a process called biotransformation. The carbon-mercury bond in organic compounds is broken, which in alkyl mercury compounds is known as demethylation, but methylation also occurs. It takes off elemental and divalent mercury cause the interconversion of the forms to each other. An intake of elemental mercury vapour is absorbed through the lungs then is oxidised in red blood cells to Hg. It is also taken up by the brain and the foetus and is also metabolised to Hg^{2+} in these tissues, and the mercury then becomes trapped in these sites as it is ionised. Organic mercury is able to distribute to the CNS, where it is oxidised (alkyl mercury compounds are demethylated) to Hg^{2+} and leads to neurological damage. Exposure of the body to mercury in any of its forms stimulates the kidney to produce metallothionein, a metal-binding protein that affords partial protection against mercury toxicity (Apostoli et al, 1998).

Elemental mercury is not well absorbed by the 01 tract, but its vapour is well absorbed by the lungs. Its half life in the blood is around 60 days, but as mentioned above, it is fat soluble so is able to cross the blood-brain barrier and the placenta.

In these tissues and in the kidneys it may be oxidised by catalase and hydrogen peroxide into mercuric chloride, and may be retained by the kidney and brain for years.

Inorganic mercury can be absorbed through the gastro-intestinal tract but also through the skin. Because large overdoses damage the GI mucosa, the loss of this barrier further enhances the absorption through this route. Once it has been absorbed, it breaks down to metallic and mercuric mercury, but relatively little crosses the blood brain barrier. Its half life in the blood is around 40 days but it may be retained in the kidneys as mercuric mercury.

Organic mercury compounds, particularly methyl mercury, can evaporate and undergo pulmonary absorption, and are also well absorbed by ingestion. However, very little of these compounds is absorbed through the skin. As it is lipid soluble, once it enters the body it crosses the blood-brain barrier and the placenta and appears in breast milk. It also concentrates in the kidneys and the CNS. The half life of organic mercury is around 70 days in the body.

Acute inhalation of elemental mercury vapour produces symptoms similar to metal fume fever, such as: Cough, Dypnoea, Tightness or burning pain in chest, "pyrexia. Severe cases have other symptoms including: Respiratory distress, pulmonary oedema, lobar pneumonia, Fibrosis. Death may sometimes occur. Neurotoxicity may also occur with symptoms such as tremors, emotional lability, headaches and polyneuropathy (damage to many nerves). Chronic exposure to elemental mercury has the characteristic symptom of tremor. The other symptoms are known as "mercurial erethism", and this definition contains a wide constellation of symptoms, including: Excitability, Memory loss, Insomnia, Timidity, sometimes delirium.

This disease was found in occupational exposure in the clot-hat industry, and lead to the expression "mad as a hatter". Inorganic mercury mainly causes poisoning by ingestion, and symptoms or an acute intake are due to the severe of corrosion which the solution produces: Haemorrhagic gastroenteritis, Stomatitis (inflammation of the mouth), Nausea, Vomiting (may contain '"blood) (may contain blood), Abdominal pain. From these symptoms, further symptoms may ensue: Acute renal failure, cardiovascular collapse, Shock. A lower level chronic intake may cause: Milder GI inflammation, Gingivitis (inflammation of the gums), Loosening of the gums, Hypertension, Tachycardia, Nephrotic syndrome, there may also be symptoms similar to erethism. Skin exposure to inorganic mercury salts may cause exfoliative dermatitis (Apostoli et al, 1998).

L-Acute ingestion of organic mercury compounds can cause: Diarrhoea, Tenesmus, Blisters in the upper tract, there may also be symptoms of neurotoxicity (nerve' damage), such as: Parasthesia, Impaired peripheral vision, Muscle weakness, Irritability, Memory loss, Depression, there is also an increased risk of fetal toxicity, with effects including: Mental retardation, Retention of primitive reflexes, Cerebellar symptoms, Dysarthria Hypokinesia, Hypersalivation, Atrophy of the cerebral cortex, corpus callosum and cerebellum, with abnormal neuronal cytoarchitecture. The fatal dose of organic mercury is estimated to be between 10 and 60 mg per kg of body weight, but symptoms start when greater than 1.7mg per kg has been ingested (Bu, 1998).

Chronic exposure to organic mercury may cause symptoms similar to chronic inorganic mercury poisoning, but by the time tremor develops, parasthesia and muscle weakness are oven also present. In advanced cases, ataxia and dysarthria are accompanied by a loss or peripheral vision, IHanng impairment and sensory deficits in the limbs.

Exposure of children to mercury in any of its forms may cause acrodynia, or Pink disease, with symptoms including: Flushing, Itching, Swelling, Tachycardia, Hypertension, Excessive salivation or perspiration, Irritability, Weakness, Rashes.

The diagram below summarises what happens to mercury in the body, as well showing the main clinical features of the disease.

Inhalation of metallic mercury should be treated with IV hydrocortisone (a steroid) for pulmonary complications acute ingestion of mercury salts should be treated initially with induced emesis and gastric lavage. Oral administration of polythiol resins may also be useful as they bind mercury in the GL tract, which helps to prevent absorption into the body. Chelating agents which may be useful are dimercaprol, succimer and penicillamine. Recent studies, however, suggest that the new agent DMPS is more effective than dimercaprol, and that it should be used with oral penicillamine later Acute intakes of inorganic mercury should be treated with chelating agents, and dimercaprol and penicillamine are the most effective compounds Chronic inorganic mercury poisoning is best treated with penicillamine Organic mercury poisoning should not be treated with the chelating agent dimercaprol as it may increase mercury levels in the brain. Chelation therapy removes mercury from the plasma very well, but it forms alkyl ligands in the tissues, which are particularly persistent in the CNS. Recovery from mercury poisoning can take months or even years even with effective chelator treatment, and is often incomplete.

2.4 Laboratory Testing and Diagnosis for the Presence of Heavy Metals

The diagnosis of heavy metal toxicity requires observation of presenting symptoms, obtaining a thorough history of potential exposure, and the results of laboratory tests. Laboratory tests routinely used for seriously exposed persons include blood tests, liver and renal function tests, urinalysis, fecal tests, x-rays, and hair and fingernail analysis. Many of these tests are not routinely performed in a doctor's office. However, your physician can take blood samples and send them to the appropriate testing laboratory. Chest x- rays are recommended for persons with respiratory symptoms, and abdominal x-rays can detect ingested metals.

Arsenic:

Arsenic levels can be measured in blood, urine, hair, and fingernails. Because Arsenic clears fairly rapidly from the blood, blood tests are not always useful. Therefore, urine tests are the most reliable for arsenic exposure within the past few days; hair and fingernail testing are used to measure exposure over the past several months. Abdominal x-rays can reveal metallic fragments. Note: Hair treatments, including hair dyes, can contaminate hair samples. When testing for any heavy metal, the most accurate results are obtained from hair that has not been chemically treated for at least 2 months.

Lead:

When there are presenting symptoms of lead toxicity, blood testing is done. Blood lead levels in children higher than 10mcg/dL are considered to be of concern. Symptoms in adults may not appear until blood lead levels exceed 80mcg/dL. However, medical treatment is usually necessary in children who have levels of 45mcg/dL. Significantly lower levels of 30mcg/dL in children can cause mental retardation or cognitive and behavioral problems. A complete blood count (CBC) is also done to check for abnormalities 011 red blood cells (basophilic stippling). In children, long-bone x-rays may reveal bands called "lead lines" that indicate failure of the bone to rebuild. These bands are not actual lead concentrations, but are bone abnormalities. Adults do not have lead lines. X-rays of the abdomen can reveal swallowed objects, such as paint chips, fishing sinkers, curtain weights, or bullets. A less common test is measurement of lead in teeth. All children with brain-related symptoms should be considered for lead toxicity.

Mercury:

A 24-hour urine specimen is collected for measurement of mercury levels. Chest X-rays can reveal a collection of mercury from exposure to elemental mercury or a .pulmonary embolism containing mercury. Abdominal X-rays tan reveal swallowed mercury as it moves through the gastrointestinal tract. Blood and urine samples are used to determine recent exposure, as well as exposure to elemental mercury and inorganic forms of mercury. Scalp hair is used in testing for exposure to methyl mercury. Liver and kidney function tests are also important in severely exposed persons. Blood mercury levels should not exceed 50mcg/L.

Cadmium:

Laboratory testing procedures for cadmium toxicity include collection of a 24-hour urine specimen, CBC, and hair and fingernail clippings. Blood levels show recent exposure; urine levels show both recent and earlier exposure. Blood levels of cadmium above 5mcg/dL and creatinine levels in urine above 10mcg/dL suggest cadmium toxicity. Note: The ATSDR is unsure of the reliability of tests for cadmium levels.

CHAPTER THREE

MATERIALS AND METHODS

Introduction

3.1 Sampling Technique

The Effluents (Wastewater) samples were collected at three main sources; at the Refining and Petrochemical Company Effluent (waste water) retention pond, Romi River Upstream and Romi River Downstream which are 1km and 3km respectively from the refinery plant site. Sample of Effluents (waste water), Upstream and Downstream were taken at various sampling points in clean empty plastics containers. The analyses were done in a suitable standard laboratory and accurate readings were recorded. All the analysis were done within the shortest possible time frame to achieve valid and reliable results

3.2 Parameters Analysis

3.2.1 pH and Temperature

The apparatus used for pH measurement is the pH meter.

The pH meter and associated electrode were standardized against reference buffer solutions.

3.2.2 Turbidity

The apparatus used is the turbidity meter. The sample cell was rinsed and filled with distilled water, and placed on the turbidity meter. The meter was then adjusted to give a zero deflection (which is the turbidity of distilled water). The sample cell that contained the distilled water were removed from the turbidity meter and refilled with the sample and replaced. The deflection of the meter was recorded as its turbidity.

3.2.3 Conductivity

The apparatus used was a conductivity meter. The conductivity cell was washed with distilled water and then the sample were placed in a beaker and stirred. The electrode was inserted into the sample and the meter deflection was noted after stirring. The deflection was multiplied by a factor thus Conductivity = deflection.

3.2.4 Total Dissolved and Suspended Solids

The apparatus used include hot plate, beakers, oven, filter paper, analytical balance, and evaporating dishes. The two 50ml beakers was washed clean, dried in the oven and weighed. The beakers were tagged for effluent total solid (ETS) and effluent dissolved solid (ES) respectively.

A quantity of the sample from each beaker was filtered and weighed and the mass noted. Both beakers were placed on a hot plate to allow for evaporation. The beakers were then cooled after which they were weighed and their masses noted.

Calculation

$$\textit{Total solid} = \frac{\text{weight of dried sample (ETS)} \times 10}{\text{weight of wet sample}}$$

$$\textit{Dissolved solid} = \frac{\text{weight of dried sample (EDS)} \times 10^6}{\text{weight of wet sample}}$$

3.2.5 Biological Oxygen Demand

The apparatus used include a low temperature incubator applied for BOD, empty stock solution bottle, air pump, two corked incubator bottles, magnetic stirrer, retort stand, burette, pipette, filter, measuring cylinder and beakers. The reagents used included distilled water, starch indicator, Sodium Thiosulphate Solution ($Na_2S_2O_4$, Sodium Azide (Na_2N), Magnesium Sulphate, dilute sulphuric acid, Dipotassium Phosphate (K_2PO_4),Potassium Phosphate, Disodium Phosphate, Ammonium Chloride, Magnesium Sulphate, Calcium Chloride, Ferric Chloride etc.

About a litre of distilled water was measured and transferred to a stock solution bottle. The Water was then aerated using the air pump for an hour after which the Dipotassium Phosphate Magnesium Sulphate anhydrous calcium chloride and Hexahydrate ferric chloride was added in the above sequence. The mixture was thoroughly shaken and then the incubator bottles partially filled with the mixture. The bottles were filled with a quantity of the effluent sample poured into it. One of the bottles was placed in the incubator at a certain Temperature and allowed for five days incubation.

The content of the other incubator bottle was put into a beaker and a small amount of Magnesium Sulphate and Sodium Azide added. The mixture was allowed to settle for a few minutes. After which about 2ml of dilute sulphuric acid was added and the contents stirred for about two minutes. About 2ml of tarc solution was also be added.

The burette was filled with sodium thiosulphate solution and titrated until a colourless mixture results. The titre values were recorded as the dissolved oxygen of the first day. On the fifth day the contents of the other incubator bottle were transferred into a beaker. The same procedure was carried out on the mixture and the titre value recorded as the dissolved Oxygen of the fifth day. Calculation:

$$\text{Dissolved oxygen (DO)} = \frac{0.2 \times \text{titre value} \times 1000}{\text{bottle volume}}$$

Where 0.2 - 0.2mg of oxygen equivalent to 1ml of $Na_2S_2O_4$

$$\text{BOD} = \frac{\text{first day DO - fifth day Do} \times \text{average of bottle volumes}}{\text{sample of volume}}$$

3.2.6 Chemical oxygen demand

The apparatus used was conical flasks, heating panels, burette, pipette filter, analytical, weighing balance, spatula, foil paper, reflux flasks, pipe/hose, incubator, cooling bath, measuring cylinder, stirrer, and retort stand. The reagents used include: Ammonium Ferrous Sulphate Solution, Distilled water, Concentrated Sulphuric acid, Silver Nitrate, Potassium dichromate Solution, Ice blocks, and Mercury Sulphate.

Two empty critical flasks were labeled blank and KPRC effluent. Distilled water was put into the blank flask. Some quantities of the effluent were put into the effluent flask and with distilled water. The flasks were placed in a cooling bath containing the ice block. A quantity of Mercury Sulphate, Concentrated, and $AgNO_3$ were added to the mixtures and shaken to ensure proper mixing and refluxing was carried out for a couple of hours. A standard was prepared by mixing a quantity of $K_2Cr_2O_7$ and H_2SO_4.The burette was filled with liquid ammonium ferrous Sulphate and titrated against the contents in the three conical flasks until there was colour change. The titre values were recorded.

Calculation

$$COD = \frac{A \times B \times 8000}{\text{sample volume}}$$

$$\text{Where } A = \frac{\text{Volume of } K_2Cr_2O_7 \text{ used for standard molarity}}{\text{titre value for standard}}$$

B = Blank titre value - sample titre value

3.2.7 Oil Content

The apparatus used include a Spectrophotometer, Measuring Cylinder, Stirrer, Funnel, Flasks, pH Meter, Beaker, and Filter Paper. The reagents used include Dilute Tetraoxosulphate acid, Sodium Chloride, Carbon Tetrachloride, and Silica Gel. A quantity of the effluent was measured and put into a beaker. The pH was noted and the meter adjusted to about a ph of 5 and a quantity of the NaCl added to the effluent. The contents were then stirred and the CCl_4 added. The mixture was shaken vigorously and then allowed to stand and then filtered. A blank was prepared using some CCl_4 and silica gel. The filtrate was scanned against the blank using an infra red spectrophotometer at 150m/s.

3.2.8 Alkalinity P (Due to Phenolphthalein)

The apparatus used included; a beaker, conical flask, and burette. The reagents used include; phenolphthalein indicator, hydrogen chloride. A few drops of the phenolphthalein indicator were added to a small quantity of the effluent sample in a conical flask. The mixture was titrated against HCl until the solution becomes colourless. The alkalinity was calculated thus:

Alkalinity P = $\frac{A \times M \times 1000}{\text{Volume of sample}}$

Volume of sample

The colour developed after a few minutes was compared to a standard *in* which a compensatory blank was used.

Calculation:

The ammonia concentration in ppm of Nitrogen was calculated in the original sample as follows:

Ammonia nitrogen (mg/l) $\frac{A \times 100}{S}$

Where A =mg of magnesium observed

S =volume of samples

Calculation of ammonia concentration in mg/l of ammonia in the original samples as follow:

Ammonia (mg/l) = Ex 1.22 where E =ppm of ammonia nitrogen

3.2.9 Alkalinity M (Due to Methyl Orange)

The apparatus used was same as above, the only difference being the methyl orange indicator. The solution was titrated against HCl until there was a colour change. The alkalinity M was calculated thus:

Alkalinity M

A x M x 1000

Volume of sample

Where A = Volume of titrated standard HCl M Molarity of titrate HCl

3.2.10 Phosphate Content

The apparatus used included Measuring Cylinder, Beaker, Double UV Spectrophotometer, Wash Bottle, Pipette, filters. The reagents used for this test included Ammonium Molybdate, Distilled water. A quantity of the effluent was measured and transferred into a beaker. A small quantity of the reagent was added to the effluent. A blank was prepared by pipetting a small quantity of the reagent into another beaker tagged blank.

3.2.11 Ammonia

The apparatus used included a pH meter, filter paper, Nessler tube, conical flasks. The reagents used include $ZnSO_4$ sodium hydroxide solution, sodium potassium tartarate solution, and Nessler solution. A small quantity of $ZnSO_4$ solution was added to the sample. NaOH solution was then gently added until the pH was about alkaline, and then filtered after settling. The Sodium Potassium Tartarate and Nessler solution was added and the readings taken using a double UV spectrophotometer.

Calculation:

Phosphate content A x 50.17

Where A = absorbency reading taken

CHAPTER FOUR

RESULTS

This chapter focuses on the laboratory analysis of the results obtained from Effluents Retention tank, Romi Upstream and Romi Downstream water samples collected from different sampling point in the project area which was earlier mentioned. The results obtained are to be compared with 2007 version of Federal Environmental Protection Agency standard (FEPA) that is Nigerian Standard for drinking water quality and World Health Organization standard (W.H.O).Then from the comparison a conclusion was reached.

Table 1: Result of Physical Parameters of Effluents during Dry Season

Points	Temperature (°C)	Turbidity (NTU)	Conductivity (us/cm)	Suspended Matter (us/cm)	Dissolved Oxygen (mg/l)	Odour
1	33.20	98.00	360.00	380.00	0.001	Oily
2	32.65	90.00	360.10	360.00	0.000	Oily
3	32.60	80.00	300.00	300.00	0.0001	Oily
4	31.20	70.00	290.43	290.43	0.000	Oily
5	30.46	60.00	250.60	250.60	0.000	Oily
6	30.20	50.60	300.00	250.00	0.000	Oily
7	27.40	50.00	320.00	100.50	0.000	Oily
8	27.30	40.60	310.00	90.60	0.000	Oily
9	26.40	40.30	320.00	80.00	0.000	Oily
10	25.30	40.00	340.00	60.00	0.000	Oily

Table 2: Result of Physical Parameters of Effluents during Raining Season

Points	Temperature (^oC)	Turbidity (NTU)	Conductivity (us/cm)	Suspended Matter (us/cm)	Dissolved Oxygen (mg/l)	Odour
1	21.20	120.00	380.00	430.00	0.000	Oily
2	22.65	126.00	390.10	420.00	0.000	Oily
3	21.60	131.00	380.00	430.00	0.000	Oily
4	21.20	130.00	390.43	490.43	0.000	Oily
5	20.46	136.00	350.60	450.60	0.000	Oily
6	20.20	135.60	380.00	450.00	0.000	Oily
7	23.40	135.00	370.00	400.50	0.000	Oily
8	21.30	139.60	390.00	400.60	0.000	Oily
9	21.40	133.0	360.00	4230.00	0.000	Oily
10	21.30	130.00	380.00	420.00	0.000	Oily

Table 3: Results of Physical Parameters (Upstream) Romi River during Dry Season

Points	Temperature(°C)	Turbidity (NTU)	Conductivity (us/cm)	Suspended Matter (mg/l)	Dissolved Oxygen (mg/l)	Odour
1	25.60	36.50	500.20	80.20	0.230	Normal
2	26.30	28.30	550.00	60.40	0.300	Normal
3	27.15	38.40	600.00	60.00	0.260	Normal
4	28.00	39.00	600.00	56.00	0.200	Normal
5	28.20	38.40	500.30	56.00	0.300	Normal
6	29.00	35.60	700.00	50.00	0.250	Normal
7	29.00	40.00	650.00	50.00	0.260	Normal
8	27.15	41.00	600.00	45.00	0.270	Normal
9	26.30	37.60	700.00	46.00	0.240	Normal
10	28.00	38.00	600.00	40.00	0.250	Normal

Table 4: Results of Physical Parameters (Upstream) Romi River during Raining Season

Points	Temperature(°C)	Turbidity (NTU)	Conductivity (us/cm)	Suspended Matter (mg/l)	Dissolved Oxygen (mg/l)	Odour
1	18.60	56.50	500.20	90.20	1.230	Normal
2	19.30	48.30	550.00	80.40	1.300	Normal
3	21.15	48.40	600.00	80.00	2.260	Normal
4	21.00	49.00	600.00	76.00	2.200	Normal
5	21.20	48.40	500.30	76.00	1.300	Normal
6	22.00	45.60	700.00	60.00	1.250	Normal
7	22.00	40.00	650.00	70.00	1.260	Normal
8	22.15	51.00	600.00	75.00	1.270	Normal
9	22.30	47.60	700.00	66.00	1.240	Normal
10	22.00	58.00	600.00	70.00	1.250	Normal

Table 5: Result of Physical Parameters (Downstream) of Romi River during Dry Season

Points	Temperature (°C)	Turbidity (NTU)	Conductivity (us/cm)	Suspended Matter (mg/l)	Dissolved Oxygen (mg/l)	Odour
1	29.30	45.00	530.00	200.00	0.001	Oily
2	29.30	47.00	520.00	150.10	0.002	Oily
3	29.26	48.10	500.10	160.00	0.001	Oily
4	29.00	48.10	490.60	170.30	0.001	Oily
5	29.01	47.70	500.10	180.10	0.003	Oily
6	30.11	49.10	560.10	200.00	0.002	Oily
7	30.15	49.10	600.00	150.00	0.001	Oily
8	30.20	48.10	700.00	180.00	0.002	Oily
9	30.00	49.10	500.00	190.00	0.002	Oily
10	31.00	47.90	600.10	180.00	0.002	Oily

Table 6: Result of Physical Parameters (Downstream) of Romi River during Raining Season

Points	Temperature (°C)	Turbidity (NTU)	Conductivity (us/cm)	Suspended Matter (mg/l)	Dissolved Oxygen (mg/l)	Odour
1	25.10	48.21	530.00	250.00	1.211	Oily
2	24.00	49.02	520.00	320.10	1.202	Oily
3	25.16	50.14	500.10	290.00	1.301	Oily
4	24.20	52.12	490.60	270.30	2.201	Oily
5	25.21	51.71	500.10	280.10	1.203	Oily
6	26.21	51.13	560.10	290.00	1.202	Oily
7	26.25	59.12	600.00	210.00	1.301	Oily
8	26.10	58.12	700.00	210.00	1.102	Oily
9	25.20	59.11	500.00	210.00	2.222	Oily
10	21.10	57.91	600.10	210.00	1.232	Oily

Table 7: Results of Chemical Parameters in Effluents during Dry Season

Points	pH	Ammonia (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	BOD (mg/l)	COD (mg/l)	Oil Content (mg/l)	Alkalinity (mg/l)
1	8.62	10.56	11.90	0.005	6.05	85.00	440.62	150.86	14.00
2	8.56	10.70	11.70	0.005	6.06	84.00	440.60	160.00	13.60
3	8.45	10.65	11.80	0.001	6.05	84.00	440.61	150.70	13.20
4	8.66	9.80	12.10	0.001	6.00	82.50	440.60	148.00	13.10
5	8.60	10.56	12.05	0.001	6.00	85.00	432.50	140.00	13.40
6	8.62	9.70	11.90	0.005	6.04	84.00	400.60	140.00	13.40
7	8.56	9.90	12.05	0.006	6.00	82.60	440.60	150.00	13.30
8	8.62	10.08	11.80	0.001	6.02	85.00	440.60	160.00	13.60
9	8.62	10.07	12.00	0.002	6.00	82.44	446.00	140.00	13.50
10	8.60	9.70	12.00	0.003	6.05	82.50	432.50	140.00	13.40

Table 8: Results of Chemical Parameters in Effluents during Raining Season

Points	pH	Ammonia (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	BOD (mg/l)	COD (mg/l)	Oil Content (mg/l)	Alkalinity (mg/l)
1	8.42	10.00	11.70	0.025	5.80	87.00	450.62	100.86	11.00
2	8.46	10.00	11.50	0.015	5.06	86.00	450.60	120.00	12.60
3	8.45	10.05	11.50	0.021	5.05	86.00	460.61	130.70	11.20
4	8.36	9.0	12.40	0.011	5.00	86.50	450.60	148.00	12.10
5	8.30	10.20	12.45	0.011	5.00	87.00	442.50	130.00	11.40
6	8.42	9.20	11.60	0.015	6.04	82.00	450.60	120.00	11.40
7	8.36	9.32	12.11	0.016	6.00	88.60	450.60	120.00	12.30
8	8.42	10.02	11.21	0.021	6.02	88.00	460.60	130.00	12.60
9	8.42	10.02	12.11	0.022	5.00	89.44	466.00	130.00	11.50
10	8.30	9.20	12.11	0.023	5.05	88.50	482.50	120.00	12.40

Table 9: Results of Chemical Parameters in Romi River (Upstream) during Dry Season

Points	pH	Ammonia (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	BOD (mg/l)	COD (mg/l)	Oil Content (mg/l)	Alkalinity (mg/l)
1	6.80	1.75	10.30	0.000	3.50	107.00	200.00	0.00	15.95
2	6.90	1.85	9.40	0.000	3.60	105.00	191.10	0.00	16.00
3	6.80	1.80	10.00	0.000	3.60	106.00	192.10	00.0	16.10
4	6.81	1.90	10.01	0.000	3.70	108.50	192.10	0.00	16.20
5	6.81	1.81	10.02	0.000	3.60	109.00	198.10	0.00	16.10
6	6.85	1.67	10.02	0.000	3.60	107.00	200.00	0.00	16.10
7	6.81	1.81	10.00	0.000	3.50	104.60	198.10	0.00	15.90
8	6.85	1.75	10.00	0.000	3.70	101.00	197.30	0.00	16.00
9	6.90	1.81	9.50	0.000	3.60	106.44	198.10	0.00	16.10
10	6.81	1.81	10.25	0.000	3.50	107.50	189.97	0.00	16.10

Table 10: Results of Chemical Parameters in Romi River (Upstream) during Raining Season

Points	pH	Ammonia (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	BOD (mg/l)	COD (mg/l)	Oil Content (mg/l)	Alkalinity (mg/l)
1	6.50	1.45	9.30	0.000	3.10	101.00	190.00	0.00	12.95
2	6.46	1.55	9.10	0.000	3.20	100.00	190.10	0.00	13.00
3	6.60	1.30	10.00	0.000	3.20	101.00	191.10	00.0	13.10
4	6.51	1.50	9.21	0.000	3.10	101.50	191.10	0.00	14.20
5	6.51	1.51	9.02	0.000	3.10	100.00	191.10	0.00	13.10
6	6.55	1.57	9.02	0.000	3.10	100.00	190.00	0.00	14.10
7	6.51	1.61	9.00	0.000	3.10	101.60	191.10	0.00	12.90
8	6.55	1.55	9.00	0.000	3.10	100.00	191.30	0.00	14.00
9	6.50	1.61	9.50	0.000	3.10	100.44	191.0	0.00	15.10
10	6.51	1.51	10.25	0.000	3.20	101.50	189.97	0.00	13.10

Table 11: Results of Chemical Parameters in Romi River (Downstream) during Dry Season

Points	pH	Ammonia (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	BOD (mg/l)	COD (mg/l)	Oil Content (mg/l)	Alkalinity (mg/l)
1	6.85	2.50	0.00	0.001	6.20	100.45	250.10	9.70	15.30
2	6.86	2.60	0.00	0.000	6.21	99.00	240.00	9.66	15.20
3	6.70	2.55	0.00	0.001	6.25	96.00	250.10	90.80	15.20
4	6.80	2.50	0.00	0.001	6.17	95.40	240.10	9.60	15.30
5	6.86	2.30	0.00	0.000	6.18	98.45	230.40	9.70	15.15
6	6.80	2.40	0.00	0.00	6.20	96.45	240.10	9.60	15.20
7	6.85	2.50	0.00	0.00	6.20	99.20	230.10	9.62	15.15
8	6.64	2.36	0.00	0.00	6.14	96.45	235.29	9.63	15.20
9	6.64	2.40	0.00	0.00	6.17	96.10	235.10	9.62	15.15
10	6.80	2.32	0.00	0.00	6.20	89.95	232.18	9.63	15.20

Table 12: Results of Chemical Parameters in Romi River (Downstream) during Raining Season

Points	pH	Ammonia (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	BOD (mg/l)	COD (mg/l)	Oil Content (mg/l)	Alkalinity (mg/l)
1	6.25	2.10	0.00	0.000	6.00	100.00	220.10	6.70	11.30
2	6.16	2.10	0.00	0.000	6.01	93.00	220.00	7.66	11.20
3	6.20	2.15	0.00	0.000	6.05	92.00	220.10	70.80	11.20
4	6.30	2.20	0.00	0.000	6.07	92.40	210.10	5.60	12.30
5	6.16	2.10	0.00	0.000	6.08	93.45	220.40	7.70	12.15
6	6.20	2.20	0.00	0.000	6.10	93.45	220.10	6.60	11.20
7	6.15	2.20	0.00	0.000	6.00	93.20	210.10	5.62	13.15
8	6.14	2.16	0.00	0.000	6.04	92.45	215.29	7.63	12.20
9	6.24	2.10	0.00	0.000	6.07	92.10	215.10	6.62	12.15
10	6.20	2.22	0.00	0.000	6.10	93.95	212.18	7.63	12.20

Table 13: Results of Heavy Metals and other Chemicals Level in Romi River (Upstream) during Dry Season

Points	Iron mg/l	Lead mg/l	Chromium mg/l	Cadmium mg/l	Phenol mg/l	Phosphate PO_4^{-3} mg/l	Zinc mg/l	Ammonia mg/l	Alkalinity mg/l
1	0.000	0.21	0.00	0.012	0.08	3.35	0.05	1.55	13.20
2	0.000	0.20	0.00	0.008	0.12	3.57	0.07	1.35	13.60
3	0.000	0.01	0.00	0.1	0.10	3.46	0.06	1.45	13.40
4	0.000	0.01	0.00	0.012	0.12	3.40	0.06	9.30	13.30
5	0.000	0.01	0.00	0.013	0.08	3.37	0.08	9.40	13.25

Table 14: Results of Heavy Metals and other Chemicals Level in Romi River (Upstream) during Raining Season

Points	Iron mg/l	Lead mg/l	Chromium mg/l	Cadmium mg/l	Phenol mg/l	Phosphate PO_4^{-3} mg/l	Zinc mg/l	Ammonia mg/l	Alkalinity mg/l
1	0.000	0.11	0.00	0.010	0.008	3.05	0.00	1.05	10.20
2	0.000	0.10	0.00	0.008	0.00	3.07	0.02	1.05	10.60
3	0.000	0.01	0.00	0.010	0.01	3.16	0.03	1.05	11.40
4	0.000	0.010	0.00	0.002	0.01	3.10	0.02	1.10	11.30
5	0.000	0.00	0.00	0.003	0.08	3.17	0.03	1.10	11.25

Table 15: Results of Heavy Metals and other Chemicals Levels in Romi (Downstream) River during Dry Season

Points	Iron mg/l	Lead mg/l	Chromium mg/l	Cadmium mg/l	Phenol mg/l	Phosphate PO_4^{-3} mg/l	Zinc mg/l	Ammonia mg/l	Alkalinity mg/l
1	0.00	0.02	0.018	0.015	0.145	6.14	0.32	2.40	15.25
2	0.00	0.02	0.002	0.005	0.15	6.20	0.28	2.32	15.15
3	0.00	0.05	0.001	0.001	0.145	6.17	0.30	2.36	15.20
4	0.00	0.02	0.002	0.002	0.15	6.18	0.31	2.40	15.15
5	0.00	0.03	0.01	0.02	0.16	6.15	0.29	2.30	15.20

Table 16: Results of Heavy Metals and other Chemicals Levels in Romi (Downstream) River during Raining Season

Points	Iron mg/l	Lead mg/l	Chromium mg/l	Cadmium mg/l	Phenol mg/l	Phosphate PO_4^{-3} mg/l	Zinc mg/l	Ammonia mg/l	Alkalinity mg/l
1	0.00	0.00	0.008	0.005	0.10	6.10	0.12	2.10	13.25
2	0.00	0.00	0.002	0.005	0.11	6.10	0.18	2.12	13.15
3	0.00	0.00	0.001	0.001	0.12	6.00	0.10	2.10	13.20
4	0.00	0.00	0.002	0.002	0.11	6.00	0.11	2.11	13.15
5	0.00	0.00	0.00	0.002	0.11	6.10	0.19	2.11	13.20

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

This chapter focuses on the discussion of laboratory analysis results obtained from various samples collected from different sampling points in the project area which was earlier mentioned. The results obtained are to be compared with 2007 version of Federal Environmental Protections Agency (FEPA), which is Nigerian Standard for maximum concentration allowed for discharge into inland water and World Health Organization standard (W.H.O).Then from the comparison a conclusion was reached.

5.1.1 Physical Parameters of Kaduna Refining and Petrochemical Company

The physical parameters of the samples such as temperature, turbidity, conductivity, suspended matter, dissolved oxygen and odour were all above the stipulated standard guidelines for maximum concentration allowed for discharge into inland water bodies by Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO, 1985).

Temperature values of the samples were high and this could be due to the massive heat transmission in the waste water treatment equipment used in the treatment processes of the effluent. The low temperature values of samples in Up and Down Stream of Romi River owe to the self cooling of the river as water flows down the stream. However, the temperatures at the three stations (effluents discharge station, Upstream point and Downstream point) are within Federal Environmental Protection Agency (FEPA) acceptable limits.

The turbidity values of the samples varied along the three points. Turbidity values of effluents were high since Total Dissolved Solid (TDS) and Suspended Solids (TSS) are higher in concentration in the same samples. Turbidity depends on these two parameters. It was observed that the turbidity values up Stream of Romi River were reduced since the total suspended solid and total dissolved solid were reduced. But the turbidity values downstream of Romi River were highly concentrated since there was an increase in the total Suspended solid downstream. Turbidity, total suspended solid and total dissolved solid were above FEPA acceptable limits. When this waste water was discharged into the Romi River. Consequently, it reduces penetration of light rays into the water which is changed into hard and dirty material.

The conductivity value of effluents waste water was high due to the accumulation of dissolved / dissociable salts in the station while the values reduced as the river flows. It was observed that there are some ionized impurities dissolved in the waste water. The values of dissolved oxygen (DO_2) were low for effluents because of the oil contents of the water which prevents atmospheric oxygen to dissolve into the waste water. But the values of dissolved oxygen for Up and Down Stream of Romi River were moderate due to river flow.

The results of effluent odour indicated that the wastewater contained a lot of oil. The smell of Up and Down Stream samples of Romi River reduced gradually as the water flows. pH values of effluent was high (alkaline in nature) than the two other stations. The low pH values of the other stations were due to dilution of effluents by incoming water (Romi River), they are slightly nearer to neutrality which is within the limits for potable water.

5.1.2 Chemical Parameters of Kaduna Refining and Petrochemical Company

The chemical parameters of the samples included. Ammonia, Nitrate, Sulphate, Phosphate, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), oil contents and alkalinity.

The values of Ammonia, Nitrate and Phosphate were present and in a high concentration due to additives used in the refining processes, and there are also impurities in the crude petroleum oil, which have to be removed totally. It was observed that the Effluents and Down Stream Romi River values showed that the concentration did not conform to FEPA standards. It implies that if there is an increase in pH values the toxicity of Ammonia, Nitrate and Phosphate increases too. They are also an oxidable chemical, which increases Chemical Oxygen Demand (COD) when present in water.

The values of Biological Oxygen Demand (BOD) revealed that the concentration is low in the Effluents since there are no plants or microorganism that utilizes Oxygen in the Effluent.

However, it was found to be higher in the Up and Down Stream samples of Romi River due to the presence of organisms and plant that are constantly using the Dissolved Oxygen (DO_2) in the water for transpiration. Therefore, Biological Demand (BOD) of the Effluent is higher than FEPA standards. It implies that aquatic plants cannot survive in such water, in a nutshell, the water is bad.

The values of Chemical Oxygen Demand (COD) of Effluent were higher, because there are many oxidizable chemicals present in the wastewater. But the values for

Up Stream Romi River were reduced due to dilution by the incoming water. While the values for samples Down Stream of Romi River was high, the reason could be as a result of inflow of other wastewaters from Southern Kaduna small scale industries and the wash down of fertilizers from farming activities in the River banks. The result shows that the water can be corrosive and as such would be harmful to aquatic life and human.

The values of oil contents of effluents were high due to many reasons such as; untreated water overflowing into retention pond during heavy rainfall, equipments failure, leakage from the storage tanks, separation of instrument joints and accidental spillage.

The oil content was not traceable in samples upstream of Romi River because it might have been checked or the source of oil content do not get. Downstream samples of Romi River have a source of oil from the plant to this point. The results of Downstream conform to World Health Organization Standard. The presence of oil in water reduces the dissolved oxygen in water because there will be no air and water interface preventing oxygen from dissolving on the surface. This water cannot be utilized by fire service units because the oil will help in rekindling the fire and it is harmful for human consumption.

The values of alkalinity for effluents and samples, Upstream and Downstream of Romi River were moderate. Alkalinity is of no importance in water quality parameters for general use because it is determined by compounds present that can collectively shift pH to the alkalinity side of neutrality. Therefore, the values of alkalinity for the three stations are insignificant to water quality guidelines for maximum concentration allowed for discharge into inland water bodies.

5.1.3 Heavy Metals and other Chemicals Parameter of Kaduna Refining and Petrochemical Company Effluent

The heavy s and other chemicals in the samples included: iron, lead, chromium, cadmium, phenol, phosphate (PO^{-3}_4) and zinc and were within or slightly above the stipulated limits by FEPA.

Heavy metals are part of the impurities present in the crude petrochemical oil. They are expelled as waste from the crude petroleum oils to prevent wears and knocks in the motor engines. The values of iron are within the standard for water quality guideline at intake for the petroleum industry. The presence of lead can be traced to anti-knocking agents used in the refining of crude petroleum oil.

The concentrations of lead and other heavy metals in the wastewater were above FEPA standards. This water when consumed causes kidney damage, dermatitis etc. They can also cause plumbing fixture problems and stain to clothes. (Fergusson, 2002)

The presence of cadmium and chromium in the wastewater in high concentration could cause serious health hazards to animals and humans. These include potential neuron-degenerative disorders, fluorosis, skeletal tissue (bone and teeth) morbidity, cancer, interference with Vitamin D metabolism, mental development failure in infants, toxicity to the central and peripheral nervous system, neurological disorders, cyanosis and asphyxia (blue – baby syndrome) in infants under 3 months etc (Bebrun, 2000).

5.2 Conclusion

Kaduna Refining and Petrochemical Company (KRPC) is one of the biggest plants for crude oil refining and processing in the country. KRPC are mindful of the hazardous nature of their wastewater to human beings, animals, plants and aquatic life. But as to whether the wastewater treatment plant is efficient, adequate and sufficient in the treatment of KRPC wastewater is highly questionable. This is vis-à-vis the Federal Environmental Protection Agency and World Health Organization stipulated standards, for guidelines of maximum concentration allowed for discharge into inland water bodies and water quality guidelines at in-take for the petroleum industries.

The production of physically, chemically and biological safe water is the primary goal in the design of wastewater treatment plants. In addition, the wastewater should be to some extent appealing for discharge into inland water bodies if the water flows or not. That is, it should be a bit clear, pleasant, odourless and cool. In the design of wastewater treatment plants, the objective is to establish facilities with reasonable capital and operating costs, various alternatives in plant design should be evaluated for cost effectiveness and wastewater quality produced. Alternatives developed should be based upon sound Engineering principles. All wastewater sources intended for discharge into inland water bodies shall comply with Nigeria Industrial Standards under Federal Environmental Protection Agency and shall receive authorization from Ministry of Health before being discharged to any flow Rivers or non flow Rivers. The presence of any contaminants shall not exceed limits specified in FEPA stipulation. Inspectors' in-charge of wastewater quality surveillance shall conduct regular verification of wastewater quality tests and sanitary inspections to determine whether wastewater utilities, community wastewater committee, food processing industries, chemical industries, private or public establishment standard for waste water quality are met.

Wastewater providers shall increase the amount of residual treating reagents during epidemics or special cases according to instructions of the Ministry of Health.

Wastewater pollution from KRPC affects the lives of many people especially those who live along the banks of the Romi River where Effluents are constantly being discharged into the River without hundred percent treatments.

The aim of this research work was to ascertain whether the quality of wastewater discharged into Romi River by Kaduna Refining and Petrochemical Company are within the Federal Environmental Protection Agency recommended standards, identify and assess those components of the effluents that pose environmental hazards.

The analytical results of KRPC wastewater and Effluents revealed that the treatments are not efficient for physical, chemical and heavy metal parameters. From the analysis, it was observed that almost all the parameters are a little higher than the required recommended ranges.

The wastewater and Effluents being constantly discharged into Romi River also flows into River Kaduna which the state uses for their source of drinking water. It implies that in the nearest future a majority of Kaduna state populace will experience serious health problems associated with wastewater pollution if drastic measures are not taken in time.

In conclusion, there are traceable heavy metals and hazardous chemical present in the wastewater being constantly discharged into Romi River. The threshold limit may be extended if not checked promptly. Although dilution by the River flows have reduced the toxicity of each of the chemicals present. But the Romi River water body has the following effects; it causes kidney damage when consumed, stains clothes, skin irritation, increases the lead level in blood, wear away materials, destroys liver, and in a nut shell it is not suitable for domestic use at all.

5.3 Recommendations

Whatever the source of wastewater, the quality of the wastewater discharged into Romi River must meet desirable required standards. Although Kaduna Refining and Petrochemical Company (KRPC) waste water treatment unit are trying to meet the expected standard, more efforts and time should be made by staff / personnel's in charge of the treatment unit to treat the wastewater in order to meet up with the Federal Environmental Protection Agency standard. The wastewater treatment plant should be renovated due to its history of being burnt and replacement of the equipments, so that the treatment of wastewater will be in conformity with standards.

Perhaps, all the units in the KRPC should provide modern ways or methods of treating their wastewater generated before discharging them outside or even they should at least minimize their waste by recycling the waste to recover the heavy metals since a little concentration of any heavy metal in water is harmful to the living organisms. That is they should employ the use if three R's (Reduce Recycle and Re-use).

The KRPC laboratory scientists should conduct regular verification of wastewater quality tests and sanitary inspections on weekly basis instead of the usual monthly checking.

There should be constant and regular record keeping of results analyses and data for the wastewater management, so that inference and deduction can be easily reached for positive effects.

The Federal Ministry of health through their various agencies should send their inspectors in charge of waste water quality surveillance to industries that discharge wastewater into inland water bodies for assessment on regular basis.

The Federal Environmental Protection Agency should enforce the stipulated standard on companies as custodians and protectors our environment by trying to on-force these laws so that they can be strictly adhered to.

And the KRPC should always inform the populace to treat, and boil their source of water especially those that reside at the banks of Romi River.

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APPENDIX I

FEPA GUIDELINES FOR MAXIMUM CONCENTRATION ALLOWED FOR DISCHARGE INTO INLAND WATER

For Petroleum Refinery

S/No.	Parameters	Concentration mg/L
1.	Temperature	30
2.	Ph	6.5 – 8.5
3.	Oil and Grease	10
4.	Phenol	0.5
5.	Ammonia (as NH_3^+)	0.210
6.	Sulphides as (H_2S)	0.2
7.	Total suspended solids	30
8.	BOD	10
9.	COD	40
10.	Chromium	0.1
11.	Lead	0.05
12.	Cadmium	0.01

APPENDIX II

FEPA WATER QUALITY GUIDELINES AT IN-TAKE FOR THE PETROLEUM INDUSTRIES

S/No.	Parameters	Concentration mg/L
1.	Ph	6.0 – 9.0
2.	Colour	NS
3.	Calcium	Less than 75
4.	Manganese	Less than 25
5.	Iron	Less than 1
6.	Bicarbonate	NS
7.	Sulphate	NS
8.	Chloride	Less than 200
9.	Nitrate	NS
10.	Fluoride	NS
11.	Silica	NS
12.	Hardness	Less than 350
13.	Total dissolved solid	Less than 750
14.	Total suspended solid	Less than 10

APPENDIX III

CHEMICAL / INORGANIC CONSTITUENTS PARAMETERS FOR MAXIMUM ALLOWABLE LIMITS IN NIGERIA INDUSTRIAL STANDARD

Parameters	Units	Maximum Permitted	Health Impact	Notes
Aluminum (Al)	mg/L	0.2	Potential neuro-degenerative disorders	Note 1
Arsenic (As)	mg/L	0.01	Cancer	
Barium (Ba)	mg/L	0.7	Hypertension	
Cadmium (Cd)	mg/L	0.003	Toxic to the kidney	
Chloride (Cl)	mg/L	250	None	
Chromium (Cr^{6+})	mg/L	0.05	Cancer	
Conductivity	μ/cm	1000	None	
Copper (Cu^{2+})	mg/L	1	Gastrointestinal disorder	
Cyanide (CN^-)	mg/L	0.01	Very toxic to the thyroid & the nervous system	
Fluoride (F^-)	mg/L	.15	Fluorosis, skeletal tissue (bones & teeth) morbidity	
Hardness ($CaCO_3$)	mg/L	150	None	
Hydrogen sulphide (H_2S)	mg/L	0.05	None	
Iron (Fe^{2+})	mg/L	0.3	None	
Lead (Pb)	mg/L	0.01	Cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous system	
Magnesium (Mg^{2+})	mg/L	0.20	Consumer acceptability	
Manganese (Mn^{2+})	mg/L	0.2	Neurological disorder	

(Continued)

Parameters	Units	Maximum Permitted	Health Impact	Notes
Mercury (Hg)	mg/L	0.001	Affect the kidney and central nervous system	
Nickel (Ni)	mg/L	0.02	Possible carcinogen	
Nitrate (NO_3)	mg/L	50	Cyanosis, and asphyxia ("blue-baby syndrome") in infants under 3 months syndrome") in infants under 3 months	
Nitrite (NO_2)	mg/L	0.2	Cyanosis, and asphyxia ("blue-baby syndrome") in infants under 3 months	
pH	-	6.5 – 8.5	None	
Sodium (Na)	mg/L	200	None	
Sulphate (SO_4)	mg/L	100	None	
Total Dissolved Solids	mg/L	500	None	
Zinc (Zn)	mg/L	3	None	

Note: Parameter to be monitored only if aluminum chemicals are used for water treatment.

APPENDIX IV

CHEMICAL / ORGANIC CONSTITUENTS PARAMETERS FOR MAXIMUM ALLOWABLE LIMIT IN NIGERIA INDUSTRIAL STANDARD

Parameter	Unit	Maximum Permitted Level	Health Impact	Note
Detergents	mg/L	0.01	Possibly Carcinogen	
Mineral	mg/L	0.003	Possibly Carcinogen	
Pesticides	mg/L	0.01	Possibly Carcinogen	
Phenols	mg/L	0.001	Possibly Carcinogen	
Poly Aromatic Hydrocarbons	mg/L	0.007	Possibly Carcinogen	
Total organic carbon or oxidizability	mg/L	5	Cancer	

APPENDIX V

DISINFECTANTS AND THEIR BY – PRODUCTS

Parameter	Unit	Maximum Permitted Level	Health Impact	Note
Free residual chlorine	mg/L	0.2 – 0.25	None	Note 2
Trihalomethanes total	mg/L	0.001	Cancer	Note 2
2,4,6-trichlorophenol	mg/L	0.02	Cancer	Note

Note 2: For chlorinated water only

APPENDIX VI

RADIOACTIVE LIMITS

S/No.	Parameter	Unit	Maximum Permitted level	Health Impact	Notes
1.	Radionuclides	βq/L	0.1	Cancer	

APPENDIX VII

Drinking Water Standard

Substance	**WHO**	**International Limits**		**European limits**	**USA limits guide level**	**Proposed ECC limits maximum admissible concentration**
		Highest desira	Maximum permiss.			
Phenolic compound	0.001	0.001	0.001	0.001	-	0.001
Fluoride	1-1.7	-	0.2-1.7	0.7-1.5	-	0.7-1.5
Nitrate as (NO_3)	50-100	-	-	10	-	0.7-1.5
pH	-	7-8.5	6.5-9.2	6.5-8.2	6.5-8.2	9.5
Turbidity (units)	-	5	25	1.5	5	10
Calcium (as Ca^{2+})	-	Nil	200	-	100	-
Organics	0.2-0.5	-	-	-	-	-
Mineral oil	-	75	0.5	0.5	-	0.01
Ammonia (as NH_3)	0.5	-	-	2.0 as N	0.05	0.5
Chloride as Cl	200-600	200	600	350	5	200
Sulphate as SO_4^{2-}	150	200	400	500	5	250
Magnesium as Mg^{2+}	50-125	50-150	150	-	50	50
Manganese	0.5	0.05	0.5	0.1	0.02	0.5
Iron as Fe^{2+}	0.1	0.1	1.0	0.5	0.1	0.05
Copper as Cu^{2+}	0.5	0.5	1.5	1.0	-	0.5
Zinc as Zn^{2+}	5.0	5.0	15	5.0	-	0.1