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Significance of Kaduna River to Kaduna Refining and Petrochemicals Complex: Some Checks and Balances

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Abstract

Kaduna Refinery and Petrochemicals Complex comprises of various processing units. The plants produce various grades of petroleum and petrochemical products. But in all of the plants and facilities, water is required in its various forms. The paper describes Desalter Process and Refinery Wastewater. The only major source of water is Kaduna River. The Chemical compositions of the raw and filtered water differ. The compositions of the treated and "imported" bottled waters are the same and thus fit for drinking. pH value is fairly constant and so also other elements. Purification is by demineralization using ion-exchange resins. Demineralised water contains a number of chemicals and compounds. The process waters are discharged either as steam or drained out as affluent water. The Sour Water Stripper (SWS) is not functioning. Consequently, the polluted wastewater is discharged directly to the environment. The Sour Water Stripper must be resuscitated and made to function. Government and KRPC would need to inform and educate members of the community about the effluent wastewater and its consequences in the environment. Ultra Filtration Membrane System is recommended for treatment of desalter effluent.

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Key words: Kaduna River, Refinery and petrochemical complex, significance of water.

Introduction

Many authorities (Braune and Sergei 1993, Debenedetti and Stanley 2003, Marks 2001, Dooge 2001 and Aderogba 2005) see water as a significant element in human settlements: In productions, transportation; recreation and tourism; for agriculture and horticulture, laboratories, hospitals and research institutions, and others. Aderogba (1999 and 2005) repeatedly remark that water is significant in all sectors of human endeavour. She went further to emphasize that it appears there is no where water is important and "mostly used like hospitality and tourism industry,'' (Aderogba in print). An attempt to look at other sectors such as in refining and petrochemical productions, Kola (2007) also sees water to be a salient element in production and manufacturing. According to him, water is one of the "key ingredients" that must be available in plentiful and various forms to ensure successful refining and manufacturing of petroleum and petrochemical products. These thus explain why raw and fresh water tanks are commonly found in refining and petrochemical complexes.

The objective of this paper is to look into the passage of water from Kaduna River through the Kaduna Refining and Petrochemicals Company (KRPC) plants and facilities and the consequent effluent water that is discharged into the immediate environment. Some suggestions were made.

Materials and methodology

Kaduna metropolis is 634 m above sea level. The temperature is about $35.2^{O}C$ and the average annual rainfall is about 36.70 cm falling mostly within 5 - 6 months in a year. Based on the favourable feasibility studies, Kaduna Refinery was conceptualized and designed for a capacity of 60,000 BPSD. But much later, the Federal Government of Nigeria decided that there should be no refinery that will be less than 100,000 BPSD in capacity. The lubricating oil complex of Kaduna Refinery is the first of its kind in West African Sub-region and one of the largest in Africa. The project was completed and commissioned in 1980 but the Lube Plants and the Petrochemical Plants were commissioned in 1983 and 1988 respectively. The initial operations and maintenance were carried out by Nigerians and expertrate personnel as technical back-ups. But by 1985, Nigerians had virtually taken over all the maintenance and operations of the plant.

As at now, the company is organized into three Divisions: Operations, Services and the Managing Director Office. Each of the Divisions has many operational and or services Departments. In the Operations Division are Production, Power Plant and Utilities, Fire Safety and Environment, Production Programming and Quality Control, Maintenance, Engineering and Technical Services and Tin and Drum Manufacturing Departments. The Plant is complex and could be described to be "very sophisticated,'' (Onoja 2005).

For instance, the Fuel Plant in the Production Department comprises of the following process Units: Crude Distillation Units (Nos 1&2) Naphtha Hydro treating Units, Catalytic Reforming Unit, Kerosene Hydro Desulphurization Units, Gas Concentration Unit, Vacuum Distillation Unit, Fluid Catalytic Cracking (FCC) Unit, Gas Treating Unit, FCC Gasoline Merox Unit, FCC LPG Merox Unit and Sulphur Recovery Unit. See Table 1. Their capacities range from 60,000 BPSD of Crude Distillation Unit No 1 to 3,800 BPSD of Gas Concentration Unit. See Table 1.

Two types of oil used are Gulf Oil Crude from Escravos (local) and Paraffin Based Crude Oil imported from Venezuela, Kuwait, and Saudi Arabia. Both were to be transported through pipelines from the Escravos Terminal in the Niger Delta to Kaduna. That is, through a distance of about 606 kms.

Based on the 60,000 BPSD of Nigerian Crude Oil and 50,000 BPSD of Light Arabian Crude, the followings, in tonnes per annum, were to be produced:

LPG - Propane/Butane Mixture	------	46,200
Gasoline – Sulphur and 5 Star	--------	1,382,700
Kerosene - Dual Purpose	-------	663,300
Gas Oil	--------	868,000
Fuel Oil – Low Pour Point	--------	803,600
Lubricating Oil (Base Oil)	---------	803,600
Wax (Basic)	---------	253,000
Asphalt - Solid & Cut Back	--------	568,000
Sulphur	--------	3,300

Like other plants, the Petrochemical Plant was similarly designed to produce:

- Linear Alkyl Benzene (LAB) for Powdered and Liquid Detergent manufacturing industries;
- Heavy Alkyl Benzene (HAB) for industries engaged in manufacturing Transformer Oil, Thermal fluid, Lubricating Oil; and
- Kerosene Solvent for industries that manufacture insecticides, paints and various vanishes, degreasers, polishers and metal cleaners.

The output capacity of the plant is 30,000 metric tonnes of Linear Alkyl Benzene (LAB) 2,700 tonnes of Heavy Alkylate per annum. The plant occupies an area of 130,000 sq. meters.

By and large, in all the Units, Processes, Productions and others, water is required in its various stages and grades and in large quantities too. The followings describe the Desalter Process and the Refinery Wastewater.

Desalter process and refinery wastewater

In order to accomplish desalting, the crude is first preheated to between 120 ^{O}C and 150 ^{O}C with heat exchangers in order to reach the required viscosity level normally in the range of 5 - 15 centistokes. The temperature is limited by the vapour pressure of the crude-oil feedstock. About 2 - 6% wash water is metered in ahead of the desalter as an extraction agent to help dissolve salts and sediments. Intense mixing then takes place over a mixing value. Once in the pressurized desalter vessel, the salts and the sediments settle with wash water and tend to form emulsions. The wash water is separated by electrostatic precipitation using de-emulsifiers and acid. The salts that are removed are mainly chlorides and carbonates. They can cause corrosion fouling downstream in the heat exchangers, furnaces, and distillation units, that is, if not removed and plugging of equipment to prevent poisoning of the catalyst in the process units.

Electrical desalting is the application of high-voltage electrostatic charges to concentrate suspended water globules in the bottom of the settling tank. Surfactants are added only when the crude has a large amount of suspended solids. Other less-common process involves filtering heated crude using diatomaceous earth and chemical treatment and settling. Ammonia is often used to reduce corrosion. Caustic or acid may be added to adjust the pH of the water wash.

Wastewater and contaminants are discharged from the bottom of the settling tank to the wastewater treatment facility. The desalted crude is continuously drawn from the top of the settling tank and sent to the crude distillation tower. Any properly performing desalter can remove about 90% of the salt in raw crude, (Greg Johnson 2006).

The desalter effluent is a major source of contaminated wastewater and a source of hydrocarbons as oil under carry to the extent that emulsions are not completely broken. Oil under carry can be the single largest source of oil losses to the wastewater treatment system. Reduction in the amount of oil in the under carry not only reduces sewer loadings but also recovers valuable raw material that would otherwise be lost.

Rates may vary with the water content of the crude oil and the degree of difficulty in desalting the crude, but a representative rate would be about 7-10 litres of wastewater per barrel of crude oil feed to the unit. Desalter water contains salts, sludge, rust, clay, and varying amounts of emulsified oil (oil under carry). Depending on the crude oil source, it may or may not contain significant levels of Hydrogen Sulphide (H_2S), Ammonia and Phenolic compounds. Relatively high levels of suspended and dissolved solids are usually observed.

Greg Johnson (2006) asserts that the Chennai Petroleum Company Limited (CPCL) attributes much of the efficiency and effectiveness of its Wastewater Reclamation Plant to Koch Membrane System's (KMS) Ultra filtration Membrane system. The KMS system pretreats feed water before it enters the reverse osmosis system.

For many years, the Chennai metropolitan area of the Tami Nadu State of India has suffered from severe water shortages because of below-average annual rainfall. In lieu of adequate rainwater, the city has had to depend on a combination of alternative sources of water, such as surface water run-off, groundwater from aquifers surrounding the city and water from the Krishna River in Andhra Pradesin. To make matters worse, the limited amount of water to which Chennai has access is polluted by sand mining and nearby textile and leather tanning plants, (Greg Johnson 2006).

During the late 1980s, CPCL curtailed its Manali Refinery operations because of the city's severe shortage of water located outside of the city. CPCL depends on water for many of its processing applications. The water shortage in Chennai posed an enormous challenge to the success of CPCL business. In order to increase the amount of available water in Chennai, the management team of the company made huge significant investment in a new wastewater reclamation plant that would take municipal sewage from the Chennai Metro Water District and render it clean enough for industrial operations in the refinery.

Literature on refinery and petrochemical plants and processes were read. Many of the publications and unpublished works on KRPC were read. The World Health Organization (WHO) water standards were perused. The Executive Director (Operations) and all his Line Managers were interviewed. The plants and facilities were inspected and or observed at work. The researchers had the opportunities of interacting with Operators, Superintendents, and Supervisors and in particular, Refinery Shift Superintendents (RSS). Some of the contributors to this work have been Refinery Operators for a good number of years. All of the management and staff contacted provided information about how the plants run, how water is consumed and at what state, temperature and pressure.

The work is devoid of highly scientific and technical jargons that would have made the paper uninteresting to non-refinery and petrochemical engineers to read and understand. Similarly, details of chemistry and chemical purification and other treatments of water were avoided. A detailed description of the plants and processes are also beyond the scope of this work. Accurate quantity of the water required in any unit and the entire complex is not determined but every unit and area where water is used were touched for completeness of data collection and write up, and the inferences drawn.

Visits were made to see the source of water, River Kaduna and ‘’Water Works’’ built to draw water over the distance of about 13 kms to the complex. Various units where water is used, treated, pumped and effluent water is discharged were visited and observed in the processing stages.

Members of the communities around Kaduna River, the Water Works, and those around the Kaduna Refinery and Petrochemical Plants, and at the point of discharge of the effluent water, Rido and Romi villages, were interviewed. They responded to questions on the impact the water drawn from Kaduna River has on its immediate environments; and also the impact of the discharge effluent water in the immediate environment, (Romi River).

Results

The only source of water for every use (in production) is Kaduna River. The water intake facilities are located around the River, about 13 kms from the refinery plant. The water is pre-treated at the intake before being pumped through the pipe line into two large Storage Tanks on site. Each of the Raw Water Storage Tanks has a capacity of 75,000 cubic metres. The storage can last the complex for a period of 10 days, (KRPC 2000). Table II shows the chemical composition of the raw water and filtered water from Kaduna River. The chemical composition of the filtered water varies with seasons.

But on the average, the pH ranges between 7.0 and 7.8, Conductivity is 13-105, Turbidity is 20-3,000 and Total Solid (ppm) is 88-3328. Total Suspended Solid, Dissolved Solids, Ion and Hardness (ppm) are 8-3000, 70-328, 0.25-5.5 and 12.0-38 respectively. Alkalinity –M (ppm CaCO3), Chloride and Silica (ppm) are 20-62, 0.2-24.8 and 0.8-8.2 respectively. After filtration, the parameter readings differ, and sometimes very significantly too: pH is between 6.8 and 7.5, Conductivity (µs/cm) is 110, Turbidity is 0 and Total Suspended Solids (ppm) is 5-10 while Total Dissolved Solids (ppm) is 205 (315 maximum). Chloride (3.2), Silica (1.7), Trioxocarbon IV Acid (H_2CO_3) is 60 and Tetraoxosulphate VI,(4.0) do occur too.

Meanwhile, there are Water Treatment Units that treat the Raw Water to meet the quality specifications for drinking water, service water, process water and boiler feed water.

Table III shows the treated water that is fit for drinking. It meets all the WHO specified standards: pH is 7.0-8.5 (minimum 6.5 and maximum 9.2) and Turbidity is 0. Total Dissolved Solid is 500-1500, Total Hardness is 100/500, Calcium is between 50 and 150, Conductivity is between 85 and 100 and free chloride is 0.7 (ppm maximum). The free chlorine ensures complete elimination of micro bios. No life forms survive.

This water compare favourably with the water obtained from the bottling company around, though "imported" for drinking in the complex and its immediate environment – the Banks the Area Office and Depot of PPMC, Independent and Major marketers' and Petroleum Tanker Drivers' Complex. Table IV. The pH is 7.4 and Turbidity is 0.

Table V shows the composition of Cooling Water. Again, pH is between 7.6 and 8.4, Total Dissolved Solid (ppm) is 3,000 maximum usually 600 – 1600, Alkalinity – µ ppm is between 50 and 300, free chloride residual ppm is between 0.5 and 1.0, Zinc (ppm) and Calcium Hardness (ppm) are 2.0 (minimum) and 900 (maximum) usually 100 -200 minimum (50-1000). Total Bacterial Count is 105 (max). Sulphate Reducer Count is Nil, Turbidity is 30 and Silica Kurizet ppm is less than 130. See Table V.

Table VI, on the other hand, shows the Boiler Blow Down Water. Its Conductivity µs/cm is less than 200, the pH is high, usually between 9.3 and 10.00. The hydrazine (ppm) is between 0.5 and 1.0; See Table VI.

Purification of filtered water is carried out through the process of Clarification (Comprising Flocculation, Coagulation and Sedimentation) and filtration using sand, gravel and anthracites as filter media. Purification of drinking water is achieved through the use of activated carbon filter and addition of Calcium hypo chloride.

Further purifications by demineralization using ion-exchange resins is carried out to meet the specifications of the boiler. Figure 1 shows the simplified diagrammatic representation of the process flow of demineralization of water. It begins with water from filters into cation exchanger through degasifier to anion exchanger, storage demine Water Tank and to Boilers via Polishers. See Figure 1. The demineralization unit ensures the removal of dissolved salts such as Silica, Magnesium and Calcium ions which if allowed to pass with the water as boiler feed will deposit on boiler tubes. It will thus, form resistance, to efficient heat transfer. Treated water is routed to the boiler feed Water Tank before being fed to the boiler. The saturated Resins in cation and anion exchangers are usually regenerated with Sulphuric Acid and Sodium Hydroxide. The regenerated solution is emptied into neutralization basin where pH correction is effected before transferring to waste water unit.

The Demineralized water as a result of several chemicals that were used in purification now contains a lot of chemical elements and compounds. The pH however remains 7.0 – 8.0, conductivity is usually about 10.00 but not less. Total Solid and Total Dissolved Solids (ppm) are usually less than 5.0; and Suspended Solid (ppm) is 1.0; See Table VII. Usually, it is very clear: Turbidity is 0. Free Chloride, Sulphur Oxide, Nitrogen tri-Oxide, Carbon dioxide Tetraoxosulphate (V), Carbon (IV) Oxide and elements of Fluorine are nil. Total anion is usually less or not more than 0.27.

Invariably, there is no water absolutely retained in the system. Particularly, the process waters are discharged either as steam (gaseous form) or drained out as effluent liquid water. Table VIII shows the composition of typical effluent water discharged from the KRPC Plants. There are large number of chemical elements and compounds contained. The pH remains 7.5 - 8.0. Turbidity is fairly low, usually about 50. Total Dissolved Solids (TDS) (ppm) is 2000. Some of the other prominent compositions are Phenol (0.1), Oil

(0.3), Hydrocarbon (7.0), Selenium (0.01), Sulphate (200), Mercury (0.0001) and Ammonia – N (0.1). See Table VIII

Consequently, water needs are met through steam of various pressure and temperature, water of varied quantity and quality for various uses too and compressed air among others. The cooling water specifications are met through the use of 10 cooling tower cells and dosing of chemicals. Water that is heated in the process of circulating through the process plants is cooled by the Induced Draft fans mounted on the towers and water circulated. The cooling water quality is monitored continuously to ensure that the quality specifications are met at all times.

The steam unit is made up of five boilers that are capable of producing 700 tonnes per hour of high pressure steam. The steam produced is used in driving the power generating turbines, compressors and pumps in the process unit. Part of the steam produced is let down into 2 pressure levels for pump turbine drivers and process units. Very salient in every respect is the effluent water. The effluent water from the complex is treated at the Waste Water Treatment (WWT) Units before disposal into the neighbouring river. The unit employs biological processes to remove pollutants purposely to prevent ecological pollution. But there was no functioning Sour Water Stripper (SWS) as at the time of visit to the complex.

Discussion and conclusion

The KRPC Plants convert crude oil into fuel (including petrol, diesel, paraffin, kerosene and petrochemical products – Linear Alkyl Benzene; and tin and drum are manufactured. There are so many processes involved including heating and chemical reactions. The only source of water is Kaduna River. The treated water also supplies the Housing Estate with over one hundred households, the Staff School, Staff Club and Staff Clinic. There is sufficient potable water for drinking at the plants, the administration offices: for keeping ornamental plants-flowers, grasses etc, for fired fighting services; cooling the machines, tools and equipment; and in the laboratories and so on.

Since there are human lives in the complex and its immediate environment, the potable drinking water is made to be available for all and sundry. The cooling water is used in exchanger units to reduce heat to between 80-90^{O}C. Otherwise, the exchanger gets defective: Corrosion leading to defects of weaker cells in the system may occur, for instance. The Boiler Blow Down ensures cooling Blow Down and Intermittent Blow Down that reduces Silica contents of the entire water in the boiler. The draining out of the water from the boiler reduces the Silica content. This invariably forms substantial part of the effluent water discharged to the outside of the plants but directly into Romi Kaduna River.

Though in theory, the Waste Water Treatment (WWT) Unit treats the waste water before discharging to the environment to reduce ecological disturbances, much harm is still done. Above all, the SWS is not functioning. Four major problems were noticed:

- There were lots of passes that have given room to abridged results – Detail discussions of these are beyond the scope of this paper;
- Waste Water Reservoirs (WWR) are sometimes overfilled and eventually turned to outlet channels with little or no purification. It pollutes the environment. The oil and grease which were supposed to have been skimmed out from the surface and transferred back to the plant for refining are noticeable;
- Sour Water Stripper (SWS) Treatment Unit appears to be malfunctioning or non-functioning at all and it has being abandoned for some time; and
- The receiving community had not been adequately educated towards an understanding of the consequences of effluent water in their environment.

The refining and petrochemicals and tin and drum manufacturing processes invariably pollute air, water and land:

- Air is polluted by up to 100 pollutants emitted from the stacks and leaking equipment at the refineries and petrochemical plants;
- Land is polluted by the large amount of harmful wastes from refinery and tin and drum plants that needs to be dumped; and
- Water is polluted by the fallout from air pollution and by refinery and petrochemicals discharging chemical pollutants into water ways and effluent site.

Particularly, the water pollutants and the consequent polluted water are discharged as effluent wastewater to the environment. It affects the life forms, the ecosystem and livelihood at the receiving end. The effects are sometimes very devastating and it could be more serious particularly with the

Climate Change and Global Warming. In simplest forms therefore, major steps and actions must be taken by the KRPC Management and governments and government agencies to:

- Get data on water pollution levels in the entire refinery environment;
- Constantly demand for detail of changes in the immediate environment of the Refining and Petrochemical Complex;
- Do a health survey of the refinery neighbourhood;
- Recruit technical and experts in Health, Safety and Environment to constantly adequately manage the situations;
- Send out community press release on consequences of the effluent water released to the environment and hold community meetings;
- Talk to workers in the plant and constantly hold discussions with members of the community; and
- Hold discussion with political representatives and or Local Government Councillor(s).

All of these will be to educate and care for the community. It should be seen beyond mere compensation but for sustainable development.

There may not be any need "importing" bottled and sachet water for drinking in the plant and its immediate environment. It is additional cost for running the plants and facilities. Though the cost may seem meagre, accumulation of it over a period of time could be substantial. The Potable water Treatment Units are quite efficient. The Sour Water Stripper (SWS) Unit must be resuscitated. A Refinery and Petrochemical plants should not run without a functional Sour Water Stripper Unit. Long term effect of the untreated effluent water on the immediate environment (community) may be disastrous and may jeopardise every effort towards the longevity of a sustainable environment.

New Logic Research has developed an innovative and rugged ultra filtration Membrane system for the treatment of desalter effluent. Now by utilizing the propriety VSEP Filtration system, desalter effluent can be treated and mitigated at the source. The ultra filtration membrane has been in use in many refineries in most developed countries of the world. KRPC and other refineries in Nigeria must adopt it and use it.

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Table 1: Various Units of Fuel Plants and their Capacities.

Units	**Designed Capacities/BPSD**
Crude Distillation No 1	60,000
Crude Distillation No 2	50,000
Naphtha Hydro treating	24,000
Catalytic Reforming	17,500
Kerosene Hydrogen Desulphurization (KHU)	17,500
Gas Concentration	3,800
Vacuum Distillation	15,200
Fluid Catalytic Cracking	21,000
Gas Treating Unit	441,200
FCC Gasoline Merox	13,200
FCC LPG Merox	6,340
Sulphur Recovery	16 Tons/Day

Source: Operations' Department, Kaduna Refining and Petrochemical Company, Kaduna

Table II: Kaduna River Raw and Filtered Water Compared.

Parameters/Variable	**Raw water**	**Filtered water**
pH	7.0 - 7.8	6.8 - 7.0
Conductivity(µs/cm)	13 - 105	110
Turbidity	20 - 3,000	0
Total Solid (ppm)	88 - 3,328	
Total Suspended Solid (ppm)	8 - 3,000	5 - 10
Total Dissolved Solid (ppm)	70 - 328	205(315 max)
Alkalinity –µ/ppm $CaCO_3$	20 - 62	41
Total ion (ppm)	0.2 - 5.5	
Chloride (ppm)	0.2 - 24.8	3.2
Silica (ppm)	0.8 - 8.3	1.7
HCO_3		60
SO_4^{2-} (ppm)		4.0
Total Hardness (ppm)	12.0 - 38.0	

Source: Kaduna Refinery and Petrochemical Company, Kaduna.

Table III: Treated Water Fit for Drinking.

Parameters/Variable	Readings/Values
pH	7.0 -8.5 (min. 6.5 max.9.2)
Turbidity	5 -20
Total Dissolved Solids	500-1500
Total Hardness	100/500
Calcium	50 -150
Conductivity	85 -105
Free Chloride	0.7 ppm –max.

Sources: Kaduna Refinery and Petrochemical Company, Kaduna.

Table IV: Bottle Water in the Plant and Environment.

Average composition	Mg/l
pH	7.4
Conductivity	180
Calcium	20
Magnesium	2
Solarium	9
Potassium	2
Chloride	7
Nitrate	0
Sulphate	5
Bicarbonate	5.2
Phosphorous	0
Turbidity	0

Source: Spring Waters Nigeria Ltd.

Table V: Characteristics of Cooling Water in the Plant.

Variable/Parameter	Readings/ Values
pH	7.6 -8.4
Total Dissolved Solids (ppm)	3,000 max usually 600 – 1600
Alkalinity M (ppm)	50 -300
Free Chloride Residue (ppm)	0.5-1.0
Total Phosphate	3.5 -6.5(kurita)
Zn (ppm)	2.0 (min)
Ca Hardness (ppm)	900 max(usually 100 -250, min 50-100.
Total Bacteria Count	105 max
Sulphate Reducer Count	NIL
Silica (Kurizert ppm)	<130
Turbidity	30

Source: Operations Report KRPC, Kaduna.

Table VI: Characteristics of Boiler Blow Down Water

Parameter	Values/Readings
pH	9.3 – 10.0
Conductivity(µs/cm)	200
SiO_2 (ppm)	5.0
PO_4^{3-} (ppm)	3 – 10 (15)
Cl^- (ppm)	<20
Hydrazine ppm	0.5 – 1.0
Fe (ppm)	< 1.0

Source: Operations Report, KRPC, Kaduna.

Table VII: Demineralized Water

Variable/Parameters	Readings/Values
pH	7.0-8.0
Conductivity (Ns/cm)	≤ 10.0
SiO_2 (ppm)	≤ 0.17
Total solids (ppm)	< 5.0
Total Dissolved Solids (ppm)	< 5.0
Suspended Solids (ppm)	1.0
Turbidity	0
Iron (ppm)	≤ 0.1
Organic Matters (ppm)	1.0
Free Chloride(ppm)	0
Total Anion (ppm CaCO3)	≤2.0
Ca^{2+}+Mg^{2+} (ppm)	0
Na^+ + K^+ (ppm)	2.0
NH_4(ppm)	Calcium
Total Anion (ppm)	0.27
HCO_3(ppm)	0
Cl^-(ppm)	0.1
SO_4^{2-}(ppm)	0
NO_3(ppm)	0
F^- (ppm)	0
CO_2 (ppm)	0

Source: Kaduna Refinery and Petrochemical Company, Kaduna