PERFORMANCE EVALUATION OF WASTEWATER TREATMENT PLANT AND ITS EFFECTS ON IRRIGATION WATER (A CASE STUDY OF KADUNA REFINERY AND PETROCHEMICAL COMPANY (KRPC) LTD)

BY

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MATRIC NO: 2005/21546EA

BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

FEBRUARY, 2010

DECLARATION

I hereby declare that this Project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any University of Institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

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CERTIFICATION

This project entitled 'Performance evaluation of wastewater treatment plant of (KRPC) and its effects on irrigation water' by Afe Peter Olusegun meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate this project work to God almighty the source of my inspiration and my sustainer from the beginning even till today, and also to my late parents, as well as my beloved elder brother, Engineer Afe Samuel Oluwatoyin, whom God has used as instruments to my success.

ACKNOLEDGEMENTS

I give God all the glory, honours and adorations for given me the grace to complete this work successfully. It was indeed the Lords doing and I give an unreserved praise to His name.

My gratitude also goes to my indefatigable Project Supervisor for his relentless assistance towards the completion of this text, especially in the way he had to occasionally edited and criticized the work in an understanding manner.

I also give gratitude to the Head of Department, Agricultural and Bioresources Engineering and all the lecturers especially my Level Adviser, Mr.Sadeeq, who is always ready to assist. They have all contributed to the success of this work. I really appreciate their efforts.

Special thanks to my brother Engineer Afe Samuel Oluwatoyin without whom my dreams would not have been actualized. He assisted me financially and morally.

Finally, thanks to my colleagues and class mates for the good and efficient advice they individually and collectively give to me towards the accomplishment of this project work.

ABSTRACT

A study was conducted to evaluate the performance of KRPC Kaduna, wastewater treatment Plant regarding its effluent effects on irrigation water. The four samples (A,B,C,D) of wastewater at different level were analyzed respectively using physiochemical parameters as indices. The physical properties including total dissolve solid (TDS), electrical conductivity, and Temperature were determined using the conductivity/TDS meter while the Gelman filter apparatus was used to determine turbidity. Atomic- absorption spectrophotometer, titration, gravimetry and evaporation to dryness were used to determine the chemical-inorganic constituents, except for PH of the wastewater samples which was determined using the PH meter. Each parameter was tested for in the four samples so as to determine the quality of the wastewater at different points along the flow; the PH(s) of the samples were found to be higher except at point A compare with standards of (APHA) and (WHO). Zero Ammonia and Nitrate in all the samples, also higher conductivity of sample at point B was found. Though some of the standards for these parameters were not readily available on the table4.6 (not sited NS) the comparison of the downstream wastewater with established standards such as: World Health Organisation (WHO, 1986), American Public Health Association (APHA, 1991), signals actual performance of each section of the Wastewater Treatment (WWT) Plant. Thus the harmful effect on the environment could be corrected if: the WWT Plant operations supervision is intensified, capable hands (experts) are used coupled with periodic training, personnel working with the spirit of responsibility, in fact penalty should be placed on any faulty personnel, for the sake of environmental safety, WWT Plant should be highly digitalized for prompt detection of faults.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The discovery of crude oil in 1957 in a town called Oloibiri Niger Delta (south south geo-political Zone) of Nigeria has brought relief to many Nigerians especially to those living in the region. Though many saw it as an economic instrument, little did they know that it also has its own dangerous implications. Any problem associated with fowl discharge from refinery wastewater treatment is mainly felt on the receiving ends. Therefore adequate treatment and disposal of wastewater and it by-products should be a groaning concern in the oil and gas industry; especially the refinery. Concern for environmental protection and sustainable development should be the priority while undertaking refinery activities.

It is known that petroleum activities has become extensive in recent time in Nigeria with increase in demand for petroleum and it product in the spot market. Kaduna refining and petrochemical company (KRPC) is a region which has experienced such extensive activities over time –since 1977 when it was constructed till now. Nigerian became an exporter of oil when production reached 6000 barrels per day. The current daily production is over two million barrels. Crude oil exploration and production, petroleum refining and marketing operations have several attendants environmental problems. Production effluence consist mainly of produce formation waters emanating continuously different oil bearing formation with crude oil and associated gas or condensate. together Produce formation waste posses great danger when disposed into fresh waters because of its salinity, heavy metals and polycyclic aromatic hydrocarbon (PAHs) content. Wastewater released by crude oil processing and petrochemical industries are characterized by the presence of large quantities of crude oil product, polycyclic and aromatic hydrocarbons, phenols, metal derivatives, surface – active substances sulphides, naphthylenic acid and other chemicals. Due to the ineffectiveness of purification systems, waste water may become seriously dangerous, leading to accumulation of toxic products in the receiving water bodies with potentially serious consequences on the ecosystem. Various studies have shown positive correlations

between pollution from refinery effluence and the health of aquatic organisms, as well as the quality of the wastewater used for irrigation. Previous observation suggested a correlation between contermination of water and sendiments with aromatic hydrocarbon, toxic nutrients from refinery effluent and thus compromise fish health as well as agricultural activities in the environment.

1.2 Statement of Problem

For the sake of public health hygiene for rural dwellers also the oil in the marine environment due to refinery fowl effluent discharges affects marine organisms in many ways. Accumulations of hydrocarbons, organic nutrients, heavy metals in the food chain and subsequent effects are usually at higher trophic level, rendering life a tentative phenomenon at the receiving end. This reasons are enough to evaluate the performance of wastewater treatment plant of KRPC .

1.3 Objectives of the Study

This research study was designed to achieve the main objective of performance evaluation of waste water treatment plant as it affects water for irrigation using KRPC as case study.

a. To determine the effluent quality of KRPC waste water.
b. To ascertain the conformity of KRPC waste water treatment plant effluent with standards of World Health Organisation (WHO), Food and Agricultural Organization (FAO) or with other established standards

c. To recommend the necessary environmental friendly treatment the waste water generated by KRPC could undergo or suggest better purification.

1.4 Justification of the Study

The importance of this assessment is of two folds. Firstly it will facilitate the assessment of the level of pollutant in the wastewater using wastewater quality indicators.

Secondly, the outcome would enable us know the level of treatment to subject wastewater before discharge into stream and rivers is made.

1.5 SCOPE OF STUDY

a. The research study was conducted on the performance of waste water treatment plant using KRPC as case study.

b. To find out the process the waste water generated by KRPC undergoes

c. To analyze the quality of the effluent and that of waste stream (secondary effluent) from KRPC waste water treatment plant using BOD, COD and TOC as waste water quality indicators.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Waste Management in Nigeria

Waste management involves the collection, transportation, storage, treatment and disposal of waters including the after care of the disposal sites.

Disposal involves the storage, tipping of deposit on or below the ground as well as all the transformation operations utilized for waste recovery, re-use or recycling (Akintola,1994). This, the best option in waste management is a no waste technology approach (Zero option), that is no waste is generated. This represents an ideal against which any other waste management options must be accessed. This is directly followed by waste minimization; and the last option is waste treatment (Akintola, 1994).

Waste minimization is mandatory for existing industries to eliminate and/or minimize waste being generated from production process. A proper waste analysis at the design stage is therefore necessary. Industry should look for the processes where there is no waste; and where that is impossible, they should practice waste minimization, where the quality of waste are, whether harmful or not, are reduced to the bearest minimum. This is so because waste, even when non-polluting, results in the depletion of the earth resources including the energy requirements for processing. Waste recycling is mandatory for waste minimization (Massoud and Ahmed, 2005).

The increasing demand for environmental protection through regulated environmental standards should force industries in Nigeria to re-evaluate the economic impact of the environmental issues and adopt new and cost effective approaches to waste management. Management must adopt new attitudes about waste and environmental problems. Waste reduction within the manufacturing process reduce cost, especially

energy cost; transportation, administrative and emission to air, water and land costs are also affected. Reducing waste in the production process in the industry can also reduce the amount of raw materials inputs in addition to final disposal costs (Massoud and Ahmed, 2005).

2.2 Risk and Opportunities in Sewage Irrigation

The rapid urbanization in developing countries has resulted in the generation of

huge volumes of municipal and industrial wastewater requiring treatment and safe disposal. Using treated wastewater for agriculture, provides a means through which sewage effluent can safely be re-used. To ensure sustainable and safe use of wastewater for food production in Urban and semi-Urban areas, there is a need to explore management options (Muhammad, 2006).

In Pakistan, Sewage irrigation is an informal and unregulated activity, making it difficult to define the pattern and extent to which it is practiced. In the case of informal irrigation, wastewater in accessed directly or indirectly. Indirect use occurs when domestic wastewater and in some instances, industrial wastewater in discharged directly into water-courses within and around the Urban areas without treatment.

(Muhammad, 2006)

Sewage disposal system entails discharging waste waters into surface water bodies, which are often irrigation channels and canals. In this case, there is no control over the subsequent use of water for crop production. Direct use occurs mainly when farmers deliberately divert sewage effluent from drain to their fields. Thus, under conditions of water scarcity and weak enforcement, waste water irrigation has thrived as an unplanned and spontaneous activity. (Muhammad, 2006)

In many developing urban centers, waste water is generally a mixture of domestic and untreated industrial effluent. The uncontrolled and varied nature of waste water used for irrigation makes it difficult to define, monitor and control the practice. There are

comprehensive figures of the extend of waste water used for irrigation but the available estimates indicate that about 900,000 hectares of farmland in developing countries are irrigated with waste water. Globally 20 million hectares producing nearly four percent of food are irrigated with waste water. The estimated sewage production of citieis like Karachi, Lahore, Deshawar, Hyderabad, Faisalabad, Multan, Rawalpindi/Islamabad, Kasur, Sukkur, Quetta, etc., range from 32 to 68 gallons per capita per day. On the basis of population census of 1998, 1,160,590 million gallons per day of sewage is generated from large industrial urban – centers. Nearly 10 percent of the municipal and industrial effluent is treated only to primary level and the rest is disposed off into irrigation system or left astray without any treatment. A major proportion of waste water is confined to the vicinity of cities. It is estimated that about 95,000 acres (32,000 hectares) in Pakistan are irrigated with municipal effluent. (Muhammad, 2006).

The main reasons for sewage irrigation are drought, high content of plant nutrients and year-round access of farmers to this source. The effluent is mainly used for raising vegetables and fodder crops because of the nearby markets. It is estimated that the application of 40cm of sewage effluent can add 100-200 kg Nitrogen, 6-20 kg Phosphorus and 100-250 kg Potassium, eliminating the need for artificial fertilizers. However, the use of raw sewage in agriculture is not without danger. The major risk is utilizing raw city effluent is food contamination by pathogenic micro organism and outbreak of waterborne diseases. (Mohammad, 2006)

Untreated city effluent contain full spectrum of pathogens (helminthes, protozoa, enteric, bacteria and viruses) found in urban population and main of these can survive for weeks when discharged into the fields. There are public health concerns for producers, handlers, consumers and communities using wastewater around production areas. These potential health risks are a major constraint of current wastewater use practices, and can

possible limit its long-term sustainability. Irrigation with raw sewage containing high

level of trace elements and heavy metals is likely to be toxic to plants and also poses risk to human health. Heavy metal in sewage effluent for most developing countries in mainly related to the mixing of domestic and industrial waste water in the same sewage system. Examples of potentially toxic trace elements include mercury, lead, arsenic, copper, cadmium, manganese. Generally farmers grow leafy vegetables and those vegetables whose edible portions are root that flourish under or near the ground e.g spinach, lettuce, radish, carrot, sugar beet, cabbages, cauls, flower, etc. These accumulate higher amounts of heavy metals like cadmium, lead, zinc, copper, nickel, manganese. (Javis, 1992).

Studies in China, Japan and Taiwan indicate that the rice accumulated high concentrations of Cadmium and other heavy metals when grown in soils contaminated with irrigation water containing substantial industrial discharge. These examples indicate that certain food crops have a high possibility of transferring heavy metals to humans. Most heavy metals are carcinogenic and cause mental disorder, respiratory problems and hormonal unbalance. A more dangerous consequence of raw municipal effluent is transmission of heavy metals through animal milk into human as fodder grown by polluted water accumulates higher quantities of heavy metals in animals. Heavy metals, therefore, remains concern especially in instances where industrial effluent is an important factor. In addition, health risks of heavy metals can be looked at from an occupational hazard point of view where chemical pollutants in wastewater can cause harm to farmers as a result of direct contact with water during farming. (Meadows, 1995).

The lack of awareness among farmers on health hazards of untreated effluent also constitutes a major problem. Training and awareness to build skills and knowledge on using raw sewage for irrigation should be considered in planning process of re-use

projects so as to protect all risk groups. Awareness campaigns and programmes should be conducted to educate and orient farmers on precautions of raw effluent use and inform consumers about the safety of agricultural product irrigated with sewage. The absence of strict regulations is resulting in damage to health and environment. The long term use of saline and sodium-rich water tends to destroy soil structure and reduces productivity. (Muhammad, 2006).

Moreover, increasing industrialization is changing the composition of wastewater, raising the level of heavy metals, acids and the like which impacts soil and crops. Groundwater contamination from nitrates and other pollutants including heavy metals is another potential danger and many such problems are irreversible. Regulations are also needed to control the re-use of treated sewage effluent. The environmental impact of sewage irrigation varies considerably from city to city depending on industrialization, type of industry, nature of water distribution and the degree of treatment and dilution if any. Environmental impact of sewage irrigation also raises doubts about its long-term sustainability and includes visual untidiness, soil erosion, and destruction of vegetation, sitting, depletion and pollution of land and water resources. However, the use of sewages in agriculture helps water conservation.

Sewage use scheme, if properly planned and managed can have positive environmental impacts. Some degree of treatment must normally be provided to raw municipal effluent before it can be used for irrigation. For local governments, using treated wastewater for irrigation can be beneficial, as an economically feasible and environmentally sound method of disposing municipal effluent. The management of wastewater through treatment has two major objectives. These are: to protect the environment by reducing the pollution of freshwater resources and productive lands and hence reducing health hazards, and to mobilize this available water resources for

mitigating water scarcity and improving crop production. Putting restrictions on the type

of crop that can be grown with raw effluent is another way of reducing risks. Instead of growing vegetables and food and fodders crops, grain crops like wheat, maize, sorghum and ornamental crops and woody trees can be grown. (Muhammad, 2006).

2.3 Objective of Waste-water Treatment

Methods of Wastewater treatment were first developed in response to the concern of public health and adverse conditions caused by the discharge of wastewater to the environment . Also important as cities continued to grow in the United States is the limited availability of land for wastewater treatment and disposal, principally by irrigation and intermittent infiltration. These are methods, which were commonly used in 1900s. The purpose of developing other methods of treatment was to accelerate the forces of nature under controlled conditions in treatment facilities of comparatively smaller size. (Stensel, 2003).

In general, from 1990 to the early 1970s, treatment objectives were concerned with:

(1) The removal of suspended and floatable materials.

(2) The treatment of biodegradable organics.

(3) Elimination of pathogenic organisms.

From the early 1970s to about 1980, wastewater treatment objectives were based primarily on aesthetics and environmental concerns. The earlier objectives of BOD, suspended solids, and pathogenic organisms' reduction continued, but at higher level. Removal of nutrients such as nitrogen and phosphorus also began to be addressed especially in some inland streams and lakes. A major effort was undertaken by both State and Federal agencies to achieve more effective and wide-spread treatment of wastewater to improve the quality of the surface waters. (Stensel, 2003).

This effort resulted in part from

(1) An increased understanding of the environmental efforts caused by wastewater discharges.

(2) A development knowledge of the adverse long-term efforts caused by the discharge of some of the specific constituents found in water.

(3) The development of national concern for environmental protection. The result of these efforts was a significant improvement in the quality of surface waters. Since 1980, because of the increased scientific knowledge and an expanded information base, wastewater treatment has begun to focus on the health concerns related to toxic and potentially toxic chemicals released to the environment. The water quality improvement objective of the 1970s have continued, but the emphasis has shifted to the

definition and removal of toxic and trace compounds that may cause long term long effects. As a consequence, while the treatment objectives must go hand in hand with the water quality objectives or standards established by the Federal, State and regional regulatory authorities. (Stensel, 2003).

2.4 Processes Involved in Treating Wastewater

The treatment of wastewater is carried out in stages to achieve dislodging of harmful microbes from the wastewater before the water is discharged into a body of water or discharged through a combined system of sewerages. This wastewater, which is to be treated, is usually disposed in a common and economic way. The treatment before disposal is aimed at removing dangerous and unsightly waste from households and industrial wastewaters. If wastewater is disposed without treatment, then it constitutes potential nuisance and dangers at the collecting bodies of water.

In the treatment of wastewater before irrigation, full recovery of the waste value of the sewage is intended with as much recovery of the fertilizing value as is consistent with:

(1) Avoiding the spread of diseases by crops grown on the sewage - irrigated lands or animals pastured on them.

(2) Preventing nuisance such as unsightliness and bad odour around disposal areas.

(3) Optimizing in an economic sense, sewage disposal costs and agricultural returns.

2.5 Economic and Financial Implication

In keeping with water works practice, the construction of wastewater systems from ground up, or their improvement and extension progresses from preliminary studies through financing design and construction to operation, maintenance and repair. The per capita investment in sewage systems varies with system type, topography, hydrology, and geology of the communities served. The nature, volume and proximity of receiving waters, need for storage treatment, availability and cost of labour and materials, size and character of the community are the determining factors. (Ifeadi, 1982).

Sewage treatment facilities cannot be sited in a community where the population is low. The government agencies in charge of municipal master plan take into consideration the financial support of a community before a unit of sewage treatment facility is sited. This is because of the high cost of building this facility. In Kaduna refining and petrochemical company Ltd., the cases under discussion, serious thought is being given to this type of project in the master plan, considering the available space.

In addition to the above factors, sewage treatment works relatively as twice as expensive compared to water purification works of the same volume. The collective system of domestic sewage is however about half as expensive compared to pure water collection works. The planning of wastewater treatment facilities should only arise when the population is very large. The traditional method of disposing sewage into the ground has been very useful in many communities in deferent parts of the world. The absorptive capacity of the soil is controlling importance. (Shuval,1972).

2.6 Ground Water Contamination

Little interest has been shown in the contamination of ground water through seepage process taking place in the refinery. This may not be unconnected with the slow degradation of many pollutants, the latter sometimes persisting for years (Golterman, 1978). However, evacuated primary sludge from process tanks may leach, the effect of which may be noticed far beyond the boundaries. George (1987) linked NO_3-N problems New-Zealand ground waters to concentrated livestock and manure usage. Also, the high nitrate content of well water in some villages in Punjab State, India was due to animal waste. (Fonseca, 2000).

Several treatment and handling systems for livestock wastes (among which is abattoir effluent) have been suggested. However, most treatment systems in abattoir wastes are not likely to produce effluent (relative to prescribe standard) fit for discharge into streams. Significant leakage from overland treatment system (e.g. lagoon) into groundwater is not desirable.

In Nigeria, the awareness of abattoir waste pollution is very low, thus tapping ground water through shallow wells, sometimes very close to an excreta dump, is common similarly extensive use of water down-streams of abattoir effluent discharge points is also common. (Abiola, 1995).

2.7 Sewage Treatment

Sewage treatment, or domestic wastewater treatment, is the process of removing contaminants from wastewater, both runoff (effluents) and domestic. It includes physical, chemical and biological processes to remove physical, chemical and biological contaminants. Its objective is to produce a waste stream (or treated effluent) and a solid waste or sludge suitable for discharge or reuse back into the environment. This material is often inadvertently contaminated with many toxic organic and inorganic compounds.

Sewage is created by residences, institutions, hospitals and commercial and industrial establishments. It can be treated close to where it is created (in septic tanks, biofilters or aerobic treatment systems), or collected and transported through a networked of pipes and pump stations to a municipal treatment plant. Sewage collection and treatment is typically subject to local, state and federal regulations standards (regulation and controls). Industrial sources of wastewater often require specialized treatment processes.(Stensel, 2003).

Typically, sewage treatment involves three stages, called primary, secondary and tertiary treatment. First the solids are separated from the wastewater stream. Then dissolved biological matter is progressively converted into a solid mass by using indigenous, water-borne micro organisms. Finally, the biological solids are neutralized then disposed of or re-used, and the treated water may be disinfected chemically or physically (for example by lagoons and micro-filtration). The final effluent can be discharged into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, greenway or park. If it is sufficiently clean, it can be used for ground water recharge. (Stensel, 2003)

2.7.1 Primary Treatment

Primary treatment removes the materials that can be easily collected from the raw wastewater and disposed of. The typical materials that are removed during primary treatment include Fats, oils, and greases (also deferred to as FOG) sand, gravels and rocks, larger settleable solids including human waste and floating materials. This step is done entirely with machinery hence the name mechanical treatment. Primary treatment typically includes a sand or grit (also called rocks) channel or chamber where the velocity of the incoming wastewater is carefully controlled to allow sand grit and stones to settle, while keeping the majority of the suspended organic material in the water column. This equipment is called a detritor or sand catcher. Sand grit and stones need to be removed early in the process to avoid damage to pumps and other equipment in the remaining treatment stages. Sometimes there is a sand washer (grit classifier) followed by a conveyor that transports the sand to a container for disposal. The contents from the sand catcher may be fed into the incinerator in a sludge processing plant, but in may cases, the sand and grit is sent to a landfill. (Amud and Odubella, 1991)

2.7.2 Secondary Treatment

Secondary treatment is designed to substantially degrade the biological content of the sewage such as are derived from human waste, abattoir waste, soaps and detergent. The majority of the municipal and industrial plants treat the settled sewage liquor using aerobic biological processes. For this is to be effective, the biota require both oxygen and a substrate on which to live. There are number of ways in which this is done. In all these methods, the bacteria and protozoa consume biodegradable soluble organic contaminants (sugar, fats, organic short - chain carbon molecules, etc) and bind much of the less soluble fractions into floc. Secondary treatment systems are classified as fixed film or suspended growth. Fixed-film treatment process including trickling filter and rotating biological contactors where the biomass grows on media and the sewage passes over its surface. Suspended growth systems - such as activated sludge - the biomass;

thoroughly mixed with the sewage and can be operated in a smaller space than fixed-film system that treat the same amount of water. However, fixed-film systems are more able to cope with drastic changes in the amount of biological material and can provide higher removal rates for organic material and suspended solids than suspended growth systems.

(Stensel, 2003)

2.7.3 Tertiary Treatment

Tertiary treatment provides a final stage to rise the effluent quality before it is discharged to the receiving environment (via, river, lake, ground, etc). More than one tertiary treatment process may be used at any treatment plant. If disinfection is practical, it is always the final process. It is also called "effluent polishing". (Stensel, 2003)

After the wastewater have, adequately been subjected to filtration by sand, lagooning to improve settleability, constructed wetlands, nutrient removal and disinfections, then, is said to have undergone treatment effectively. However, to ensure effective nutrient removal, wastewater must be carefully examined.

Wastewater may contain high levels of the nutrients nitrogen and phosphorus. Excessive release to environment can lead to a build-up of nutrients, called eutrophication, which can in turn encourage the overgrowth of weeds, algae, and

Cyanbacteria (blue-green algae). This may cause an algal bloom, a rapid growth in the population of algae. The algae number is unsustainable and eventually most of them die. The decomposition of the algae by bacteria uses up so much oxygen in the water that most or all of the animal die, which creates more organic matter for the bacteria to decompose. In addition to causing deoxygenation, some algal species produce toxins that contaminate drinking water supplies. Different treatment processes are required to remove nitrogen and phosphorus.(Tylor, 1997).

The removal of nitrogen is effected through the biological oxidation of nitrogen

from ammonia (nitrification) to nitrate, followed by denitrification, the reduction of nitrate to nitrogen gas. Nitrogen gas is released to the atmosphere and this removed from the water.

Nitrification itself is a two-step aerobic process, each step facilitated by a different type of bacteria. The oxidation of ammonia (NH_3) to nitrate ($N0_2^-$) is most often facilitated by Nitrosomonas SPP (nitroso referring to the formation of a nitroso functional group). Nitrite oxidation to nitrate ($N0_3^-$), though traditionally believed to be facilitated by Nitrospira SPP. Denitrification requires anoxic conditions to encourage the appropriate biological communities to form. It is facilitated by a wide diversity of bacteria. Sand filters, lagooning and reed beds can all be used to reduce nitrogen, but the activated sludge process (if designed well) can do the job the most easily. Since denitrication is the reduction of nitrate to dinitrogen gas, an electron donor is needed. This can be, depending on the wastewater, organic matter (from faeces), sulphide, or an added donor like methanol. Sometimes the conversion of toxic ammonia to nitrate alone is referred to an tertiary treatment. (Beychok, 1971).

Phosphorus can be removed biologically in a process called enhanced biological phosphorus removal. In this process, specific bacteria, called polyphosphate accumulating organisms are selectively enriched and accumulate large quantities of phosphorus within their cells (up to 20% of their mass). When the biomass enriched in these bacteria is separated from the treated water, these biosolids have a high fertilizer value. Phosphorus removal can also be achieved by chemical precipitation, usually with salts of iron (e.g. ferric chloride) or aluminum (e.g. alum). The resulting chemical sludge is difficult to handle and the added chemicals can be expensive. Despite this, chemical phosphorus removal requires significantly smaller equipment footprint than biological removal, is easier to operate and can be more reliable in areas that biological phosphorus removal difficult.

The purpose of disinfection in the treatment of wastewater is to substantially reduce the number of micro organisms in the water to be discharged back into the environment. The effectiveness of disinfection depends on the quality of the water being treated (e.g. cloudiness, PH etc), the type of disinfection being used, the disinfectant dosage (concentration and time), and other environmental variables. Cloudy water will be treated less successfully from ultraviolet light or if contact times are low. Generally, short contact times, low doses and high flows all militate against effective disinfection. Common methods of disinfection include ozone, chlorine, or ultraviolet light. Chloramine, which is used for drinking water, is not used in wastewater treatment because of its persistence. (Massoud and Ahmed, 2005).

2.8 Water Quality Guidelines for Maximum Crop Production

Municipal wastewater effluents may contain a number of toxic elements, including heavy metals, because under practical conditions wastes from many small and informal industrial sites are directly discharged into the common sewer system. These toxic elements are normally present in small amounts and, hence, they are called traced elements. Some of them may be removed during the treatment process but others will persist and could present phototoxic problems. Thus, municipal wastewater effluents should be checked for trace element toxicity hazards, particularly when trace element contamination is suspected. (Ayers and Westcot (FAO 1985)). Table 2.1 presents phototoxic threshold levels of some selected trace elements.

Table 2.1: Threshold Levels of Trace Elements for Crop Production

Symbol	Element	Recommended Maximum Concentration (mg/l)	Remarks
Al	Aluminum	5.0	Can cause non-productivity in acid soils (PH<5.5), but more alkaline soils at PH>7.0 will precipitate the ion and eliminate any toxicity.
As	Arsenic	0.10	Toxicity to plants varies widely, ranging from 12mgii for Sudan grass to less than 0.05 mg/l for rice.
			Toxicity to plants varies widely, ranging from 5 mg/l for Kale and 0.5 mg/l for bush bear
Be	Beryllium	0.10	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limit recommended due to its potential for accumulation in plants and soils to
Cd	Cadmium	0.01	concentrations that may be harmful to humans.
			Toxic to tomato plans at 0.1 mg/l in nutrient solution, tends to be inactivated by neutral and alkaline soils.
Co	Cobalt	0.05	Not generally recognized as an essential growth element conservative limit recommended due to lack of knowledge on the toxicity to plants.
			Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.

			Inactivated by neutral and alkaline soils
Cr	Chromium	0.10	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum overhead sprinkling may rebuilt in unsightly deposits on plants, equipment and buildings
Cu	Copper	0.20	Tolerated by most crops up to 5 mg/l mobile in soil. Toxic to citrus at low concentrations (0.075 mg/l). Acts similarly to boron.
F	Florid	1.0	Toxic to a number of crops at a few - tenths to a few mg/l, but usually only in acid soils.
Fe	Iron	5.0	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
			Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline PH.
Li	Lithium	2.5	Can inhibits plan cell growth at very high concentration.
Mn	Manganese	0.20	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock. If forage is grown in soils with relatively high levels of added selenium. As essential elements to animals but in very low concentrations.
Mo	Molybdenum	0.01	- Effectively excluded by plants specific tolerance unknown.

-

			Toxic to many plants at relatively low concentrations.
Ni	Nickel	0.20	Toxic to many plants at widely varying concentrations, reduced toxicity at PH .6.0 and in fine textured or organic soils.
Pb	Lead	5.0	
Se	Selenium	0.02	
Sn	Tin	-	
Ti	Titanium	-	
W	Tungsten	-	
C	Vanadium	0.01	
Zn	Zinc	2.0	

The maximum concentration is based on a water application rate which is consistent with good irrigation practice (10000 m^3 per hectare per year). If the water application rate greatly exceeds this, the maximum concentration should be adjusted downward accordingly. No adjustment should be made for application rates less than 10,000 cm^3 per hectare per year. The values given are for water used in continuous basis at one site.

Source: Adapted from National Academy of Sciences Pratt, 1972

Table 2.2: Guidelines for Interpretation of Water Quality for Irrigation.

Potential Irrigation Problem	Units	Degree of restriction on use		
		None	Slight to Moderate	Severe
Salinity				
ECW	Ds/m	<0.7	0.7-3.0	>3.0
TDS	Mg/l	<450	450-200	>2000
Infiltration				
SAR^2=0-3 and ECW		>0.7	0.7-0.2	<0.2
3 – 6		>1.2	1.2-0.3	<0.3
6 – 12		>1.9	1.9-0.5	<0.5
12 – 20		>2.9	2.9-1.3	<1.3
20 – 40		>5.0	5.0-2.9	<2.9
Specific ion toxicity				
Sodium (Na)				
➢ Surface Irrigation	SAR	<3	3-9	
➢ Sprinkler irrigation	Mg/l	<3	>3	>9

Chloride (Cl)				
➢ Surface irrigation	Mg/l	<4	4-10	>10
➢ Sprinkler irrigation	Mg/l	<3	>3	
Boron (B)	Mg/l	<0.7	0.7-3.0	>3.C
Trace element				
(See Table 2.1)				
Miscellaneous effects				
Nitrogen ($N0_3$-N)[3]	Mg/l	<5	5-30	>30
Bicarbonate ($HC0_3$)	Mg/l	<1.5	1.5-8.5	>8.5
PH		Normal range 6.5-8		

1. ECW means electrical conductivity in decisiemens per metre at 25^0C
2. SAR means sodium adsorption ratio
3. $N0_3$-N – Means nitrate nitrogen reported in terms of elemental nitrogen.

Source: FAO (1985)

Table 2.3 Schedule of World Health Organization (WHO) Drinking Water Action levels for various pollutants and South Africa's Aquatic Ecosystems. Guideline Values.

Parameter	WHO Action levels	Aquatic Ecosystems levels (South Africa) Mg/l
PH	6.5 to 8.5	Not vary by >0.5
Turbidity	5	
Colour (Hazen units)	5	
Total Dissolved solids	1000 mg/l	Not vary by >15%
Dissolved Oxygen		>60%
Fluoride (F)	1.5 mg/l	1.5
Chloride (Cl)	250 mg/l	
Sulphate ($S0_4$)	400 mg/l	
Cyanide (CN)	0.1 mg/l	0.004
Nitrate (N)	10.0mg/l	
Total Hardness ($CaCO_3$)	500 mg/l	
Arsenic (As)	0.05 mg/l	
Cadmium (Cd)	0.005 mg/l	0.005
Chromium (Cr)	0.05 mg/l	0.014
Lead (pd)	0.05 mg/l	0.001
Mercury (Hg)	0.001 mg/l	0.00008
Nickel (Ni)	0.05 mg/l	
Selenium (Se)	0.01 mg/l	0.002
Aluminum (Al)	0.20 mg/l	0.01
Ammonia		0.007

Arsenic		0.01
Copper (Cu)	1.0 mg/l	0.0015
Iron (Fe)	0.30 mg/l	10% 0f background
Manganese (Mn)	0.10 mg/l	0.18
Sodium (Na)	200 mg/l	
Zinc (Zn)	5.0 mg/l	
DDT	0.001	
24D	0.10 mg/l	
Lidane	0.003 mg/l	
Chloroform	0.03 mg/l	
Coliform bacteria per 100 ml	Nil	
Faecal coliform bacteria per 100 ml	Nil	

Source: WHO Geneva 1986; Government of South Africa.

Table 2.4: Comparison of Selected Water Quality Parameters for Alternative Water Sources (Concentrations in mg/L, except as noted)

Parameter	Typical Kraft Mill Effluent	Typical Domestic Secondary Effluent	Beverage Distillation Process Wastewater	Groundwater Standard
Biochemical Oxygen Demand	19	25	4,522	None
Total suspended Solids	26	25	5,875	None
Total Dissolved Solids	1.533	100	1,050	500
Total Nitrogen	7	20	877	None
Nitrate	1	18	1	10
Total Phosphorus	0.71	10	65	None
Total Potassium	NA	10	3,691	None
Sodium	404	50	145	160
Chloride	370	45	1,600	250
Colour, APHA Units	873	5	750	15
Cadmium	0.005	0.015	0.14	0.005
Iron	0.42	0.0-4.3	10.5	0.30
Lead	<0.9	0.1-0.3	0.83	0.015
Zinc	0.046	0.2-0.44	0.14	5.0
Copper	0.034	0.07-0.14	24.9	1.0

Source: APHA = American Public Health Association, 1999.

2.9 Sewage Treatment Plant Operator Series

1. In accordance with Federal Wage System Job Grading Standard for Wastewater Treatment Plant, Operator, 5408 Ts-64 May 1992, US Office of Personnel Management, this series is categorized thus:

   i. Sewage Treatment Plant Operator I.

   ii. Sewage Treatment Plant Operator II.

   iii. Sewage Treatment Plant Operator III.

2.9.1 Summary of Series:

Incumbents of positions in this series operate sewage treatment plant equipment; make minor repair to equipment; collect and test sewage samples; monitor control panels; adjust valves and gates; record data regarding sewage treatment plant operations; and perform related work as required. The basic purpose of this work is to operate sewage treatment plant efficiently.

2.9.2 Organizational Levels:

- Sewage treatment plant operator I is the entry – level technical job in this series.
- Sewage treatment plant operator II is the first – level supervisory service job in this series.
- Sewage treatment plant operator III is the second – level supervisory service job in this series.
-

2.9.3 Examples of Duties Common to all Levels in the Series:

Operates sewage treatment plant equipment by turning valves, starting and stopping pumps, engines etc in order to control the flow and processing of sewage.

1. Makes minor repairs to sewer treatment plant equipment, including chlorinates, sewage pump and relative equipment
2. Collect sample and use laboratory equipment to test final effluent, record chlorine residual level and PH level; and adjusts chlorinating on the basis of data obtained from test result.
3. Monitors control panels and adjust valves and gates to regulate the flow of sewage.
4. Records various data regarding sewage plant operations based on observation and inspection.
5. Performs related duties such as maintaining records and preparing reports.

2.9.4 Differences between Levels in Series:

Incumbents of positions at the level of higher also:

1. Give instructions to employees on work to be performed, equipment to be used etc.
2. Impact assigned area to evaluate work progress, detect malfunction of equipment etc in order to ensure effective operations and performers to established standards.
3. Prepare reports to provide information to superior concerning problems encounters and to make recommendations regarding assigned activities.

2.9.4.1 Sewage Treatment Plant Operator III

Incumbent of position at this level also:

1. Monitor assigned activities in order to ensure effective operations and compliance with established procedures and standards and to make recommendations for changes in procedures.
2. Confer with agency staff in order to exchange information, resolve problem and coordinate effort.
3. Review and evaluate report and recommendation concerning assigned sewage treatment plant activities.
4. Relationship with others: major work contacts are with agencies staff.

2.9.4.2 Supervision Recieved:

- Sewage Treatment Plant Operator I: Incumbent of positions at this level receives direct supervision from Sewage Treatment Plant Operators or other employees of higher grade who provide instruction, assign work and review performance through inspection and reports for effectiveness with established standards.
- Sewage Treatment Plant Operator II: Incumbent of position at this level receives general supervision from Sewage Treatment Plant Operators or other employees of higher grades who provide guidance on procedures, assign work and review performance through inspections and reports for effectiveness and conformance with established standard.
- Sewage Treatment Plant Operator III: Incumbent of position at this level receive general supervision from employees of higher grades who provide guidance on

procedures, assign work and review performance through conferences and reports for effectiveness and conformance with established standards.

2.9.4.3 Supervision Exercise

- Sewage Treatment Plant Operator I: Incumbent of positions at this level exercise functional supervision (i.e over certain but not all work activities or over all work activities on a temporary) over 1- 5 personnel.
- Sewage Treatment Plant Operator II: Incumbent of position at this level exercise direct supervision (i.e not through an intermediate level supervisor over, asign work to and review the performance of 1-5 labourers or technical personnel).
- Sewage Treatment Plant Operator III: Incumbent of position of this level exercise direct supervision (i.e not through an intermediate level supervisor over, assign work to and review the performance of 1-5 personnel) and indirect supervision (i.e through an intermediate level supervisor) over 5 – 15 personnel .

2.9.4.4 Working Conditions:

Sewage Treatment Plant Operators work under exposure to adverse weather conditions, raw sewage and the harmful effect of toxic fumes, gases, chemical and excessive noise; climb stare and ladders, lift and carry heavy objects, work varied shifts weekends, holidays, nights and are subject to a standby (on call) work status. Therefore provision should be made by the management to enhance working conditions of wastewater operators to boost their moral and subsequently improve performance at work.

2.9.4.5 Qualifications Required at Hire for all Levels in Series:

1. Knowledge of the standard methods materials and procedures followed in sewage treatment plant operation, repair and maintenance.
2. Knowledge of types and uses of equipment used in the sewage treatment plant.
3. Knowledge of the safety practices and procedures followed in sewage treatment.
4. Knowledge of the terminologies, symbols and standard abbreviations used in sewage treatment.
5. Knowledge of types and uses of small hand tools such as wrenches, pliers, screwdriver etc.
6. Knowledge of the types and uses of hand held power tools such as power saw, drill, hammer etc.
7. Knowledge of the methods used in the care and maintenance of small hand tools.
8. Knowledge of the method used in the care and maintenance of hand held power tools.
9. Skill in the use of precision measuring devices and instrument such as gauges.
10. Skill in the use of small hand tools such as wrenches, pliers, screwdriver etc.
11. Skill in the use of hand held tools such as power saw, drills, hammer etc.
12. Ability to give oral and writing instructions in a precise understandable manner.
13. Ability to follow oral and writing instructions.
14. Ability to understand, explain and apply the laws, rules regulations, policies, procedures, specifications, standards and guidelines governing assign unit activites.
15. Ability to maintain accurate records

16. Ability to assemble items of information in accordance with established procedures.
17. Ability to lead a group of workers
18. Ability to establish and maintain harmonious working relationships with others.
19. Ability to lift and carry heavy objects.
20. Ability to climb high stairs and ladders.
21. Physical stamina and endurance.

Base on assignment the following additional qualification may or should be required at hire:

1. Knowledge of the principle and practices of wastewater treatment
2. Knowledge of various types of wastewater treatment facilities.

Additional qualifications required at hire for Sewage Treatment Plant Operator II and higher positions should include:

1. Ability to supervise; including planning and assigning work according to the nature of job to be accomplished, the capacities of subordinate and available resources; controlling work through periodic reviews and/or evaluation; determining subordinates training needs and providing or arranging for such training; motivating subordinates to work effectively determining the need for disciplinary action and either recommending or initiating disciplinary action.

    Additional qualification required at hire for Sewage Treatment Plant Operator III position should include: knowledge of the principles practices and techniques of supervision.

2.9.4.6 Qualification Acquired on the Job for all Levels in the Series:

Knowledge of the principles, practices and techniques of supervision

2.9.4.7 Minimum Entrance Requirements:

Sewage Treatment Plant Operator I: Applicant should or must have at least (A) one year of fulltime, or equivalent part-time experience in operation, maintenance and/ or repair of mechanical, electrical and related equipment in the water or sewage treatment plant, stationary power plant or pumping station, or (B) any equivalent combination of the required experience and the substitution below.

Substitution:

1. A certificate of completion of a programme in waste water treatment (say: soil and water conservation engineering an option under Agric/Bioresources Engineering F.U.T Minna Nigeria) should be considered; or any equivalent from the recognized school above higher school level or O' level should be substituted for the required experience.
2. Education toward such a certificate will be prorated on the basis of the proportion of the requirements actually completed.

   Sewage Treatment Plant Operation III: applicant should or must have at least (A) two years of full time or equivalent part time experience in the operation, maintenance and /or repair of mechanical, electrical and related equipment in a water or sewage plant, stationary power plant or pumping station, or (B) any equivalent combination of the required experience and the substitution below:

   Substitutions:

1. A certificate of completion of a programme in wastewater treatment from a recognized school above high school level may be substituded for a maximum of one year of required experience.
2. Education toward a certificate will be prorated on the basis of the proportion of the required actually completed.

2.10 System Outline of the Refinery Waste Water Treatment Method.

The overall waste water treatment outlines as shown in figure 1 and 2. The waste water treatment (W.W.T) system consist of two main systems.

i. No.1 waste water treatment system and
ii. No.2 waste water treatment

2.10.1 No 1 Waste Water Treatment.

The system consist of the following facilities:

i. No .1 Oil separator
ii. No.1 equalization tank
iii. Biological treater (Bio filter in)
iv. No.1 Chemical clarifier
v. Filter
vi. This system treats the following sewage:
i. Process oily waste
ii. Sanitry waste.

For economic design and effective operation of the biological triter,

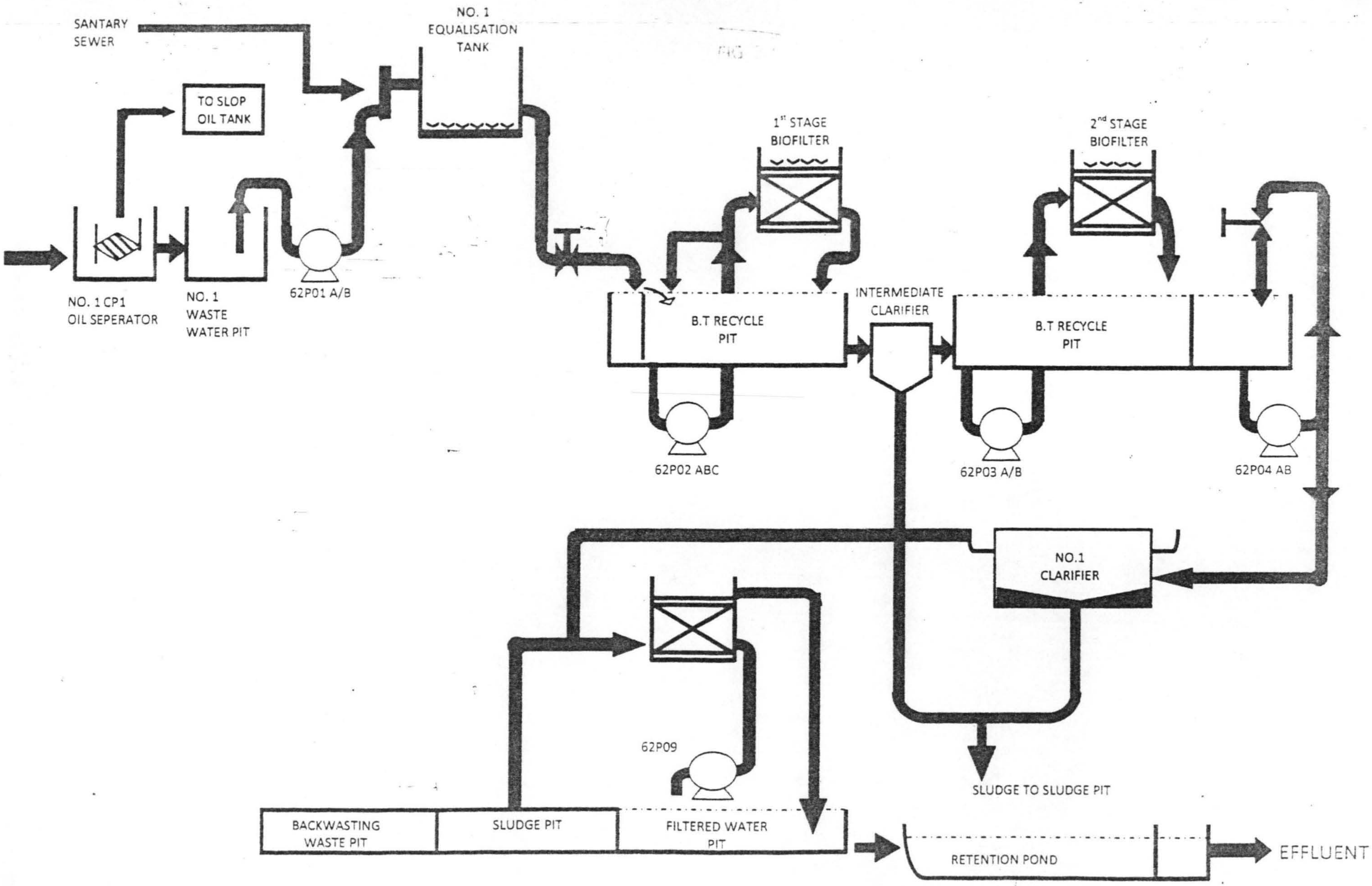
No. 1 waste water treatment system and BOD and COD content of waste water i.e process oily waste and sanitry waste see fig one

2.10.2 Liquid Waste Inlet Condition to No. 1 W.W.T System:-

Process oily waste generation areas

- WSW/Desalter $55m^3/hr$

- FCC SWS $15.8m^3/hr$
- Lube plant $11.om^3/hr$ $88m^3/hr$
- Spent caustic soda treater $2.0m^3/hr$
- Boiler blowdown/laboratory waste $4.2m^3/hr$



WASTE WATER TREATMENT UNIT: LINE 1

2.10.3 Sanitary Waste Generation Areas

i. Central administration block

ii. W.W.T. control building

iii. P.P.U control building

iv. Process control building

v. Oil movement control building

vi. Chemical laboratory block

15m^3/hr

vii. Clinic and security/safety block

viii. Tin and drum manufacturing plant

The network of sewer/waste line can be shown in table 2.5

Table 2.5: Sewer/waste line flow rate and connection.

SEWER AND WASTELINE	FLOW RATE	CONNECTED TO
Process oil waste	Maximum of 88m^3/hr	No.1 oil separator
Sanitary waste	Maximum of 15m^3/hr	No. 1 equalization tank

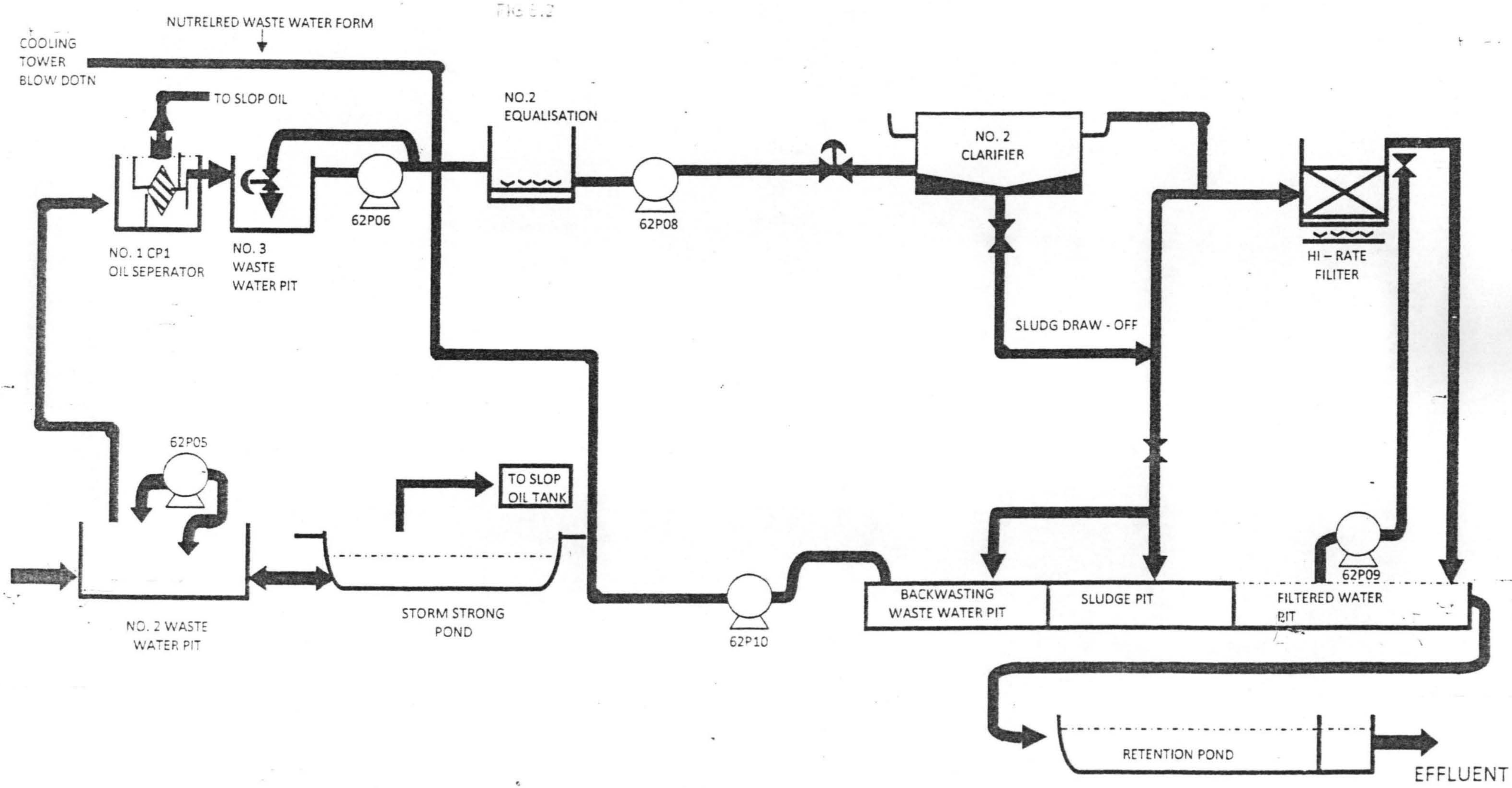
2.10.4 No. 2 waste water and solid waste treatment system

The system consist of the following facilities

i. Storm storage pond
ii. No. 2 oil separator
iii. No. 2 equalization tank
iv. Chemical clarifier
v. H1-Rate filters

This system only treats effluents with low B.O.D and C.O.D content of sewage i.e

i. Stormity oily water
ii. Pump cooling water
iii. Demineralised waste and
iv. Cooling tower blow down



WASTE WATER TREATMENT UNIT: LINE 2

2.11 Treatment of the Process Oily Waste Water in the Various Units of Waste Water Treatment Line 1

Oil separator has the function of separating oil from the water distillation. It is used in the recovery of solvent e.g Phenol and Benzene.

The treatment of process oily waste water (w w) in the refinery involves allowing the oily components to go through the separator where the free oil is separated from the w.w, in a pit (Pit 6202 as shown in fig 1). The separated oil float on the surface of water in the separator and is manually collected with the skinning pipe into the sump, from where it is automatically transferred to the slope tank (a tank used for storage of recovered oil from w.w treatment line)

The w.w then meet the rest in the equalization tank where high pressure air is used in mixing it properly and oxidizing some of the harmful chemicals.

The water coming into the treatment systems (1 and 2) are different in quality and quantity. This variation in quality and quantity extremely disturb the effluent quality especially in the biofilter and the chemical clarifiers. In order to prevent this disturbances an equalization tank is provided for both No. 1 and No.2 w.w treatment systems to mix mildly by bubbling service air form the bottom of the tank. In addition to equalization of water quality and quantity, the pollutant matters are oxidized and aerated.

The water from the equalization tank goes into the biofilter via the mixing pit. In the mixing pit nutrients for the bacteria are added. The water is then pumped into the biofilter where harmful pollutants and excess hydrocarbons are digested by the bacteria in the system. Biofilter is a fixed bed of rocks, slag or plastic media over which waste water flows. Waste water is contacted with the microbial slime which is formed into a thin layer of film covering the filter media. Aerobic condition are maintained by air flowing through the filter media.

Biological W.W.T, system depend on bacteria and other micro organism to reduce the organic chemical and materials present in the waste water.

Two types of biological treatment are available in the refinery. The trickling filter and the activated sludge treater, both of which have been discussed previously in the biological unit process.

The trickling filter method is applied to the No.1 W.W.T. system for the reason that. It produce greater quantity of water with very high quality and there is no bulking and breaking up of sludge as in the activated sludge treatment and settleable sludge is formed.

The solid waste formed in the process above is removed in the intermediate clarifier. The solid waste is delivered for sludge treatment as semi waste.

This liquid waste from the biofilter is then allowed to go to the chemical clarifier where coagulation takes place by the use of coagulants. During this process, the suspended solids in the waste water are removed in the form of sludge (semi solid waste)

The chemical clarifiers are equipment design for removing suspended solids in water by coagulating and flocculating them into larger clumps of agglomeration (flocs) they are arranged so that coagulation flocculation and sludge settling and collection are carried out in one compact vessel.

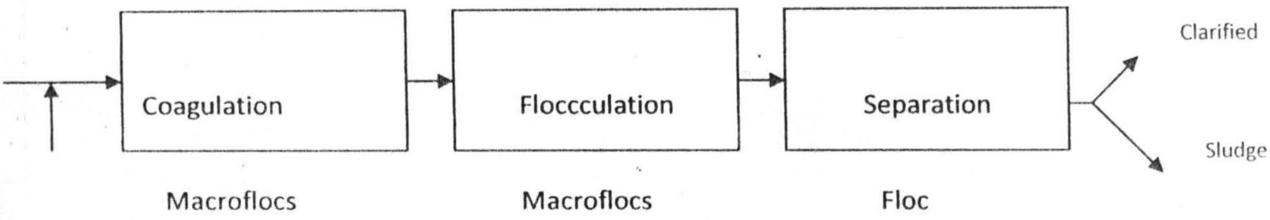


Fig. 2.3

2.11.1 **Chemicals used in the clarifier are:**

Coagulant: Poly Aluminum chloride $AL_2(OH)_n\ (16n)_m$ is mainly used.

Slaked limed: Is used to keep the PH of the waste water by PH controller at 7.5 - 8.8.

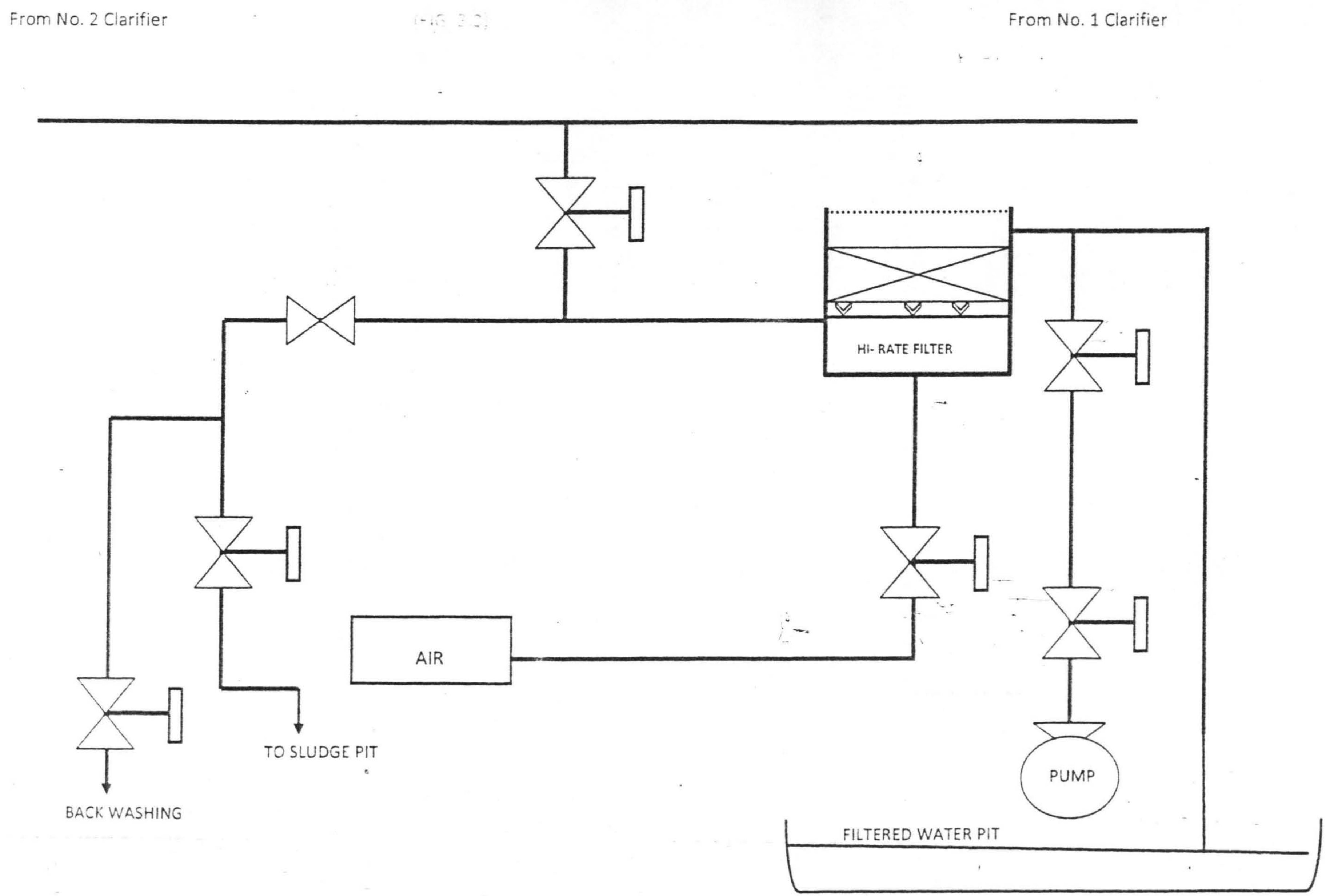
Coagulant aid: To improve flocculation on the making it denser and larger poly electrolyte is (Kuri Floc PA 332).

The waste water from the clarifier is filtered using the HI-Rate filer for the removal of any break through solid before allowing it to go out via the retention basin.

HI rate filter removes suspended solids by clogging them in the filter media layer. The HI-Rate filter is a gravity filter with an open top and is made up of two layers of filtering media the anthracite and the sand layers.

Sanitary Waste Water Treatment in Line 1

The treatment of the sanitary water is basically the same with that of process oily water. The only difference is that sanitary water does go through the oil separator because no reasonable amount of oil is contained in this sewage.


From No. 2 Clarifier
From No. 1 Clarifier
HI- RATE FILTER
AIR
PUMP
TO SLUDGE PIT
BACK WASHING
FILTERED WATER PIT

2.12 Treatment of the Oily W.W and Chemical W.W. in the Various Units of W.sW Treatment Line 2.

This is basically the same with the treatment involved in line 1. The difference between the two lines is that line 2 does not go through biofilter because the level of waste contaminants is very low.

The oily parts of this group is allowed to go into the oil separator, equalized into equalization tank clarified and then filtered before allowing it out through the retention basin.

Appropriate care must be taken during the plant design so as to ensure that the water in the two lines or systems (1 and 2) does not meet except all the H1-rate filters.

2.12.1 Rain Water Treatment

The rain water that is stored in the basin in treated as the oily water for the fear that this water must have washed some oily pollutant along the line.

2.13 Solid Waste Treament

2.13.1 Sludge Incineration Unit

The incineration unit handle the treatment of solid waste by burning them in the incinerator.

The generation source of solid waste are sludge, waste food papers, and wood print dreg etc.

In most countries including Nigeria solid waste are incinerated. The residue of combustion (ash) is disposed in pits at selected sites while the gaseous product is cooled down and allowed to go out through the stack.

The incineration process involves crushing the solid waste into bits and pieces using crusher. Thereafter, the waste goes into the incinerator via the hopper and feeder. Incinerator is kept at high temperature of $750^{O}C$ before sending in the waste.

After incineration, the flue gas product of the incineration is allowed to go into the secondary combustion chamber already at $900^{o}C$ for complete combustion of the carbon monoxide. The hot gas is cooled down at the cooling chamber before it is allowed to pass through the stack after passing through the dust collector for the removal of any dust particles that might have been carried over.

Other methods include burning the waste at selected dump sites. This is very cheap compared to the incineration process, which is safer but expensive. The burning method has the disadvantage for causing underground water pollution and gas formation with time.

Weathering is another type of solid disposal. This involves dumping the refuse at a marked area and allowing it to decompose. This method is hazardous and should never be encouraged because of the nuisance this waste do cause to the surrounding and its populate in general. These wastes do have unfavourable odour during decomposition which could lead to wide spread of diseases.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

3.1.1 Study Site

The Kaduna refinery and petrochemical company (KRPC) occupies a land area of 2.89 sq kilometers approximately 15 kilometer south east of Kaduna city. Its location has an elevation of approximately 6.5 meter above mean sea level, Kaduna refinery was constructed by chiyoda chemical engineering and construction company (now chiyoda corporation) and was commissioned in 1980 with an initial capacity of 100,000 BPSD as the third refinery in Nigeria in order to cope with the tremendous and growing demand for petroleum products. In December 1986, the design capacity of fuels plants of the refinery was successfully increased by an addition of 60,000 BPSD to the initial 50,000 BPSD bringing the total refinery installed capacity to 110,000 BPSD. The refinery was designed to process two types of crude oils: The imported heavy crude and Nigerian light crude which is basically naphthenic is reserved for the manufacture of fuel procducts and the imported heavy crude, that is paraffinic is on the order hand, used mainly for the production of lubrication oils, waxes and asphalts. Consequently the refinery has two process sections: The fuel section and the lubricating oil, wax and asphalt section.

3.1.2 Sample Collection

Samples of wastewater from KRPC were respectively collected separately using 5L sterile polyethylene vessel. Samples were transported in ice chest and the analysed for some physiochemical parameters when the temperature of the sample had normalized within 2 weeks of cultivation. The distribution of vegetation over a surface of the earth

is controlled by availability of water than any other single factor. It is not enough that there is water availability for plants, the quality of irrigation water must be determined since all natural water contain dissolved salts, which when present in large quantities can be detrimental and harmful to agricultural crops.

These excess potential constituent nutrients in the plants could also be harmful to human and other living organisms that feed on plants if not determined; one of the effects is cancerous disease resulting in death in human.

3.1.3 Material Used for Analysis of Physical parameters

3.1.3.1 For Determining Electrical Conductivity and Temperature :

Beakers

Conductivity meters

Electrode

Waste water sample

3.1.3.2 For Determining the Turbidity:

Gelman filter apparatus

Some white membrane

Standard colour chart

Waste water sample

3.1.4 Analysis of Chemical Inorganic Parameters

3.1.4.1 Determination of Chloride Content:

The material include waste water sample, $10cm^3$ pipette, burette, distilled water in a wash bottle, three (3) conical flasks, white tile, potassium chromate indicator, $50cm^3$ nitrate solution (2.73g $100cm^{-3}$

3.1.4.2 Determination of Dissolved Oxygen Content (By Winkler Method)

$10cm^3$ of alkaline iodide solution (3.3g NaOH,2.0gKI in $10cm^3$ distilled water)

$5cm^3$ of concentrated Hydrochloric acid (Care)

Starch solution (as indicator)

Distilled water in a wash bottle

0.01m odium thiosulphate solution

$3x3cm^3$ graduated pipette

Burrette

White tile

Three conical flasks

Glass stopper

3.1.4.3 Determination of Biochemical Oxygen Demand of the Wastewater Samples

The materials include

$500cm^3$ - $1dm^3$ wastewater samples.

An appropriate calibrated oxygen electrode.

Glass stopper bottles.

3.2. Methods

3.2.1 Analysis of Physical Parameters

Electrical Conductivity (ECw), Total dissolved solids (TDS) Temperature and Turbidity were tested for in the waste water samples A, B, C, D. The method employed was as described in the American Public Health Association (APHA, 1995)

3.2.1.1 Determination of Electrical Conductivity and Temperature of the Waste Water Samples.

The samples labeled A, B, C and D on four separate beakers, were analysed for the ECW, DS, Temperature using the Conductivity/TDS meter. The meter is so designed to measure these parameters at a glance.

The conductivity/TDS meter has an electrode with the aid of which any change in wastewater sample can be noted. Firstly, the electrode was dipped and swirled into the beaker containing distilled water. This was done to ensure that the meter was standardized before measurement commences. Secondly, the electrode was removed from the beaker containing distilled water and dipped and swirled into another beaker containing wastewater, which is A. By pressing the buttons on the machine against the required parameter, readings were noted down.

The whole procedure was repeated for samples labeled B, C and D respectively, each noting the readings of the parameters desired.

3.2.1.2 **Determination of Turbidity of the Wastewater samples.**

A white gridded filter was placed on the Gelman filter apparatus, handled with the fingers. A 100 ml of a well scooped wastewater from point A of the refinery discharge was poured into the top of the filer apparatus until it filled to the mark

required. The sample was then filtered, after which the filter was removed from the machine to dry.

Now, the turbidity of the wastewater samples A was estimated by comparing its colour with the standard colour chart.

The procedure was repeated for samples B C and D respectively.

3.2.2 **Analysis of Chemical-inorganic Parameters.**

The chemical-inorganic parameters tested for include the PH, chloride content, nitrate content,ammonia, dissolved oxygen content, biochemical oxygen demand (BOD), Chemical oxygen demand and (COD) and heavy metals such as K, Mg, Ca, Zn, Cr and Na of the samples of wastewater.

3.2.2.1 Determination of PH Value of the Wastewater Samples

The PH meter was used for this purpose. The probe of the meter was first rinsed with water (distilled) to remove any contaminant and to help standardize the meter. The probe was then placed into the beakers of the samples A, B, C and D respectively, each time reading off the PH value.

3.2.2.2 Determination of Chloride content of the Wastewater Samples

$10cm^3$ of the wastewater sample from A was placed in a conical flask and 2 drops of potassium chromate indicator solution was added. The silver nitrate solution was placed in the burette and titrated against the wastewater sample - indicator mixture in the conical flask. As titration progressed, the conical flask was continually shaken

until the reddened precipitate of silver chloride just form as end-point. The experiment was repeated on a further two, $10cm^3$ wastewater samples.

The two mean volume of the nitrate used was calculated. This volume was found to be approximately equal the chloride content of the wastewater samples (in g/ld m^3).The procedure was repeated for the remaining samples B, C, and D respectively.

3.2.2.3 Determination of Dissolved Oxygen Content of Wastewater Samples (By Winkler Method)

The wastewater sample A was collected carefully without splashing and plugged to be kept under water to prevent entry of air bobbles. 2cm^3 each of Manganese chloride and alkaline iodide solution was added to the sample using pipette with its tip dipped down the bottom of the sample bottle under water. The mixed regent was adequately shaken throughout the wastewater sample. A complex precipitate of

Manganic - oxide - hydroxide was formed in direct proportion to the amount of oxygen present in the sample. The sample was then set aside.

2cm^3 of concentrated hydrochloric acid was added to the sample bottle and plugged immediately to avoid air bubbles being trapped-in. The bottle was shaken thoroughly to dissolve the complex precipitate. This leaves a solution of iodine in an excess potassium iodide. The iodine formed was found to be directly proportional to the oxygen originally present in the wastewater sample. The dissolved oxygen was fixed at this stage and exposure to the air will not affect its value.

50cm^3 of the solution of iodine in an excess potassium iodide was however collected in a conical flask. It was then titrated against a 0.01m sodium thiosulphate solution from the burette until the yellow colour becomes pate. Also, three drops of starch solution was added thereafter and titration continued until the blue-black colouration of the starch just disappears. This stage was repeated with a 50cm^3 of the solution of iodine in excess potassium iodide and the mean value used was calculated as (X).

It is important to note that using these solutions, $1cm^3$ of 0.01m thiosulphate solution corresponds to $0.056cm^3$ of oxygen at standard temperature and pressure (STP). The concentration of oxygen per dm3 of wastewater was calculated from the relation,

Oxygen in cm^3 dm^{-3}= 0.056 x (X) x 1000/50 at STP where, X = volume of thiosulphate solution required for the titration of $50cm^3$ of wastewater sample.

The whole procedure was repeated for samples of wastewater from B, C and D respectively.

3.2.2.4 Determination of Biochemical Oxygen Demand of the Wastewater Samples

Three portions of wastewater sample was placed into 3 separate glass-stopper bottles of $125cm^3$ capacity. The bottles were filled to the brim with adequate care taken to avoid trapping air bubbles in the process.

The oxygen content of one of the bottles was immediately determined using the calibrated oxygen electrode (mg/l). The remaining 2 bottles were incubated in the dark (no photosynthesis) at a standard temperature of 20^oC for 5 days, after which the oxygen content of the bottles were also determined in mg/l. Subtracting the mean value for the incubated samples from the original sample gives the BOD mm mg/l.

3.2.2.5 Determination of the Chemical Oxygen Demand of the Wastewater Samples

The Chemical Oxygen Demand (COD) of the samples of wastewater was determined by heating a portion of sample from A in an acidic chromate solution (Acidified, $K_2Cr_20_7$ solution); which oxidizes organic matter chemically. The amount of chromate remaining (measured by titration) is translated into an oxygen demand value. Biodegradability, toxins, and bacteria are not important, and the test was completed in 2 hours.

The procedure was repeated for other samples, B, C and D in that order.

3.2.2.6 Determination of Potassium and Sodium Using Flame Photometer

Pipette 50mm into a clean, dry testube or 125mm Erlenmeyer's flask. Add one drop of phenolphthalein indicator. If a red color develops and add 5N H_2 SO_4 solution drop wise to just discharge the colour. Add 8ml combined reagent and mix thoroughly. After at least 10 minutes, but no more than 30 minutes, measure absorbance of each sample at 880nm, using reagent blank as reference solution.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIN

I. **Temperature:-** This is a measure of how cold or hot the wastewater sample is. There are no set standard for temperature but 0^0C is the freezing point of pure water sample, while 100^0C is its boiling point (Ayers and Westcot, 1994). Different organisms (micro and macro) can survive under varying water temperatures, temperature of the wastewater as an infinitesimal effect on plant nutrient via the soil since it practically diminishes/vary with period and medium, meaning that the temperature of the wastewater applied to the soil can be altered by the ambient environmental weather condition.

II. **PH:-** This is an indication of the acidity or basicity of water but is seldom a problem by itself. The main use of pH in water analysis is for detecting abnormal water. The normal pH range for irrigation is 6.5 to 8.5; pH value outside this range would be a good warning that the water is abnormal in quality (Motsara and Roy, 2008). The PH of the results of samples of point A,B,C and D which are: 10.38,10.27 and 9.92 respectively are outside the range with higher alkalinity. Irrigation water with pH outside the normal range may cause a nutritional imbalance or may contain toxic ions. The municipal wastewater pH result of 7.56 satisfies the pH standard of irrigation water but more is required to meet full standard, meaning that away from pH, there are so many other analytical parameter in their standards that tells if irrigation water is safe to use.

IV. **Dissolved Oxygen:-** Knowing the amount of dissolved oxygen in water is important for microorganisms and plants to survive. Dissolved oxygen between 910ppm is considered very high while 4ppm is very bad. If dissolved oxygen is too low in irrigation water as in the wastewater analysis result (7.06ppm) of point C, this is an indication that the bacteria concentration is high and if used for irrigation, portends danger to plant growth and nutrient (Motsara and Roy, 2008)

V. **Chloride (Cl) and Sodium (Na):-** These are toxic ions. Irrigation water that contain these ions at threshold value can cause plant toxicity problems. Such as impaired growth, reduced yield, changes in morphology of plant and even death. For safe, chlorine and sodium should be present in irrigation in the range (0 – 30mg/L) and (0 – 40mg/L) respectively (FAO, 1994). From the wastewater analysis, chlorine (23.98mg/L) and sodium (31.5mg/L) are within the safe range.

VI. **Total Dissolved Solids:-** This is a measure of the impurities in a water sample. It can also be referred to as the total salt concentration of a wastewater sample. It is one of the most important agricultural water quality parameters. Plant growth, crop yield and quality of produce are affected when the total dissolved solid in the irrigation water is above 2000mg/L (Ayers and Westcot, 1994). From the refinery wastewater analysis result, in composition, it contains between (7.06-14.41)mg/L of total dissolved solid which is satisfactory compared to the FAO standard in Table

VII **Nitrates:-** This represents the final product of the biochemical oxidation of ammonia. In water, the presence of nitrate is probably due to the presence of nitrogen organic matter and to some extent, of vegetable origin, for only small quantities are naturally present in water. However, wastewater may contain high nitrates. The use of wastewater for irrigation should be of immense benefit because the nitrate centered of wastewater might reduce the requirements for commercial fertilizer. Nitrate content may be considered toxic if it exceeds 10mg/L (FAO, 1994). From the refinery wastewater analysis, zero nitrate content shows no presence of nitrogen organic matter, therefore needs complementary effect of commercial fertilizer.

VIII Ammonia:- The level ammonia in wastewater effluent must be strictly controlled as excessive level of it can be toxic to animal and plant life. Ammonia content in solution of wastewater may be consider toxic if it exceeds 5mg/L (FAO,1994).From the refinery wastewater analysis, zero ammonia content in solution makes the process of nitrogen removal from the wastewater extremely difficult.

IX Dissolved Solids:- Dissolved solids in surface of wastewater come from the natural dissolution of rocks and minerals or from discharges from municipal or industrial sources. Dissolved solids are mainly composed of cations such as calcium, magnesium, sodium, potassium; and the anions bicarbonate, carbonate, sulfate, and chloride. Excessively large concentrations of dissolved minerals in wastewater may result in increased costs due to corrosion or the necessity for additional treatment.

X Biological Oxygen Demand and Chemical Oxygen Demand:- Biological Oxygen Demand (BOD) is usually measured by allowing a sample of wastewater to stand at 20^0C for five days and calculating the amount of oxygen used up during the oxidation of the organic matter by bacteria. Chemical Oxygen Demand (COD) is the equivalent amount oxidizing chemical required to act on behalf of the bacteria. The essence of this analysis is to know the amount of biodegradable organic matter in wastewater sample.

Table 4.1 Laboratory Determinations Needed to Evaluate Common Irrigation Water Quality Problems

Water parameters	Unit	Range in irrigation water
Electrical conductivity	ds/m	0 – 3
Total dissolved solid	mg/L	0 – 2000
Calcium	mg/L	0 – 20
Magnesium	mg/L	0 – 5
Sodium	mg/L	0 – 40
Carbonate	mg/L	0 – 1
Bicarbonate	mg/L	0 – 10
Chlorine	mg/L	0 – 30
Sulphate	mg/L	0 – 20
Nitrate	mg/L	0 – 10
Ammonium	mg/L	0 – 5
Phosphate	mg/L	0 – 2
Potassium	mg/L	0 – 2
Boron	mg/L	0 – 2
Ph	1 – 14	6.0 – 8.5
Sodium adsorption ratio	mg/L	0 – 15

Source: FAO, 1994

4.1 Presentation of Results4.2 Discussion of Results

The analysis of the sample result is presented in the table 4.2 below and further discussed using these subsequent Bar Charts below.

Table 4.2 : Analysis of the sample results

Parameter	Unit	Sample at Point A	Sample at Point B	Sample at Point C	Sample at Point D	Maximum permitted level By APHA	Maximum permitted level By WHO
Temperature	^0C	27.1	27.3	27.6	27.5	30	25 (amb)
PH	-	7.90	10.38	10.27	9.92	9.2	8.5
Conductivity	uS/cm	108	1038	814	665	NS	1000
Turbidity	Mg/L	2.30	3.40	4.40	10.5	NS	5
$D0_2$	Mg/L	12.57	13.41	7.06	12.97	NS	NS
COD	Mg/L	162.0	70.40	60.0	95.0	NS	NS
BOD	Mg/L	70.0	45.50	29.40	58.0	NS	Ns
Sulfate	Mg/L	49.0	21.50	3.0	22.50	NS	NS
Suspended	Mg/L	0.0	1.0	0.0	0.0	NS	400
Solid						30	NS
Chloride	Mg/L	31.99	58.48	56.98	49.48		
Ca^{2+}	Mg/L	5.62	7.62	9.63	10.83	NS	250
Chromium	Mg/L	0.01	0.18	0.04	0.03	NS	NS
gMg^{2+}	Mg/L	2.44	0.03	1.71	2.44	0.1	0.05
Sodium	Mg/L	6.50	130.0	90.2	49.0	NS	NS
Potassium	Mg/L	1.34	6.03	5.36	4.02	160	200
Ammonia	Mg/L	0.0	0.0	0.0	0.0	NS	NS
Zinc	Mg/L	0.24	0.27	0.27	0.27	NS	NS
Nitrate	Mg/L	0.0	0.0	0.0	0.0	5.0	0.2
						10	10

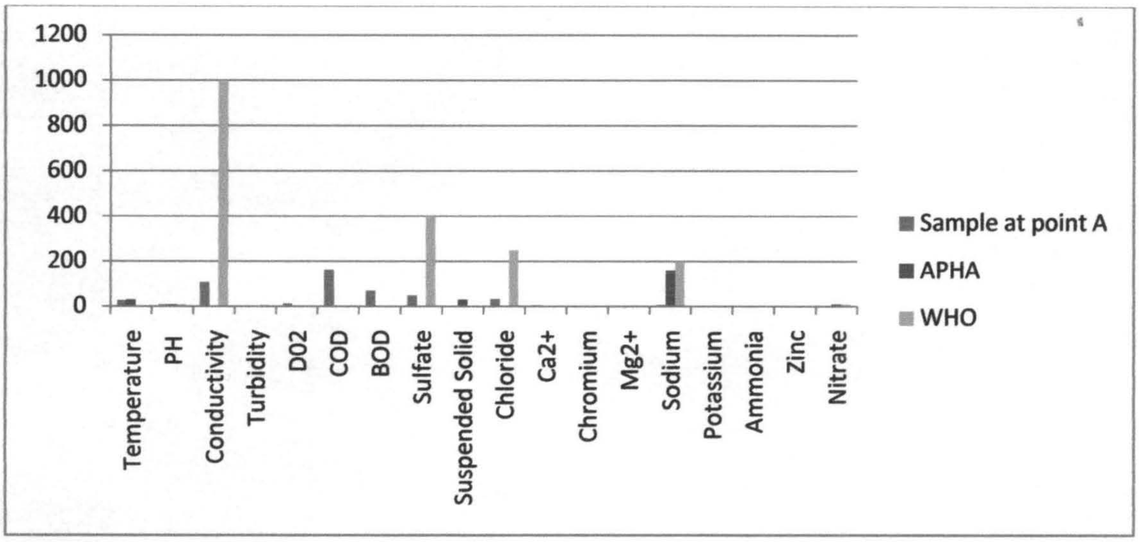


Fig 4.1: The comparison of the results of sample at point A with the standards given by (APHA) and (WHO).

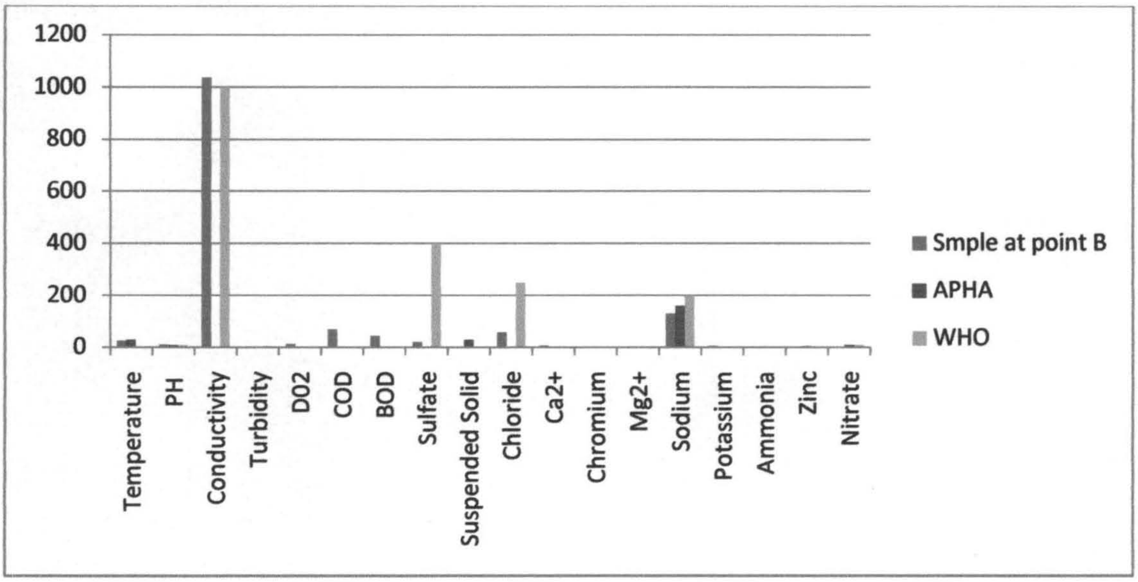


Fig 4.2: The comparison of the results of sample at point B with the standards given by (APHA) and (WHO).

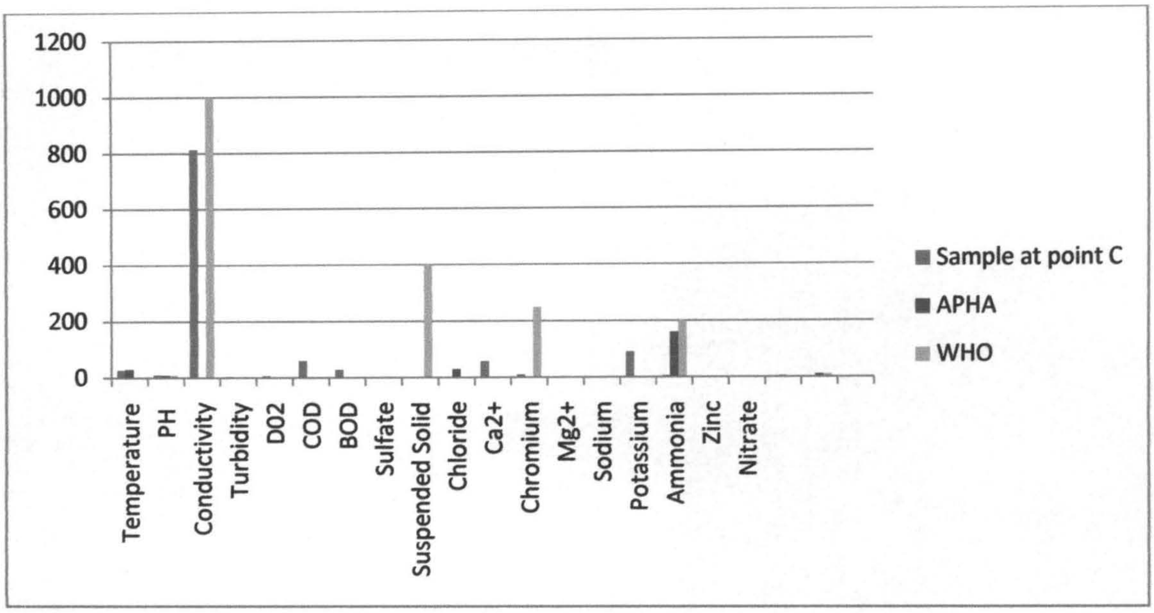


Fig 4.3: The comparison of the results of sample at point C with the standards given by (APHA) and (WHO).

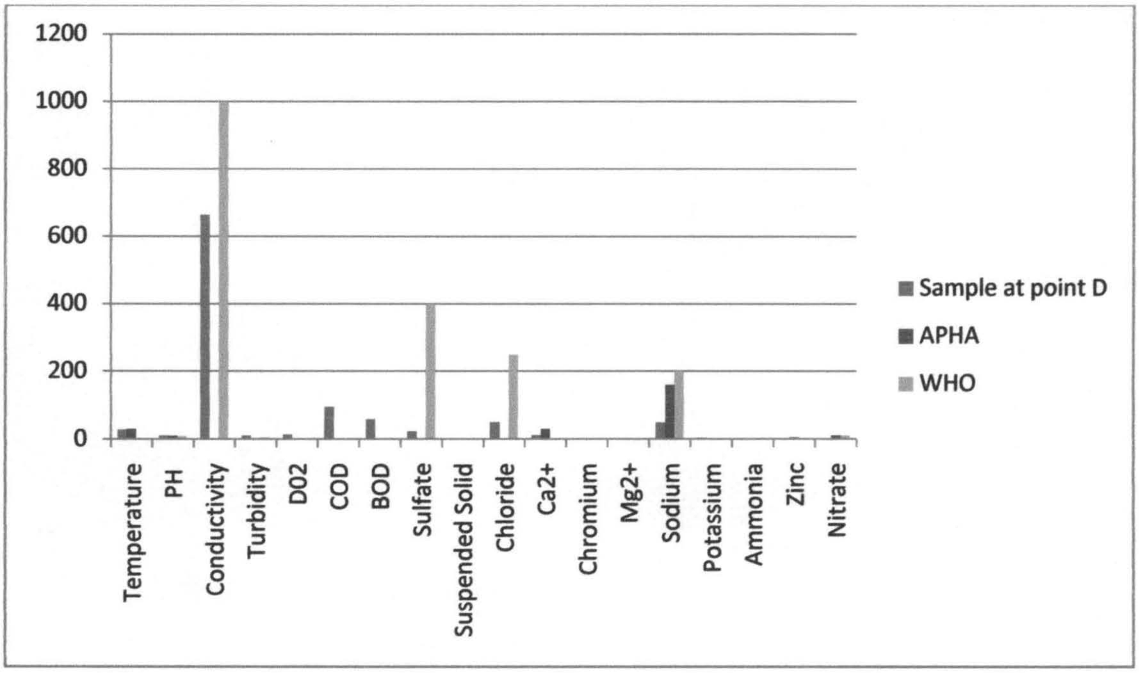


Fig 4.4: The comparison of the results of sample at point D with the standards given by (APHA) and (WHO).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

According to the World Health Organization (WHO) the maximum value of Total Dissolved Solids (TDS) irrigation water can contain to sustain plant growth is 500mg/l. The maximum value obtained from both DO_2 and Suspended solid is far below the standard. Since this value is less than the recommended value, the wastewaters are fit for irrigation.

The American Public Health Association (APHA) recommended that the chloride concentration of ground water supply required to support plant growth is a maximum of 250mg/l. The chloride concentration obtained from the field work is a maximum of 58.48mg/l. Clearly, the field values are within the recommended limit and so can be effectively used for irrigation.

Food and Agricultural Organization (FAO) suggested that the level of stream standard of Dissolved Oxygen required for fish farming is not to be less than 2mg/l. The highest Dissolved Oxygen concentration recorded from the field work is 13.41mg/l, thus indicating that the wastewaters can be used for fish farming.

The recommended maximum concentration of sodium metal required for irrigation as a typical secondary effluent is 160mg/l; according to American Public Health Association (APHA).

A maximum of 130mg/l and 90.2mg/l of sodium was obtained from the field wor signifying that the wastewaters, from locations B and C, can be used for irrigation.

The National Academy of Sciences and Pratt, 1972 recommended a maximum concentration 0.1mg/l of Chromium in wastewaters to be used for irrigation. A maximum of 0.18mg/l sample point B is an indication that though not toxic to plant aerated soil, but can contribute to soil acidification. Also, according to the National Academy of Sciences and Pratt, 1972 the recommended maximum concentration of zinc metal ion is 2.0mg/l for crop production. The highest value of Zinc obtained from the field is 0.25mg/l which is below the value recommended for irrigation. Therefore, the wastewaters from the two locations can be used for irrigation.

The field values obtained for Electrical Conductivity has a high value of 1038micros/cm. The implication of this is that Electrical Conductivity indicates how saline is a given soil type (Metcalf and Eddy, 1991). Irrigation with these wastewaters is capable of causing salinity problem which is often detested.

5.2 Recommendations

Based on the above conclusions, the following recommendations are made:

There should be an adequate number of well equipped laboratories and trained and highly experienced Wastewater Plant Operators who will run analysis of effluent samples and advise effectively on what should be done to improve performance of wastewater treatment plants;

The wastewater at point B (immediately after treatment) has conductivity 1038us/cm beyond the scientific recommendations required for irrigation and the PH of 10.38 shows higher level of alkalinity so the wastewater can only be used for this purpose by adding equivalent acid for neutralization.

Refinery wastewater provides a good and excellent ground for fish farming. The Dissolved Oxygen level is highly significant to support aquatic lives. Therefore appropriate means can be created where the wastewater can pass directly to ponds or ditches for fish farming.

There is need to buy conventional fertilizers to replenish lost nutrients in soil since the wastewater its self has no enough nutrients to supply the plants. The wastewater from the refinery can be used to grow leafy vegetables since they do not contain toxic heavy metals that could eventually be harmful to humans but should be supplemented with commercial fertilizer because of zero content of nitrate and ammonia solution in wastewater.

There should be a proper way of handling equipment and wastewater from refinery to minimize the possible danger associated with it.

The pH of the wastewater samples from point B,C and D is generally not satisfactory if not that of point A that is moderately neutral; regular check of this parameter in the irrigation water is very essential to avoid the possible problems of acidity and alkalinity;

There should be an agency responsible to scientifically assess, evaluate and monitor the implementation of the wastewater quality standards to be used for irrigation;

With regards to sanitation, penalties should be equal to the damage caused by the pollution to the surrounding, rather than low penalty which encourage the polluters to pollute the more.

Also, adequate standards should be set for the water bodies receiving wastewater so as to prevent indiscriminate disposal.

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APPENDICES

APPENDIX A

Theory Questions

(1) The management of wastewater through treatment has two major objectives. What are they?

(2) What is the advantage of using micro-irrigation techniques to irrigate vegetables over flood or furrow irrigation?

(3) What are the challenges encountered in wastewater irrigation?

(4) Wastewater irrigation is advantageous to farmers who can not afford to buy conventional fertilizer. True or False. Comment on your answer.

(5) Briefly explain how turbidity test is carried out in the laboratory.

(6) Of what significance is turbidity measurement to wastewater engineers?

(7) What are the ways of reducing risks in sewage irrigation?

(8) Explain how the population of algae in receiving water does affect the dissolved oxygen levels required for aquatic animal survival.

(9) What is the relationship between the biochemical oxygen demand (BOD) and chemical oxygen demand (COD)? Which is most important?

(10)State the differences between the chemical and physical properties of wastewater.

APPENDIX B

Objective Questions

(1) Diseases of growing plants have resulted in

(a) substantial food economic loss to farmers

(b) a great epidemics of pest and associated diseases.

(c) The demand for more research work in the field of wastewater engineering

(d) great benefit to farmers

(2) Plant diseases can be treated using all the following **except**

(a) toxic metals

(b) organic fungicides

(c) herbicides

(d) planting less resistant variety of plant

(3) Waste management involves the collection, transportation, storage, treatment and

(a) arrangement of waste

(b) deposition of waste

(c) disposal of wastes

(d) aeration

(4) Which of the following compound is used to treat acid soils

(a)$CaCO_3$

(b)Al_2CO_3

(c) H_2SO_4

(5) The COD is generally.......... of BOD values in most literatures

(a) 2.5

(b)1.5

(c) 3.0

(d) 2.0

APPENDIX C

Definition of some key terms

(3)**Wastewater management** is the process of collecting, transporting, storing, and disposing the wastewater.

(4) **Biochemical Oxygen Demand (BOD)** is a test for measuring the amount of biodegradable organic material present in a sample of wastewater. It is expressed in mg/l of dissolved oxygen; which micro-organism will consume while degrading these materials.

(5)**Chemical Oxygen Demand (COD)** also measures the amount of organic material in solution in a sample of wastewater, but more rapid than the BOD test in that it is completed in just two hours.

(6) **pH** is a measure of how acidic or alkaline a solution is. In pure water at room temperature, a small fraction (about two out of every billion) of water molecules (H_2O, or really, H-O-H) splits, or dissociates, spontaneously, into one positively charged hydrogen ion (H^+) and one negatively charged hydroxide ion (OH^-) each . There is an equal number of each ion so the water is said to be 'neutral'. If there are more H^+ than the $OH^-$the solution is said to be 'acidic' and 'alkaline' if OH is more.

(7) **Irrigation** is the process of supplying water to the growing plant on an agricultural land in order to supplement rainfall.

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Our Ref:........................
Your Ref:........................

RESULT OF PHYSICO-CHEMICAL ANALYSIS

Parameter	Unit	Measured Valve 1 R/EFF A	2 Dis Imm After Treatment	3 R /UP	4 R/ DOUND	NIS 554:2007 MAXIMUM PERMITTED LEVELS
Temperature	^oC	27.1	27.3	27.6	27.5	Ambient
P^H	-	7.90	10.38	10.27	9.92	6.5-8.5
Conductivity	µS/cm	108	1038	814	665	10-1000
DO_2	Mg/L	12.57	13.41	7.06	12.97	-
Suspended Solid	Mg/L	0	1	0	0	
Chloride	Mg/L	31.99	58.48	56.98	49.48	250
Ca^{2+}	Mg/L	5.62	7.62	9.63	10.83	-
Chromium	Mg/L	0.01	0.18	0.04	0.03	
Mg^{2+}	Mg/L	2.44	0.73	1.71	2.44	-
Sodium	Mg/L	6.5	130	90	49	200
Potassium	Mg/L	1.34	6.03	5.36	4.02	-
Ammonia	Mg/L	0.00	0.00	0.00	0.00	-
Zinc	Mg/L	0.24	0.27	0.27	0.27	5
Nitrate	Mg/L	0.00	0.00	0.00	0.00	10

JAMILU HABU
LABORATORY MANAGER

REGIONAL ... QUALITY LAB ... MINNA.
MICROBIOLOGY LAB.
SIGN ___
DATE 21-12-2009