# EVALUATION OF OTAMIRI RIVER, NWORIE RIVER AND BOREHOLE WATER AS SOURCES OF MUNICIPAL WATER SUPPLY SYSTEM

**BY**

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## CERTIFICATION

This is to certify that the work titled **Evaluation of Otamiri River, Nworie River and Borehole Water as Sources of Municipal Water Supply System** was carried out by **CHRISTOPHER KPARMEKPO ADEME** (Reg. No: **20074586938**) in accordance with the regulations governing the award of Master of Engineering. M.Eng (Water Resources Engineering) in the Post Graduate School, Federal University of Technology Owerri, Imo State Nigeria.

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## DEDICATION

This work is dedicated to God Almighty

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My gratitude goes to God the Almighty for seeing me through this arduous task.

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Many thanks to the staff of Owerri Water Co-operation and staff of Up-Dike Industries Ltd, to you all I say may the Almighty God bless and reward you in Jesus Name -Amen.

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## ABSTRACT

The quality of water from Otamiri River, Nworie River and Bore hole water as sources of municipal water supply system in Owerri has been evaluated by analyzing samples of raw water collected from Otamiri River and Nworie River and comparing them with selected borehole and treated water samples. Some selected borehole water analyses were carried out for their physiochemical parameters, major ions, nutrients and bacteriological quality. The obtained values from the analysis are:- Ammonia (mg/l) = 0.65, Total Iron ($Fe^{3+}$) (mg/l) = 0.40, pH = 7.57, Sodium ($Na^{+}$) (mg/l) – 0.95, Nitrate (mg/l) = 0.96, Nitrite (mg/l) = 1.30. The observed values were compared with standard values of the World Health Organization (WHO) for potable water. The lack of adequate funding by government has been identified as one of the problems faced by operators for the supply of potable water to consumers.

# CHAPTER ONE

# INTRODUCTION

## 1.1 BACKGROUND

Water is one of the basic elements of life only second to air. However, according to Garg (2005) "Water is a chemical compound and may occur in a liquid, solid or gaseous form. All these three forms of water are extremely useful to man, providing him the luxuries and comforts, in addition to fulfilling his basic necessities of life."

According to the WHO/UNEP (1996) "problems associated with the lack of adequate and quality water resources in Nigeria have threaten to place the health of about 40 million people at risk" In Imo State, past and present governments have not been left out with the problem of water supply for example on the 15th May, 1986, the Imo State Government established the Imo State Water Treatment Scheme by His Excellency Chief Samuel Onunaka Mbakwe. The Imo State Water Cooperation has the major responsibility of providing safe and potable water for the people of the State. The treatment method adopted includes steps shown in Fig 1

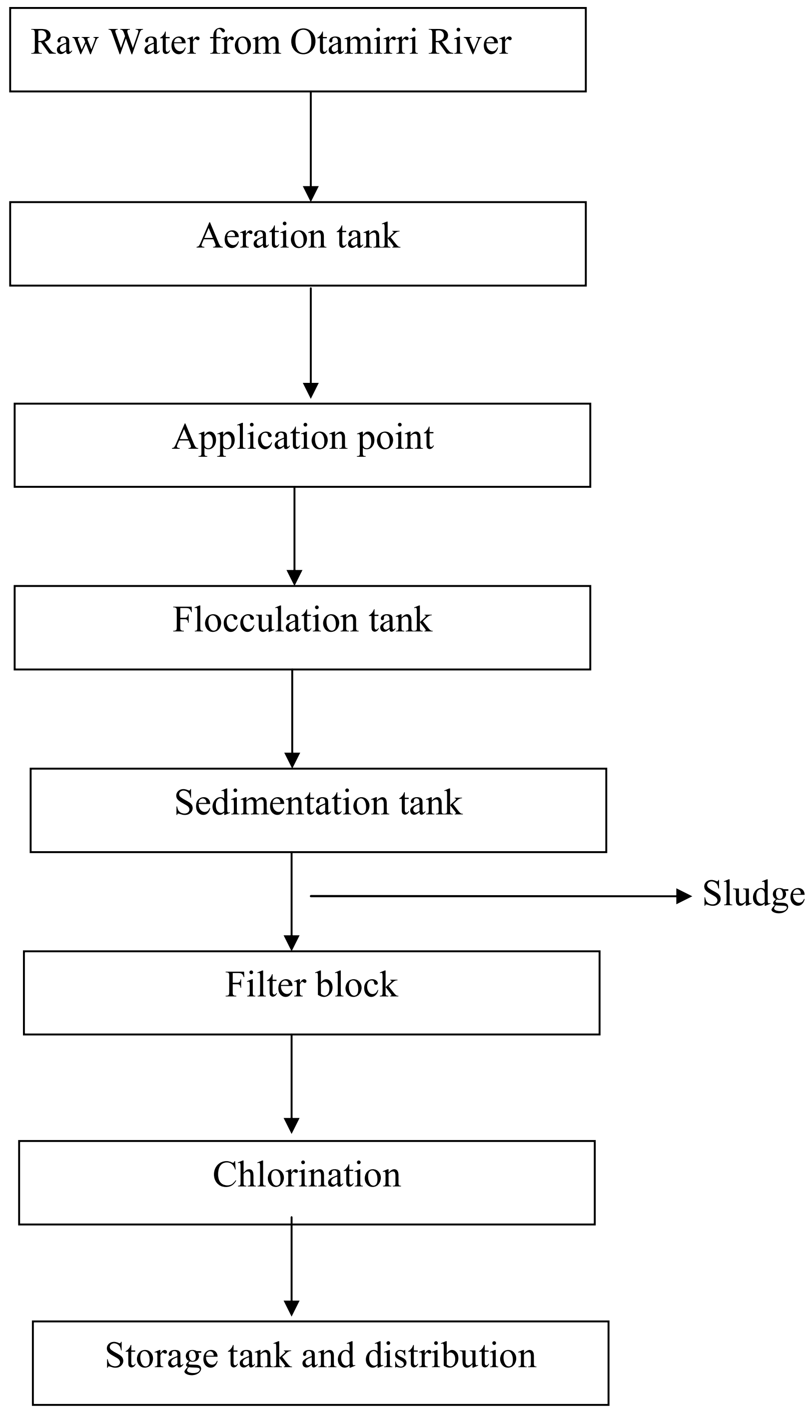


Fig 1: Flow chart showing steps in treating raw water by the Imo State water cooperation.

UNECEF/ WHO (2004) defines water quality as its fitness for the beneficial uses, which is provided for drinking by man and animals for the support of marine life, for irrigation ,for industry, for recreation and for anesthetic purposes. The present study is aimed at assessing the effectiveness of these treatment methods on the quality of water supply to consumers. It is certain, however that with out water there would be no life of any kind on the earth and that, without water readily available in adequate quantity and free of pathogenic organisms, man's progress is tremendously hindered.

Although no actual account is possible, million of man-days of labour are undoubtedly lost annually because of illness and death resulting from water-born disease.

The responsibility for reducing this tremendous waste, falls on the governments and, specifically, on health administrations. It is the aim of this thesis to assist the government officials who must meet this challenge. Among those directly concerned are public health administrators, medical officers, civil or sanitary engineers in public health. An effort has been made to discuss the problems of rural water-supply in a clear and realistic manner and to avoid nebulous concepts which can not possibly apply to most of the rural undeveloped areas of the world at the present time. Perhaps the most important single step in a water-supply programme is to get it started.

## 1.2 STUDY OBJECTIVES

The following are the objectives of the study:

i. To evaluate the quality of surface water from Otamiri river, Nworie river and borehole water for drinking purposes;
ii. To evaluate other possible sources of water (Nworie and Boreholes) for Owerri Municipal water supply system;
iii. To evaluate the Owerri water treatment plant;
iv. To evaluate the efficiency of the treatment processes in the treatment plant;
v. To make recommendations on the Owerri municipal water supply system.

## 1.3 SCOPE OF STUDY

The study was limited to the quality of raw water from Otamiri River, Nworie River and selected boreholes in Owerri municipal and that of treated water produced from the Owerri water treatment plant. This was to ascertain the quality of drinking water provided by the Owerri water treatment plant.

## 1.4 AREA OF STUDY

Owerri is the capital of Imo State and is located $5^0$ 29' 0" N and $7^0$ 2' 0" E South-East Nigeria. Owerri water treatment plant is located 2km from the water source (Otamiri river). It is situated at Egbu in Owerri North Local Government Area of Imo State (as shown in Appendix 6). Also, water samples were collected from Nworie River and selected boreholes.

Owerri which is an urban city, has a population of about 2.5million people. It is located in the South-Eastern part of Nigeria. The source of water is Otamiri River (See Appendix 3). The water scheme is located 2km from the source at Egbu in Owerri North local government area of Imo state. (See Appendix 6). The Otamiri head works has low lift and high lift pumps for the water – works of the treatment plant. The capacity of the low lift pump is 800KVA while that of the high lift pump is 1500KVA.

## 1.5 STATEMENT OF PROBLEM

In the last 10 years, there had been complaints from the public about the taste and odour of the Owerri municipal water supply. The source of the municipal water supply is the Otamiri river which is treated at the Otamiri water treatment plant. Proper funding for the maintenance of the municipal water supply system has been identified as one of the problems by the operators for the supply of potable water to consumers. The study aims at identifying the concern of the public about the quality of the municipal water supply system and thereby recommend possible source(s) of potable water supply for the metropolis.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 WATER SUPPLY

According to Warren and Mark (1998), “the human search for pure water supplies must have begun in prehistoric times much of that earliest activity is subject to speculation”. Water is a basic necessity for the survival of human beings, animals, plants and other living beings. Furthermore, it is necessary that the water required for their needs must be potable, and it should not contain unwanted impurities or harmful chemical compounds or bacteria in it. Therefore, in order to ensure the availability of sufficient quantity of good quality water, it becomes almost imperative in a modern society, to plan and build suitable water supply schemes, which may provide potable water to the various sections of the community in accordance with demands and requirements.

According to Garg (2005), “the provision of such a scheme shall not only help in supplying safe wholesome water to the people for drinking, cooking bathing, washing etc. so as to keep diseases away and thereby promoting better health. It has been estimated that two-third of the human body is constituted of water” thus, the need for quality water supply is important.

### 2.1.1. Water supply in Nigeria

In the pre-independent era, provision of domestic water supply was largely through individual and community efforts. The regional governments later got involved with the main concern of developing schemes for urban and semi-urban areas to the neglect of the rural communities. Water boards or corporations were established for this purposes by the regional governments to provide the services.

According to FEPA (1991), “the drought of the early seventies, prompted the intervention of the federal government to take a number of actions. This resulted in the establishment of some Federal Agencies. These Agencies include the Federal Ministry of Water Resources (1976), National Water Resource Institute (1977), and the River Basin Development Authorities (RBDAs), (1976). While the ministry has the responsibility to formulate policies and give advice, training and research, the RBDAs are executing agencies, providing irrigation water and domestic water supply to the communities. The tempo of water supply was raised in the

1980s with the preparation for and campaign in favour of the United Nation's International Drinking water supply and sanitation decade (1981-1990)".

According to www.safewater.com (2006), "the goal of the program is to provide water for all by the year 1990, 120litres/day of water (WHO standard) for domestic use. However, just before the commencement of this program, only 22% of the rural and 55% of the urban population enjoyed potable water. These figures have increased only marginally. In absolute terms, by 1986, rural dweller had access to 25liters of potable water per day while his urban counterpart has access to 60 litres/day".

### 2.1.2 Adequacy of water supply

Water is literally the source of life on earth. According to Nwaogazie (2010), "the human body is 70% water. Water is a basic human right. Without it societies wither and people die. Much of the ill-health which affects humanity, especially in the developing countries can be traced to lack of safe and wholesome water supply, that is, water that is easily accessible, adequate in quantity, free from contamination, safe and readily available through out the year. There can be no state of positive health and well-being with out sufficient and safe water supply".

Water must not only be adequate in quantity, it must also be adequate in terms of its quality. According to WHO/UNEP (1996), "the basic physiological requirement for drinking water has been estimated at about 20litres per person per day". However the daily supply of 140-160 litres per capita per day is considered adequate to meet the needs for all domestic purpose. According to FEPA (1991), "it is estimated that more than one billion people in developing countries lack access to safe drinking water". This study, therefore reaffirms the need for adequate water supply within Owerri metropolis.

### 2.1.3 Water quality

Quality of water can be completely defined and estimated by studying its physical, chemical and bacterial characteristics, as shown in table 4.1 to 4.6. All surface water should be of adequate quality to support aquatic life and be aesthetically pleasing. Additionally, if needed as a source of supply, the water should be treated by conventional process to provided a potable supply meeting the drinking water standard.

A normal, healthy stream or a lake has a balance of plant and animal life represented by great diversity species. Pollution disrupts this balance, resulting in a reduction in the variety of individuals and dominance of the surviving organisms. Complete absence of species normally associated with a particular habitat reveals extreme degradation.

## 2.2 CONSTRAINTS TO WATER SUPPLY

### 2.2.1 Lack of basic planning data

One of the major constraints to water resources development is lack of basic planning data. The task of data collection has regrettably either been underplayed or ignored. It is therefore always very difficult to assemble reliable, adequate technical and socio-economic data capable of assisting in the assessment, planning, design, construction and maintenance of various water resources developmental projects.

According to www.uneca.org (2000) "many projects have failed because of the unreliable and inadequate data in which analysis, planning and management were based. The recent failure of some water resources projects such as Bagauda dam, Ogumpa flood disaster and other hydraulic structures are living testimonies. Flow patterns in space and time in rives have largely been neglected and at best of time sporadic measurements. All these affect down stream development. Within the borders, the situation is not different either, hence Nigeria experiences persistent drought, flood and erosion without any long term solution".

### 2.2.2 Effects Flood and Erosion in water supply infrastructure

The effect of flood has particularly been very devastating in the coastal areas of the country. This has some times led to severe erosion and consequent loss of agricultural soil lands and damages to engineering structures including those for water resources development. Under this circumstance, a lot of sediment is transported which ends up in siltation and clogging up of reservoirs; river channels etc. and thus reducing their potentials for water storage. With a little more commitment on adequate manpower, the situation can be improved and the water harnessed for more productive activity and economic uses.

### 2.2.3 Lack of Adequate Manpower

The proper planning, implementation and management of water resources programmes and project depend principally on the availability of competent personnel. It is common knowledge that in Nigeria, there has been a marked inadequatency of manpower in water resources particularly at professional and sub-professional levels. This lack of trained personnel in the middle technical and management levels has been limiting the scale of success of various developments. The professional and sub-professional are very few in number and some of them inexperienced. The few available ones have been spread too thinly on the design, construction, operation and maintenance of the existing projects. In order to cope with the challenges in the next decade, there is need to step up manpower training.

### 2.2.4 Inadequate funding for water supply projects

The non availability of funds has always posed a major problem to the development of water resources programmes and projects. Most of the developments in this sector are government financed. The swindling of resources at the government disposal has also adversely affected successive allocations of money to water resources projects. The Federal government allocations have declined, while State Government releases only 20-30% of their budgeted expenses to water supply. Most projects therefore remain uncompleted and those whose systems have broken down and cannot be easily rehabilitated all over the country.

According to National Growth (2006) on water demand and supply strategies in Nigeria, "the uncompleted land works and irrigations infrastructures have reduced and potentials for attaining self sufficiency in water supplies, food production is further frustrated, thus a loss in revenue the case of irrigated agriculture, the 470,000 ha of land yet to be completed is capable of producing 2,800 metric tones of rice at two cropping per season. The construction cost of these projects has been major concern to policy makers".

A lot of funds have similarly been invested on the national borehole programme; a programme designed for the States of the federation in bringing potable water to the rural areas of the country despite the huge investments, the program is yet to be completed. According to national growth (2006) on water demand and supply strategies in Nigeria only 330 of the 851 productive boreholes drilled have been commissioned to date. There had been no sufficient fund to procure the foreign input of pump generation and tank materials.

In order to meet the water demands for increased food crop production through irrigation, and demands for domestic for domestic and industrial water supply, hydropower generation, navigation, recreation etc. some of the constraints discussed earlier need to be removed. Before any meaningful strategy could be adopted, the issue of ownership of water has to be settled through legislation.

### 2.2.5 Enactment of water legislation

The nagging question has always been who owns the water? Is it the government? (Federal, State or local)? its agencies or the individual who has title to the land that also has the water which flows through or passes his land? In addressing this issue, one should take note of the fact that water does not respect any sectional or political boundaries, this issue of water should be tackled as a common problem and looked at on a global basis. Unlike the existing land use decree, the ownership of water should be vested in the Federal Government. Potential water users can then apply to the Federal Government for licences to develop the water as part of the national resource. This measure will ensure a controlled use of water resources (surface or ground water).

A lot of fund has been invested on a number of water projects, which are temporarily abandoned for lack of fund to execute such projects. The investments should not be allowed to go down the drain; rather the projects should be salvaged if these projects can be realized, example, the on-going dam projects in Nigeria is capable of supplying large quantities of water for irrigation and other purposes. The revenue to accrue to the economy is considerable and the issue of completing existing projects should be a priority.

### 2.2.6 Procurement of Equipment

In order to facilitate the completion of on-going projects and maintain existing ones, there is the urgent need to procure essential equipment and spare parts. According to www.uneca.org (2000), "most of these equipments are imported, apart from the time delay; the foreign exchange for their procurement is very high. The establishment of foundries to fabricate some of our materials will be a welcome solution. Already, a laudable step has been taken by the federal ministry of water resources. In a joint effort with the Defense Industries Corporation (DIC), Kaduna, the Ruwatsan hand pump designed to our taste has been fabricated. The production of similar water resources equipments and spare parts will no doubt speed up the pace of our development".

### 2.2.7 Provision of fund and trained manpower

The demand of water resources is dynamic and should not be stagnant hence there is need for changes in management. Thus, the need for sufficient and adequately trained personnel to cope with the changing demands and technologies is important. This calls for the need of various resources of government (Federal, State and

Local) to increase their annual allocation to water resources projects. In addition, institutionalized credit facilities similar to peoples bank should be established to take care of our small-scale farmers and water related industrialists.

## 2.3 QUANTIFICATION OF GROUND WATER RESERVE

According to www.uneca.org. (2000), "the rough estimate of surface water is (224 billion $m^3$) but the quantity of ground water remains unknown. Thus, the need to direct attention on this issue through identification of various aquifer availability". When the ground water reserve is quantified, their judicious exploitation can be planned to meet there multipurpose uses.

## 2.4 WATER TREATMENT

According Garg (2007), "pure water is a chemical compound with each of its molecule (the smallest unit of a compound) containing two hydrogen atoms and one oxygen atom, and nothing else ($H_2O$ being the chemical formula for water)". However, pure water can never be available in nature. Even a man-made drop of water, prepared in a laboratory by lighting the hydrogen and oxygen gases in a test-tube may not be perfectly pure, because the water drop so formed will dissolved the glass of the test-tube (although, very little bit). The precipitation, in the same manner, at the instant of its formation contains no impurities, but during the process of formation and fall through the earth's atmosphere, may dissolve certain gases, traces of minerals and other substances. When once the precipitation reaches the earth's surface, many more opportunities are presented for the introduction of various physical, chemical or bacterial impurities in it.

As the rain water flows over the surface of the earth, it picks up or dissolves particles of soil , garbage, sewage, pesticides and other human, animal or chemical waste, it may also pick and dissolve certain decayed organic materials, such as plants or dead animals. As the surface water seeps into the ground-water reservoir most of the suspended particles are filtered out, but on the other hand, the water dissolves the minerals and salts present in the earth's layers, through which it travels to reach an aquifer.

The impurities which water dissolves or picks up as suspended solids, may sometimes make it more useful and potable for public use and especially for drinking, and sometimes it may render it harmful and unfit for example, certain minerals such as iron, calcium, magnesium, fluorine etc. in small quantities may be useful and good for the health of the people, because human beings need a certain amount of these elements in their bodies. But when these materials and others are dissolved in large amount or in certain combinations, the water become unfit or less useful for municipal, industrial and other uses, for example, sometimes the water may contain toxic or poisonous substances such as arsenic, barium, cadmium chromium, cyanides, lead, selenium, silver, copper etc. which will be very harmful to the public health, even in low quantities. Sometimes, the water may contain too much of common salt, there by rendering it blackish and making it drinkable and less useful for cloth washing, irrigation and farming.

However, microbiological contamination is generally the most important to human health as this lead to infections, diseases which affects population. Many of which may cause epidemics. According to Harrison (2004), "fatal chemical contamination tends to represent a more long-term health risk. An example of this is nitrate which can cause methaemogblobinaemenia in babies". Substances in water which effect the colour or taste of water may make water objectionable to consumers. As many micro organisms are found associated with particles in water, physical contamination may also represent a health rick as it extends microbial survival.

Most treatment systems are designed to remove microbiological contamination and those physical constituents which affects the acceptability or promote micro organism survival- largely related to the suspended solid in the water. A disinfectant is nearly always included in treatment plant of ant size. This is done for two main reasons:

Firstly, it is added to inactivate any remaining bacteria as the final unit of treatment; and secondly, to provide residual disinfectants which kill any bacteria introduced during storage and /or distribution.

According to Keller and Henry (1992), "to ensure safety to public health, economy and utility in industries and other uses, it therefore becomes imperative upon the planners and designers of the public water supply schemes, to properly check, analyze and treat the raw available water to safe and permissible limits before supplying to the public".

### 2.4.1 Water treatment process

Treatment processes usually function either through the physical removal of contaminants through filtration, settling (often aided by some form of chemical addition).

There are many different treatment processes available and whose suitability is a function of the source water quality, level of staff training and resources available for operation and maintenance. It is imperative that the selection of technology for treatment plants in done taking the forgoing into consideration to ensure that the systems remains sustainable.

### 2.4.2 Difference between modern and the conventional treatment processes

In modern water treatment facilities, the chemical process of treating water source such as: lakes, rivers, reservoirs, or ground water has nearly eradicated the spread of water borne diseases. However, chlorine hypochlorite, ozone, chlorine dioxide and chloramines are the most often used chemical in the disinfection process of source water. These disinfectants will form other chemicals in the presence of natural organic matter that are described as disinfection by-products (DBP), which have been shown to cause adverse health risk to humans over time.

The conventional water treatment plants use a combination of coagulation, sedimentation, filtration and disinfection to provide clean safe drinking water to the public. Worldwide, a combination of coagulation, sedimentation and filtration is the most widely applied water treatment technology as shown in Appendix 7.

## 2.5 PREFILTRATION

Many secondary filtration processes, and in particular, slows and filtration require low influent turbidities, some form of pretreatment (addition of choroamines) to reduce suspended solids load. One way to achieve this is by using prefiltration of water through coarse media, usually gravel or coarse sand. Prefilters can have many different configurations: horizontal; vertical, up flow; and vertical up flow down flow. Vertical prefilters have become increasingly popular as they require far less land than horizontal prefilters and can take faster flow runs through them. An alternative are pressure filters, through which water is pumped at pressure to remove the suspended solid load.

According to WHO/ UNEP (1996) "Prefilters have an advantage in that they do not require chemicals, have limited working parts and are robust". They do however, require frequent cleaning and maintenance and are in effective in removing fine particles, thus where the suspended solid load is primarily made up of silt and clay particles prefiltration is ineffective. Prefiltration is a physical process (rapid mixing of aluminum sulfate) designed to remove suspended solids and therefore it's efficiency in removal of micro organisms is a function of the microbes associated with particles. Virus removal is poor and prefiltration is not effective in the removal of cysts or bacterial associated with fine particles.

## 2.6 SEDIMENTATION

Sedimentation is the removal of suspended solids through the settling of particles moving through a tank at a slow rate. There are a number of forms of sedimentation. In water treatment plants, treating source /raw water, a high proportion of suspended solids of coarse grades (e.g sand and coarse silt), a grit chamber may be used to remove the largest particles through simple sedimentation.

In this process, water is passed through a tank at a slow rate and suspended solids fall out of suspension. In small supplies, simple sedimentors may also be used to remove fine grained particles because the flow rates remain too high and the retention time is insufficient. A further common fault with simple sedimenters is that design flow rates really achieved in practice and certain element of “short-circuiting” can occur unless construction, operation and maintenance is very careful.

As a result of the drawbacks in simple sedimentation, it is common to find that the sedimentation process is enhanced through the addition of chemicals or coagulation. Coagulants carry a charge and therefore attract charge particles. The particles begin to aggregate and form flocs; once the flocs reach a critical mass, they sink to the bottom of the settler. The outlet of the sediment is generally around the top of the structure, thus the clear water is removed by a surface channel. This system can be further refined with the use of modular or plate settlers which reduces the time required for settling by providing a wide surface area for aggregation of particles.

The most commonly used coagulants is aluminum sulphate, although there are other coagulants available including ferric salts (sulphate and chlorides) and polyelectrolyte's coagulants are dosed in solution at a rate determined by raw water quality near the inlet of a mixing tank or flocculate. It is essential that the coagulant is rapidly and thorough with the use of a hydraulic jump. The water then passes into the settler to allow aggregation of the flcos. Increasing use is now been made of synthetic polymer compounds or polyelectrolytes. As these are highly charged, there is a rapid increase in the formation of flocs, particularly where clay makes up a large proportion of the suspended solid load.

The advantages of the coagulation is that it reduces the time required to settle out, suspended solids are very difficult to remove from water. Coagulation can also be effective in removing protozoa, bacteria and viruses, particularly when polyelectrolyte is used as the highly charged microorganisms into the flocs. Coagulation can also be effective in removing by precipitating certain contaminants such as lead and barium. The principal disadvantage of using coagulants is the cost and the need for accurate dosing, jar testing and dose adjustment and frequent monitoring. Coagulants can be expensive to buy (particularly polyelectrolyte) and need dosing equipment to junction effectively.

## 2.7 FILTRATION

Screening and sedimentation removes a large percentage of the suspended solid and organic matter present in raw supplies. The percentage of removal of the colloidal matter increases when coagulants are also used in sedimentation. However, the resultant water will not be pure, and may contain some very fine suspended particles (discrete, or flocculated when coagulation is used) and bacterial present in it. To remove or reduce the remaining impurities still further, and to produce potable and palatable water, the water is filtered through the beds of fine granular materials, such as sands etc. the process of passing the water though the beds of such granular materials (filters) is known as filtration. It may help in removing colour, odour, turbidity and pathogenic bacterial from water.

### 2.7.1 Sand Filtration

Sand filtration can be either rapid or slow. The difference between the two is not a simple matter of the speed of filtration, but in the underlying concept of the treatment process. Slow sand filtration is essentially a biological process whereas rapid sand filtration is a physical treatment process.

Slow sand filters have an advantage over rapid sand filters in that they produce microbiologically "clean" water which should not require disinfectant to provide a residual for the distribution system is, still advisable. However, because of their slow flow rate slow sand filters require large tracts of land if they are to supply large population, and can be relatively labour intensive to operate and maintain. Rapid sand filtration is not commonly used world wide and is more popular than slow sand filtration. The principal factor in this decision as been the smaller land requirement for rapid sand filters and lower labour costs. However, rapid sand filters do not produce water of the same quality as slow sand filters and far greater reliance is placed on disinfection to in activate bacteria. It is also worth noting that sand filters are not effective in removing viruses.

### 2.7.2 Slow Sand Filters

Slow sand filters (see Fig 2.1) operate at slow rates, 0.1-0.3 metres per hour. The top layers of the sand become biologically active by the establishment of a microbial community on the top layers of the sand becomes biologically active by the establishment of a microbial community on the top layer of the sand substrate.

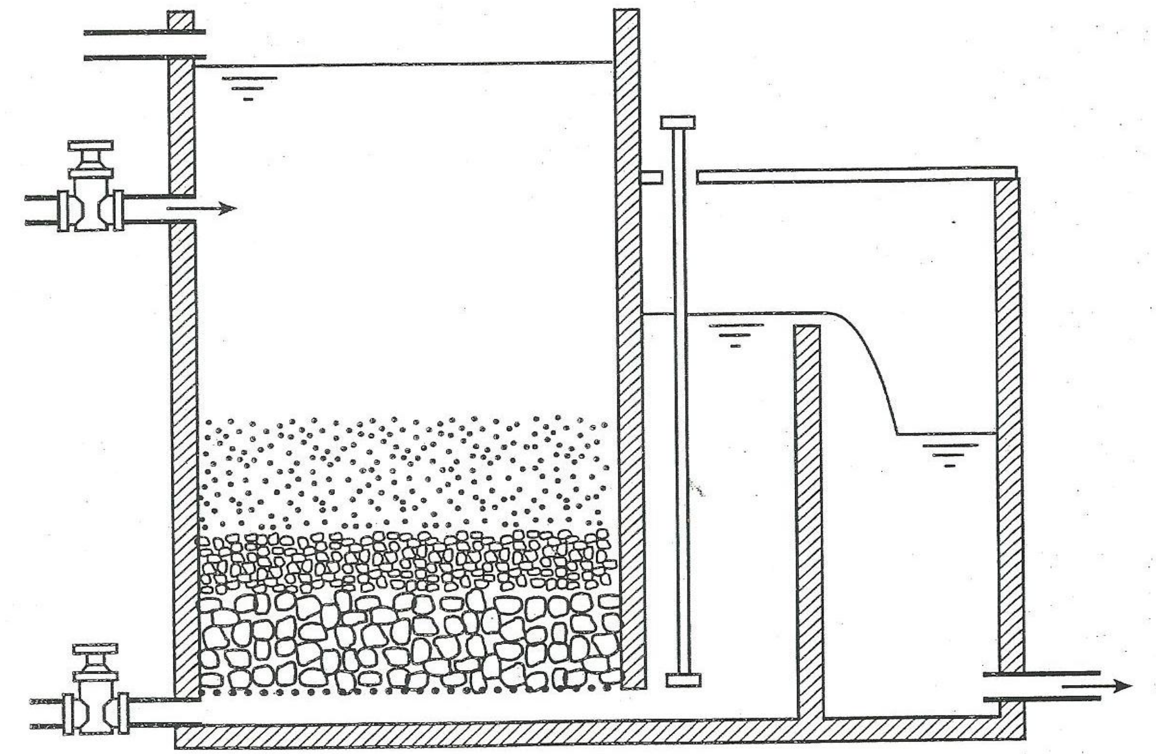

Fig 2.1 Schematic of Slow Sand Filter

Source : Garg, (2005) Water Supply Engineering

The fine sand slow filtration rate facilitates the establishment of this microbial community. The majority of the communities are predatory bacteria who feed on water borne microbial passing through the filter.

The microbial community forms a layer called the schumtzdecke and can develop up to 2cm thick before the filter requires cleaning. Once the schumtzdecks becomes too thick and the rate of filtration declines further, it is scraped off, a process done every couple of months or so depending on the source water Once this has been carried out, the slow sand filter will not be fully functional for another 3 to 4 days until a new schymtzdecke has developed, although this procedure can be speeded up by seeding filter with bacteria from the removed schumtxdecke slow sand filtration is extremely good in removing microbial contaminants and will usually have no indicator bacteria present at the outlet. Slow sand filters are also effective in removing protozoa and viruses.

Slow sand filters require low influent turbidity. This means that efficient pretreatment is required to ensure that the filters do not become overloaded. Slow sand filters can cope with shock turbidities of up to 50 litres but only for very short periods of time before they block. The sand used in slow filters is fine, thus high turbidities cause the bed to block rapidly and necessitates more frequent cleaning and therefore greater time of action.

Nevertheless, slow sand filters are still common elsewhere in the world. The shift from slow sand filtration has largely been a function of rising land prices and labour cost which increased the cost of slow sand filter produced water, where this is not the case, slow sand filters still represent a cost effective method of water treatment.

### 2.7.3 Rapid sand filters

Rapid sand filters (see Fig 2.2) work at much higher rates of flow (up and 20 metres per hour) and essentially rely on physical removal of suspended solids, including any floc carried over from the settlers. Although rapid sand filters achieve some reduction in microbial populations in water as it removes particles to which bacteria are attached, it is not a biological treatment and the use of a terminal disinfectant is important to ensure that bacteria in the water have been inactivated.

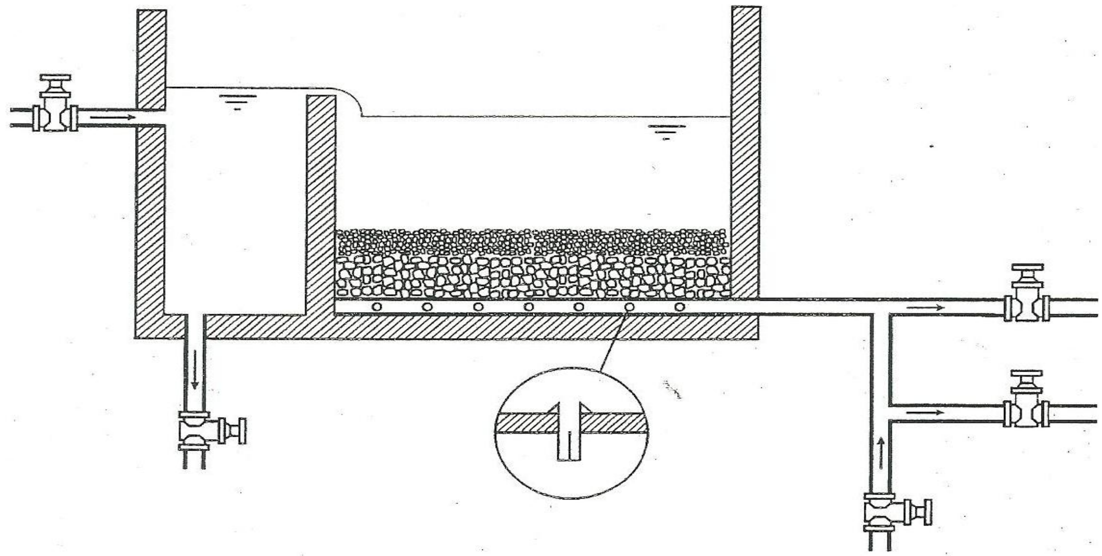

Fig 2.2 Schematic of Rapid Sand Filter

Source : Garg, (2005) Water Supply Engineering

Rapid sand filters requires frequent cleaning (daily or twice daily) which is achieved though backwashing filters with clean water to re-suspend the sediment. Cleaning takes relatively little time and the filters can be put back into operation immediately? Rapid sand filters are smaller in size than slow sand filters and are commonly employed in batteries. The rapid flow rate through these filters means that demand can be more easily met from smaller plants. Rapid sand filters do not require loss influent turbidities, as they are essentially a physical treatment process, although higher suspended solids loads will result in more frequent cleaning.

Backwashing is usually rapid and filters are not out of commission for more than a matter of minutes. Cleaning and operation can be largely mechanized and air scour is commonly employed to make backwashing more effective. With the small land requirement, several rapid sand filters can be accommodated in small area and thus it is easy to maintain capacity to meet demand when filters are being cleaned.

## 2.8 DISINFECTION

All water supplies should be disinfected in order to protect public health. Disinfection inactivates any remaining bacteria in the water after previous treatment steps and provides a residual disinfectant to inactivate bacteria introduced by any subsequent ingress of contaminated water during storage or distribution.

At present, the principal disinfectant used worldwide is chlorine although alternatives are being increasingly investigated and processes such as ozonation are becoming popular in industrialized countries. It is important to note that all disinfectants produce by-products and that the greater knowledge about the by-products formed from the used of chlorine because it is the most widely used disinfectants should not compromise it's use. According to Cong (1999) "it is also important that disinfection of water supplies is never compromised because of a risk of potential health effects from by-products in the treated water, any health impacts from chemical contamination is likely to be long-term, whereas the absence of disinfection puts the consumers at risk from infection diarrheal disease".

The treatment processes presented earlier are all designed to make drinking water safe by the removal of micro-organisms and suspended solids. However, drinking-water, particular contaminants from ground water sources, may also contain chemical contaminants which must be removed. Generally the removal of chemicals from waters is more difficult and much more expensive than removing microbial or physical contaminants. Basic filtration and coagulation techniques are not generally effective for the majority of chemicals.

As there are many different chemicals which could be dealt with, a few relevant examples will be provided. Iron can be a major constituent of both ground and surface waters (where it is commonly associated with bacteria and algae). Although iron does not represent any health risk, it causes problems of acceptability of the water as many consumers find the colour off putting and because it stains cloths. The principal method of removing iron from water is through aeration or oxidation of the $Fe^{2+}$ to the $Fe^{3+}$ species. This is easily achieved by flowing the water over a simple cascade and followed by sedimentation.

Note that aeration is also used for waters known to be anoxic or oxygen deficient.

A variety of processes are used for the removal of organic and inorganic contaminants including ion exchange and precipitation. For instance, fluoride may be removed through coagulation with lime or by ion exchange using calcinated burnt bone or activated alumina.

Granulated activated carbon (GAC) is commonly used for pesticide removal through adsorption. This is expensive but unfortunately no other process appears to work effectively and therefore GAC remain the sole option.

## 2.9 OWERRI WATER TREATMENT PLANT

It is important that a full picture of the water sources and quality is available (Otamiri River, see Appendix 3). The physical treatment of the water starts from the low lift water intake section that is the radial gate which protects foreign object (water hyacinths) from entering the pump house to prevent any harm to the impellers of the pump. Another observation from the source of the water is the weir (concrete wall, see Appendix 2), the aim is to maintain the water level for the pump. The height of the water is 2m (6ft),that is the level of water flowing into the intake. The gate valves control the flow of water into the pump house which houses the electrical panel that controls the amount of water going into the pumps. Three pumps are used to supply water into the aeration tank through 0.9 meters metal pipe that conveys the raw water from the pump house to the aeration tank, (See Appendix 5).

Due to the topography of the land the size of the pipe reduces to 0.4 meters to maintain the pressure of water. Water moves from the aeration tank. Oxygen is introduced and carbon dioxide is expelled during the aeration process. The water then flows to the application point were aluminum sulphate is added to purify the colour of the water, chlorine is added to kill harmful bacteria, and soda ash to maintain pH level.

The water then flows to the flocculation basin then to the sedimentation tank then to the filter beds. Plastic nozzles are used instead of metal to avoid corrosion. After disinfectant is applied, finally the purified water is pumped to the elevated water tank for distribution.

### 2.9.1 Sources of water

After estimating the water requirement for the proposed water supply scheme, the planners of the scheme must go in for search of nearby water sources, that will meet the demand, the various sources of water available on earth can be classified into two categories:

- Surface sources and
- Sub-surface (ground water)

### 2.9.2 Surface source

Surface sources are those sources of water in which the water is contained over the surface of the earth and is directly available for water supplies.

#### 2.9.2.1 Ponds and lakes

A natural large sized depression formed within the surface of the earth, when it gets filled up with water, is known as pond or lake. The difference between a pond and a lake is only the size. If the depression is comparatively small, it is known as a pond; when the depression is large, if is known as lake. The flow of water in a lake is just like the flow of water in a stream channel.

Generally, the surface run-off from the catchment area, contributing to a particular lake, enters the lake through small drains or stream. Sometimes, the ground water through some spring, also enters the natural depression and gets collected there, forming a pond or lake. The quality of water in a lake is general good and does not need much purification. Larger and older lakes, however, provides comparatively pure water than the smaller and newer lakes. Self purification of water due to sedimentation of suspended matter, bleaching of colour, removal of bacteria etc makes the lake water purer and better. On the other hand, in still waters of lakes and ponds, the algae, weed and vegetable growth takes place freely, importing bad smells, tastes and colour of such waters.

The quantity of water available from lakes is, however, generally small. It depends upon the catchment area of the lake basin, annual rainfall and geological formations. Due to the smaller quantity of water available from them, lakes are not considered as principal sources of water supplies. However, when no other sources are available, larger lakes may become the principal sources of supplies.

#### 2.9.2.2 Stream and river

Small streams channels feed their waters to the lake or river. Small streams are therefore, generally not suitable for water supplies schemes because the quantity of water available in them is generally very small and they may even sometimes go dry. They may, therefore, be useful as sources of water, only for small villages. Larger and perennial streams may, however, be used as sources of water supplies by providing storage reservoirs, barrages etc. across them.

When water in the stream channels flows for a long distance, sand and mineral impurities get dissolved in it, thereby making it harmful. Such water therefore requires treatment before supplying. According to www.fao.org (2000), "rivers are the most important sources of water for public water supply schemes. It is a well known fact that most of the cities are settled near the river, and it is generally easy to find a river for supplying water". River may be perennial or non-perennial.

Perennial river are those in which water is available through out of the year while non-perennial rivers can be used as sources of public supplies by providing storage on the upstream of the intake works. The construction of a dam is generally adopted on a highly non-perennial river and perennial river when water is used for multiple purposes such as irrigation, hydropower, e.t.c. the head work such as weir may also be constructed on those perennial river, where supplies are considerably reduced during dry weather periods. The quality of water obtained from river is generally not reliable, as it contains large amounts of silt, sand and a lot of suspended matter. The disposal of the untreated or treated sewage into the rivers is further liable to contaminate the river water. The river water must, therefore be properly well analyzed and well treated before supplying to the public.

#### 2.9.2.3 Impounding reservoir

A water supply scheme drawing water directly from a river or a stream may fail to satisfy the consumers' demands during extremely low flows, during such flows it may become difficult to carry out its operations due to drought. A barrier in the form of dam is therefore, constructed across the river, so as to form a pool of water on the upstream side of the dam. This pool or artificial lake on the upstream side of the dam known as dam reservoir or an impounding reservoir or river reservoir. The quality of this water is not much different from that of a natural lake. The water stored in this reservoir can be used for supplying water to the society for meeting its different needs for almost all through the year especially during the dry season.

### 2.9.3 Sub-surface source

To understand how groundwater functions, think of it as a series of lakes below the surface of the earth. The earth is built up of different layers-sand, gravel, clay, rock etc. The layers of rock or compact clay cannot store water as they are solid rather than porous. The layers of coarse sand and gravel, on the other hand, contain many pores and cracks, which allow rainfall to enter the soil and percolate from the surface. These porous layers filled with water are called aquifers. Ground water flows, in most cases slowly to the lower parts.

The availability of groundwater is less irregular than that of small rivers. Aquifer at shallow depths, however, is likely to be very thin with a limited storage capacity for ground water. One may start pumping the water during the rainy season, after the aquifer has been replenished, and find a dry well after a few months. The total water availability from shallow ground water is determined by the number of wells and the capacity of these wells or the capacity of the pumps installed. When a borehole is drilled to access deep groundwater the engineer always carries out pump tests to measure the capacity of the well. The volume of water stored in deeper aquifers is quite large, so that the monthly limitation of water availability is the capacity of the well and the pump to be installed. Excessive exploitation of the groundwater by many users, however, will bring about decline in the water table. To ensure a stable supply of groundwater, the rate of use should not exceed the rate of recharge.

## 2.10 WATER DEMAND

The increasing water demand linked to population growth and harsh climatic conditions not withstanding, obtaining safe water for drinking and other domestic activities has remained a prerogative to the privileged few. Water is required by a community for fulfilling its several needs and for surviving not only human life but also animal and plant life moreover, the water requires for fulfilling their needs, should not only be in sufficient quantity, but should be of good quality, so as not to cause any harmful effects on such lives. Prevalence of water-borne disease (typhoid fever etc) has been on the increase, especially among the children and the elderly.

### 2.10.1 Water demand for municipal and industrial supplies-:

Water is required by the public for various uses, such as domestic use, industries and commercial use, public use, fire-fighting etc. To satisfy all these uses, water is supplied to the public, through properly designed and well planned public water supply scheme.

### 2.10.2 Domestic water demand

This includes the water required in private buildings for drinking, cooking, bathing, lawn-sprinkling, gardening, sanitary toiletry uses. The amount of domestic water consumption per person shall vary according to the living conditions of the consumers. According to. Garg (2007), "the average water required per person in a developed country is as high as 340litres/day/person".

This is because more water is consumed in rich effluent living in air cooling, air-conditioning, automatic household appliances, etc. The total domestic consumption generally amounts to 55 to 60% of the total water consumed for municipal and industrial purposes.

### 2.10.3 Industrial water demand

The industrial water demand represents the water demand for industries. According to Garg (2007), "the ordinary precipitate consumption on account of industrial needs of a city is generally taken as 450 litres/person/day which may suffice only to met water demand of small scattered industries, without catering for larger industries". Separate provision will have to be made to meet the water demand of such specific industries. Their requirements will have to approximate on the quality of water required per unit of production. The potential for expansion should also be investigated, so that the availability of water supply may attract such industries and add to economic prosperity of the community. Some of the industries may develop their own water supplies and may place a very little or virtually no demand on the public supplies.

### 2.10.4 Water demand for irrigation

Every crop requires certain quantity of water after a certain fixed interval. If the natural rain is sufficient and timely so as to satisfy both these requirements, no irrigation water is required for raising crop. In England, for example the natural rainfall satisfies both these requirements for practically all crops and therefore, irrigation is not significantly needed. But in tropical countries like Nigeria, the natural rainfall is either insufficient or rain does not fall after fixed intervals, artificially from some outside sources by irrigation methods.

### 2.10.5 Water demand for navigation and recreation

Navigation is another important use of water. Which provides us a cheap means of transportation without any consumption of water. In modern days, in addition to providing transport of heavy cargo trucks which cannot be lifted and packed on wagon trains. It provides us recreational boating, although no water is consumed in this use of water, however, sufficient quantity of water must remain available throughout the year, so as to enable ships boats etc to safely float over it with minimum drag.

### 2.10.6 Water for health

Water and health are closely related, and by drinking enough water the body stays healthy. Water benefits are extraordinary. Washing hands after defecation and before preparing food is of particular importance in reducing disease transmission, but without abundant water in or near homes hygiene becomes difficult or impossible. The lack of water supply and sanitation is the primary reason why diseases transmitted via feaces are so common in developing countries.

Water is not only a vital environmental factor to all forms of life, but it has also a great role to play in socio-economic development of human populations. It was in the recognition of this that the $34^{th}$ World Health Assembly in 1981 made a basic element of "Primary Health Care" which is the key to the attainment of health for all citizens of the world.

## 2. 11 DESIGN PERIOD AND POPULATION GROWTH

A water supply scheme includes huge and costly structures (such as dams, Weir, reservoir, treatment works etc.) which cannot be replaced or increased in their capacities easily and conveniently. In order to avoid future expansions, the various components of a water supply scheme are purposely made larger, so as to satisfy the community needs for a reasonable number of years to come. This future period or the number of years for which a provision is made in designing the capacities of the various components of the water supply scheme is known as design period.

In order, to predict the future population as correctly as possible, it is necessary to know the factors affecting population growth. There are three main factors responsible for changes in population. They are:

i. Births;

ii. Deaths; and

iii. Migrations,

All these factors are influenced by social and economic factors and conditions prevailing in the various communities. For example, birth rates may decrease due to excessive family planning practices and legalized abortions spread of education and development of extra recreational facilities for the people also tends to reduce birth rates. The death rates may decrease with developments and advancement of medical facilities thereby controlling infact mortality rates and adult rates due to control of infections and other diseases.

The migrations are dependent upon the industrialization and commercialization of the particular cities or towns where people generally migrate from villages to cities and towns where more opportunities for earning livelihood are available. The migration rates therefore, tend to increase sharply with the development of industries and commerce in the city of in the nearby areas. The migration rates may decrease when immigration restrictions are imposed. Besides these three main factors, like wars, natural havocs and disasters may also bring about sharp reductions in the populations.

All these varying influences make the task of predicting future population very difficult and highly inexact, it is very difficult and time consuming especially for the engineers, to evaluate all these economic and social factors. It is therefore, more common to rely upon mathematical formulas and graphical solutions based upon previous population records.

# CHAPTER THREE

# METHODOLOGY

Water samples were collected at the upstream, mainstream and downstream locations in Otamiri river, Nworie river and borehole locations. This water samples were analyzed of the following parameters; pH, temperature, colour, total dissolved solid, conductivity, magnesium, hardness, total hardness, nitrate, nitrite, phosphate, sulphate, free chlorine, iron, sodium, turbidity and ammonia.

The results were compared with World Health Organization (WHO) standards of permissible limits. A further check on the removal efficiency of the treatment process was done.

## 3.1 DETERMINATION OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER

Water samples were collected with plastic containers, 0.3m depth from the source (See Appendix 1)

### 3.1.1 pH and Temperature

**Equipments:** Suntex pH and Temperature metre.

**Reagents:** Buffer solutions, 7.00 pH for alkalinity and 4.00 pH for acidity, De-ionized water.

**Procedure:** First calibrate the pH probe using the buffer solution. After calibration, rinse the probe using de-ionized water.

Pour 50ml of the sample into a beaker and insert the probe knob. Switch on the meter and read the value for the pH when the reading becomes stable. For temperature, press the mode button of the meter twice and then read the temperature of the sample in $^0$C.

### 3.1.2 Total Dissolved Solids (TDS) and Conductivity

**Equipments:** TDS/Conductivity meter.

**Procedure:** Rinse the probe with de-ionized water. Pour about 50ml of the sample into a beaker and insert the TDS probe. Press the TDS button and then read the value in micro Siemens (µs/cm). for Conductivity, press the TDS button and read the value (mg/l).

### 3.1.3 Turbidity

**Equipments**: DR2010 data logging spectrophometer.

**Procedure**: Pour 25mls of filtered de-ionized water into a 25ml sample cell bottle. Pour another 25ml of the filtered sample into the sample cell bottle and switch on the spectrophometer. Get the programme number 750, and the wavelength 869nm. Then press the enter button, using the filtered de-ionized water as blank for zeroing. After zeroing, place the sample into the spectrophometer shield and press the READ button. The value is then displaced in Nephometric Turbidity unit (NTU).

### 3.1.4 Colour

**Equipment**: Spectrophometer

**Procedure**: Pour 25mls of filtered de-ionized water into a 25ml sample cell bottle. Pour another 25ml of the filtered sample into the sample cell bottle and switch on the spectrophometer. Get the programme number 120, and the wavelength 455nm. Then press the enter button, using the filtered de-ionized water as blank for zeroing. After zeroing, place the sample into the spectrophometer shield and press the READ button. The value is then displaced in Platinum Cobalt Unit (PtCO).

### 3.1.5 Total Suspended Solids (TSS)

**Equipment**: Spectrophometer

**Procedure**: Pour 25mls of filtered de-ionized water into a 25ml sample cell bottle. Pour another 25ml of the filtered sample into the sample cell bottle and shake the sample vigorously. Switch on the spectrophometer. Get the programme number 630, and the wavelength 810nm. Then press the enter button, using the filtered de-ionized water as blank for zeroing. After zeroing, place the sample into the spectrophometer shield and press the READ button. The value is then displaced in mg/l.

### 3.1.6 Iron

**Equipment**: Spectrophometer

**Reagent:** Ferrover Reagent Powder Pillow.

**Procedure**: Switch on the Spectrophometer. Enter the programme number 265, wavelength 510nm. Get two sample cell bottles of 10mls. Shake the sample vigorously and with pipette, add 10mls sample in each of the sample cell bottles. Keep one as the blank, and in the other add one Ferrover reagent powder pillow, swirl to mix thoroughly. Press shift-time and time for 3 minutes. After zeroing with the blank, within 3 minutes, put ion the treated sample into the shield light of the spectrophometer and close the lid. Press READ and read out the value digitally in mg/l

### 3.1.7 Copper

**Equipment:** Spectophometer

**Reagent:** Cuver 1 reagent powder pillow

**Procedure**: Switch on the Spectrophometer. Enter the programme number 135, wavelength 560nm. Get two sample cell bottles of 10mls. Shake the sample vigorously and with pipette, add 10mls sample in each of the sample cell bottles. Keep one as the blank, and in the other add one Cuver 1 Reagent Powder Pillow, swirl to mix thoroughly. Press shift-time and time for 2 minutes. After zeroing with the blank, within 2 minutes, put ion the treated sample into the shield light of the spectrophometer and close the lid. Press READ and read out the value digitally in mg/l

### 3.1.8 Nitrate

**Equipment:** Hi83200 Multiparameter Bench Photometer

**Method:** Cadmium Reduction Method

**Reagent:** Hi93728-0 reagent powder pillow, De-ionized water.

**Procedure**: Switch on the photometer. Select Nitrate method using the pipette, fill the Cuvette with 6ml of sample, up to half of its height and place the cap. Press the zero button, when the meter is zero, remove the Cuvette and add one content of the powder pillow replace the cap and shake vigorously for 10 seconds. Reinsert the Cuvette into the instrument and press Time then select read button to display the result in mg/l.

### 3.1.9 Ammonia

**Equipment:** Hi83200 Multiparameter Bench Photometer

**Method:** Nessler Method

**Reagent:** Hi93715A-0 reagent powder pillow, De-ionized water.

**Procedure**: Switch on the photometer. Select Ammonia method using the pipette, fill the Cuvette with 6ml of sample, up to half of its height and place the cap. Press the zero button, when the meter is zero, remove the Cuvette and add one content of the powder pillow replace the cap and shake vigorously for 10 seconds. Reinsert the Cuvette into the instrument and press Time then select read button to display the result in mg/l.

### 3.1.10 Free Chlorine

**Equipment:** Hi83200 Multiparameter Bench Photometer

**Method:** EPA DPD Method

**Reagent:** Hi93701-0 reagent powder pillow, De-ionized water.

**Procedure**: Switch on the photometer. Select Free Chlorine method using the pipette, fill the Cuvette with 10ml of un-reacted sample, and replace the cap, and close the lid. Press the zero button, when the meter is zero, remove the Cuvette and add one content of the powder pillow replace the cap and shake vigorously for 10 seconds. Reinsert the Cuvette into the instrument and press Time then select read button to display the result in mg/l.

### 3.1.11 Phosphorous

**Equipment:** Hi83200 Multiparameter Bench Photometer

**Method:** Amino Acid Method

**Reagent:** Hi93706B-03 Amino acid powder, De-ionized water.

**Procedure**: Switch on the photometer. Select Phosphorous method using the pipette, fill the Cuvette with 10ml of un-reacted sample, and replace the cap, and close the lid. Press the zero button, when the meter is zero, remove the Cuvette and add one content of the

Amino acid powder replace the cap and shake vigorously for 10 seconds. Reinsert the Cuvette into the instrument and press Time then select read button to display the result in mg/l.

### 3.1.12 Magnesium Hardness

**Equipment:** Hi83200 Multiparameter Bench Photometer

**Method:** Calorimeter Method

**Reagent:** Hi93719-01 reagents

**Procedure**: Switch on the photometer. Select method. Rinse a graduated beaker several times with un-reacted sample then fill it to 50ml. add 0.5ml of the reagent indicator solution then swirl to mix. Using the pipette, fill the Cuvette with 10ml of un-reacted sample, and replace the cap, and close the lid. Press the zero button to zero the meter. Insert the sample into the instrument, close the lid, press READ, to start reading and the result is displayed in mg/l.

### 3.1.13 Sulphate ($SO_4^{2-}$)

Apparatus used include magnetic stirrer, ultra-violent spectrophotometer, stop watch, measuring spoon and volumetric flask. The turbid meter method was used to determine the parameter. Here, 100ml of sample was measured into a 250ml flask and 20ml buffer solution was added and mixed with the magnetic stirrer going on a spoon full of barium chloride crystals was added and the stirring was timed with the stopwatch for about 60 seconds. At the end of the stirring, the solution was poured into the absorption cell of the ultra violent spectrophometer to measure turbidity for about 5 minutes.

The sulphate concentration was estimated by comparing the turbidity reading with a calibrated curved prepared by carrying sulphate standard and through the entire procedure.

# CHAPTER FOUR

# RESULTS AND DISCUSSION

## 4.1 RESULTS

The results of the physciochemical parameters of the treated, raw water from Otamiri river, Nworie river and selected borehole water are as shown in Tables 4.1 to 4.16, compared with World Health Organization (WHO) water quality standards.

**Table 4.1 Major ions in water sample 1**

| S/No | Major Ions | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Total iron ($Fe^{3+}$) (mg/l) | 0.40 | 0.26 | 0.36 | 35% |
| 2 | Sodium ($Na^{+}$)(mg/l) | 0.95 | 0.77 | 200.00 | 18% |
| 3 | Sulphate ($S0_4^{2-}$) (mg/l) | 1.10 | 1.00 | 42 | 10% |
| 4 | Chloride ($Cl^{-}$) (mg/l) | 178.69 | 138.08 | 600 | 29.41% |
| 5 | Sulphide ($S0_4^{-}$) (mg/l) | 0.92 | 0.83 | 42 | 10.84% |

Average removal efficiency = 20.7%

**Table 4.2 Physciochemical Parameters of Water sample 1**

| S/No | Physical Parameters | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Appearance | Clear | Clear | Clear | |
| 2 | Colour | Slightly brown | Colourless | Colourless | |
| 3 | Odour | Inoffensive | Inoffensive | inoffensive | |
| 4 | Temperature ($^0$C) | 27.0 | 26.57 | 27.0-28.0 | |
| 5 | pH | 7.57 | 5.34 | 6.5-8.5 | 41.76% |
| 6 | Residual chloride (mg/l) | 2.20 | 2.00 | 250 | 9.09% |
| 7 | Hardness (mg/l) | 22.50 | 13.50 | 500 | 66.67% |
| 8 | Total dissolved solid (mg/l) | 23.40 | 18.40 | 100 | 29.17% |
| 9 | Ammoia (mg/l) | 0.65 | 0.55 | 0.2-0.5 | 15.38% |
| 10 | Turbidity (NTU) | 6.20 | 0.65 | 5.0 | 89.5% |

Average removal efficiency = 42.0%

**Table 4.3 Nutrient Content of Water sample 1**

| S/No | Nutrients | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Nitrate (mg/l) | 0.96 | 0.82 | 10.00 | 14.58% |
| 2 | Nitrite (mg/l) | 1.30 | 1.10 | 3.00 | 15.38% |
| 3 | Phosphate (mg/l) | 1.20 | 0.91 | 3.50 | 24.17% |

Average removal efficiency = 18.0%

**Table 4.4 Bacteriological Quality of Water sample 1**

| S/No | Nutrients | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Total Coliform (mpn/ml) | 30.00 | 2.00 | 20 | 93.33% |
| 2 | BOD (mg/l) | 0.60 | 0.40 | 0 | 33.30% |
| 3 | COD (mg/l) | 1.20 | 0.80 | 0 | 33.47% |

Average removal efficiency = 53.4%

**Table 4.5 Major ions in water sample 2**

| S/N | Major ions | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Total iron (mg/l) | 0.25 | 0.04 | 0.36 | 84.0% |
| 2 | Sodium (mg/l) | 70.20 | 50.1 | 200 | 28.63% |
| 3 | Sulphate (mg/l) | 2.0 | 1.00 | 42 | 50.0% |
| 4 | Chloride (mg/l) | 185.37 | 142.0 | 600 | 30.54% |
| 5 | Sulphide (mg/l) | 3.70 | 2.30 | 45 | 37.84% |

Average removal efficiency = 46.0%

**Table 4.6 Physicochemical parameters of water sample 2**

| S/N | Physical parameters | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Appearance | Clear | Clear | Clear | |
| 2 | Colour | Slightly brownish | Colourless | Colourless | |
| 3 | Odour | Inoffensive | Inoffensive | Inoffensive | |
| 4 | Temperature ($^0$c) | 29.0 | 27.0 | 27.0-28.0 | |
| 5 | pH | 7.53 | 5.21 | 6.5-8.5 | 44.5% |
| 6 | Turbidity (NTU) | 4.97 | 0.58 | 5.0 | 88.33% |
| 7 | Residual Chloride (mg/l) | 0.90 | 0.75 | 250 | 25.0% |
| 8 | Total hardness (mg/l) | 11.30 | 10.10 | 500 | 10.61% |
| 9 | Ammonia (mg/l) | 0.58 | 0.49 | 0.2-0.5 | 15.52% |

Average removal efficiency = 36.8%

**Table 4.7 Nutrient content of water sample 2**

| S/N | Nutrient | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Nitrite (mg/l) | 0.27 | 0.15 | 1.0 | 44.44% |
| 2 | Nitrate (mg/l) | 1.28 | 1.00 | 10.0 | 21.88% |
| 3 | Phosphate (mg/l) | 0.31 | 0.12 | 3.50 | 61.29% |

Average removal efficiency = 42.6%

**Table 4.8 Bacteriological quality of water sample 2**

| S/N | Nutrients | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Total Coli Form (mpn/ml) | 1.0 | Nil | 0 | Nil |
| 2 | BOD (mg/l) | 0.2 | Nil | 0 | Nil |
| 3 | COD (mg/l) | 0.5 | Nil | 0 | Nil |

**Table 4.9 Major ions in water sample 3**

| S/N | Nutrients | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Total iron (mg/l) | 0.24 | 0.04 | 0.36 | 83.33% |
| 2 | Sodium (mg/l) | 185.4 | 70.0 | 200.00 | 18.03% |
| 3 | Sulphate (mg/l) | 3.0 | 2.0 | 42 | 33.3% |
| 4 | Chloride (mg/l) | 190.70 | 150.30 | 600 | 21.19% |
| 5 | Sulphide (mg/l) | 3.5 | 1.5 | 45 | 57.14% |

Average removal efficiency = 42.6%

**Table 4.10 Physicochemical parameters of water sample 3**

| S/N | Physical parameters | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Appearance | Clear | Clear | Clear | |
| 2 | Colour | Slightly brownish | Colourless | Colourless | |
| 3 | Odour | Inoffensive | Inoffensive | Inoffensive | |
| 4 | Temperature ($^{0}$c) | 28.5 | 27.0 | 27.0-28.0 | |
| 5 | pH | 7.58 | 5.32 | 6.5-8.5 | 42.48% |
| 6 | Turbidity (NTU) | 5.20 | 0.59 | 5.0 | 88.65% |
| 7 | Residual Chloride(mg/l) | 1.10 | 0.70 | 250 | 36.37% |
| 8 | Total hardness (mg/l) | 11.90 | 10.83 | 500 | 13.45% |
| 9 | Ammonia (mg/l) | 0.55 | 0.39 | 0.2-0.5 | 29.09% |

Average removal efficiency = 42.0%

**Table 4.11 Nutrient content of water sample 3**

| S/N | Nutrient | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Nitrite (mg/l) | 0.27 | 0.17 | 3.0 | 37.03% |
| 2 | Nitrate (mg/l) | 1.30 | 0.90 | 10 | 30.77% |
| 3 | Phosphate (mg/l) | 0.30 | 0.20 | 3.50 | 33.33% |

Average removal efficiency = 33.7%

**Table 4.12 Bacteriological quality of water sample 3**

| S/N | Nutrients | Raw Otamiri River water | Treated Owerri Municipal water | WHO Standard | Removal Efficiency |
|---|---|---|---|---|---|
| 1 | Total Coliform (mpn/ml) | 0.9 | Nil | 0 | Nil |
| 2 | BOD (mg/l) | 0.2 | Nil | 0 | Nil |
| 3 | COD (mg/l) | 0.15 | Nil | 0 | Nil |

**Table 4.13 Physical Parameters of Water Sample 4**

| S/N | Parameters | Raw Water, Ibada (Nworie River) | Borehole Water Umuoba, Uratta | WHO Standard |
|---|---|---|---|---|
| 1 | Colour (Hazen unit) | 8 | 3.24 | 5.0 – 15 |
| 2 | Temperature ($^0$C) | 28.6 | 30 | 27-28 |
| 3 | Turbidity (NTU) | 28 | 5.9 | 5.0 |
| 4 | Copper (mg/l) | 2.15 | Nil | Nil |
| 5 | Iron (mg/l) | 0.53 | 0.01 | 0.36 |
| 6 | Nitrate (mg/l) | 25 | 1.86 | 10.0 |
| 7 | Nitrite (mg/l) | 8.3 | Nil | 1.0 |
| 8 | TDS (mg/l) | 22.1 | 16.3 | 1000 |
| 9 | pH | 6.8 | 5.85 | 6.5-8.5 |
| 10 | Hardness (mg/l) | 1.2 | 2.8 | 500 |
| 11 | Conductivity (μs/cm) | 34 | 33 | 1000 |
| 12 | Free Chlorine(mg/l) | 0.84 | 0.00 | 200 |

**Table 4.14 Physical Parameters of Water Sample 5**

| S/N | Parameters | Raw Water F.M.C (Nworie River) | Borehole Water Fire Service | WHO Standard |
|---|---|---|---|---|
| 1 | Colour (Hazen unit) | 7 | 3.4 | 5.0 – 15 |
| 2 | Temperature ($^0$C) | 28.8 | 29 | 27-28 |
| 3 | Turbidity (NTU) | 61 | 5.8 | 5.0 |
| 4 | Copper (mg/l) | 2.73 | Nil | Nil |
| 5 | Iron (mg/l) | 0.9 | 0.02 | 0.36 |
| 6 | Nitrate (mg/l) | 20 | 2.0 | 10.0 |
| 7 | Nitrite (mg/l) | 2.5 | Nil | 1.0 |
| 8 | TDS (mg/l) | 44.8 | 18.1 | 100 |
| 9 | pH | 7.5 | 5.9 | 6.5-8.5 |
| 10 | Hardness (mg/l) | 2.4 | 3.0 | 500 |
| 11 | Conductivity (µs/cm) | 69 | 30 | 600 |
| 12 | Free Chlorine(mg/l) | 1.02 | 0.01 | 250 |

**Table 4.15 Physical Parameters of Water Sample 6**

| S/N | Parameters | Raw Water, Old Nekede (Nworie River) | Borehole Water Egbu | WHO Standard |
|---|---|---|---|---|
| 1 | Colour (Hazen unit) | 9 | 3.3 | 5.0 – 15 |
| 2 | Temperature ($^0$C) | 27.5 | 29.5 | 27-28 |
| 3 | Turbidity (NTU) | 98 | 5.75 | 5.0 |
| 4 | Copper (mg/l) | 2.28 | Nil | Nil |
| 5 | Iron (mg/l) | 1.20 | 0.03 | 0.36 |
| 6 | Nitrate (mg/l) | 7.2 | 3.0 | 10.0 |
| 7 | Nitrite (mg/l) | 1.0 | Nil | 1.0 |
| 8 | TDS (mg/l) | 71.5 | 17.0 | 100 |
| 9 | pH | 7.3 | 5.7 | 6.5-8.5 |
| 10 | Hardness (mg/l) | 1.56 | 2.9 | 500 |
| 11 | Conductivity (µs/cm) | 110 | 31 | 600 |
| 12 | Free Chlorine(mg/l) | 1.16 | 0.00 | 250 |

**Table 4.16 Average of samples from Otamiri River, Nworie River, borehole water and treated water and compares with World Health Organization standard (WHO)**

| **Parameter** | **Average Otamiri River (1)** | **Average Nworie River (2)** | **Average borehole water (3)** | **Average Treated Water (4)** | **WHO standard** | **Remarks** |
|---|---|---|---|---|---|---|
| Total Iron (mg/l) | 0.29 | 0.88 | 0.02 | 0.31 | 0.36 | (1), (3),(4) pass, (2) fail |
| Turbidity (NTU) | 5.46 | 63.33 | 5.8 | 0.64 | 5.0 | (1), (2) (3) fail, (4) pass |
| TDS (mg/l) | 22.23 | 46.13 | 17.13 | 18.0 | 100 | Satisfactory |
| pH | 7.56 | 7.20 | 5.82 | 5.29 | 6.5-8.5 | Pass |
| Temperature ($^0$C) | 28 | 28.3 | 29.5 | 26.8 | 27-28 | (1) & (4) pass, (2) & (3) fail |
| Hardness (mg/l) | 12.23 | 1.72 | 29.0 | 14.48 | 500 | Pass |
| Nitrate (mg/l) | 1.18 | 17.4 | 2.29 | 0.91 | 10 | (1), (3) & (4) pass, (2) fail |
| Nitrite (mg/l) | 0.61 | 3.9 | 0.00 | 0.47 | 3 | (1), (3) & (4) pass, (2) fail |
| Free Chlorine (mg/l) | 1.40 | 1.00 | 0.00 | 1.15 | 250 | Satisfactory |
| Sulphate (mg/l) | 2.03 | 4.17 | 14.73 | 1.33 | 42 | Pass |

## 4.2 DISCUSSION

From tables 4.2, 4.4 and 4.6, it could be observed that turbidity, total coliform and ammonia contents were above the recommended World Health Organization (WHO) standard, while other parameters of Otamiri River as a source of drinking water were adequately handled by the Owerri Municipal water treatment units.

The removal efficiencies of the units at 89.5% (turbidity), 93.3% (total coliform) and 84.0% (total iron) are very satisfactory.

From tables 4.13, 4.14 and 4.15, it could be observed that the turbidity, total iron, nitrate and nitrite of Nworie River are all above the recommended WHO standard. This means that treatment of more unacceptable parameters is required in Nworie River and that of Otamiri River.

Tables 4.13, 4.14 and 4.15, showed that the selected borehole samples is very acceptable as a source of drinking water based on WHO standard except their temperature range.

Table 4.16 presented a comparison of all the possible sources of drinking water in Owerri Municipal system and how adequate or acceptable each source is to the WHO standard.

The colour of the raw water sample was slightly brownish, while that of the borehole water was colourless which implies that the treated water is not polluted with respect to colour. The appearance of the treated water and its odour were within acceptable quality when compared with the WHO guideline for drinking water quality.

According to Edet (2002), “the colour of any water sample depends on the amount and type of soluble ions (especially cations) and treatment method adopted that may likely present the colour of the water within acceptable ranges is coagulation”. This process can coagulate iron and remove it in form of collids as shown by Equations (4.1) and (4.2):

$Al^{3+}$ + (collids)$^{n}$ $\rightleftharpoons$ AL (collid)$^{3n}$............................ (4.1)

$F^{3+}$ + (collids)$^{n}$ $\rightleftharpoons$ Fe (collid)$^{3n}$............................ (4.2)

The odour of the most water bodies is mostly attributed to the amount of organic matter present in the water for example; amount is a product of decomposition of organic matter. The acceptable colour presented by the treated water shows that treatment measures adopted by Imo state water co-operation is effective in giving the water, a good colour.

The iron content of the treated water sample was found to be within the permissible limit of drinking water quality. Therefore the water sample is not polluted with respect to iron (see Figure 4.1).

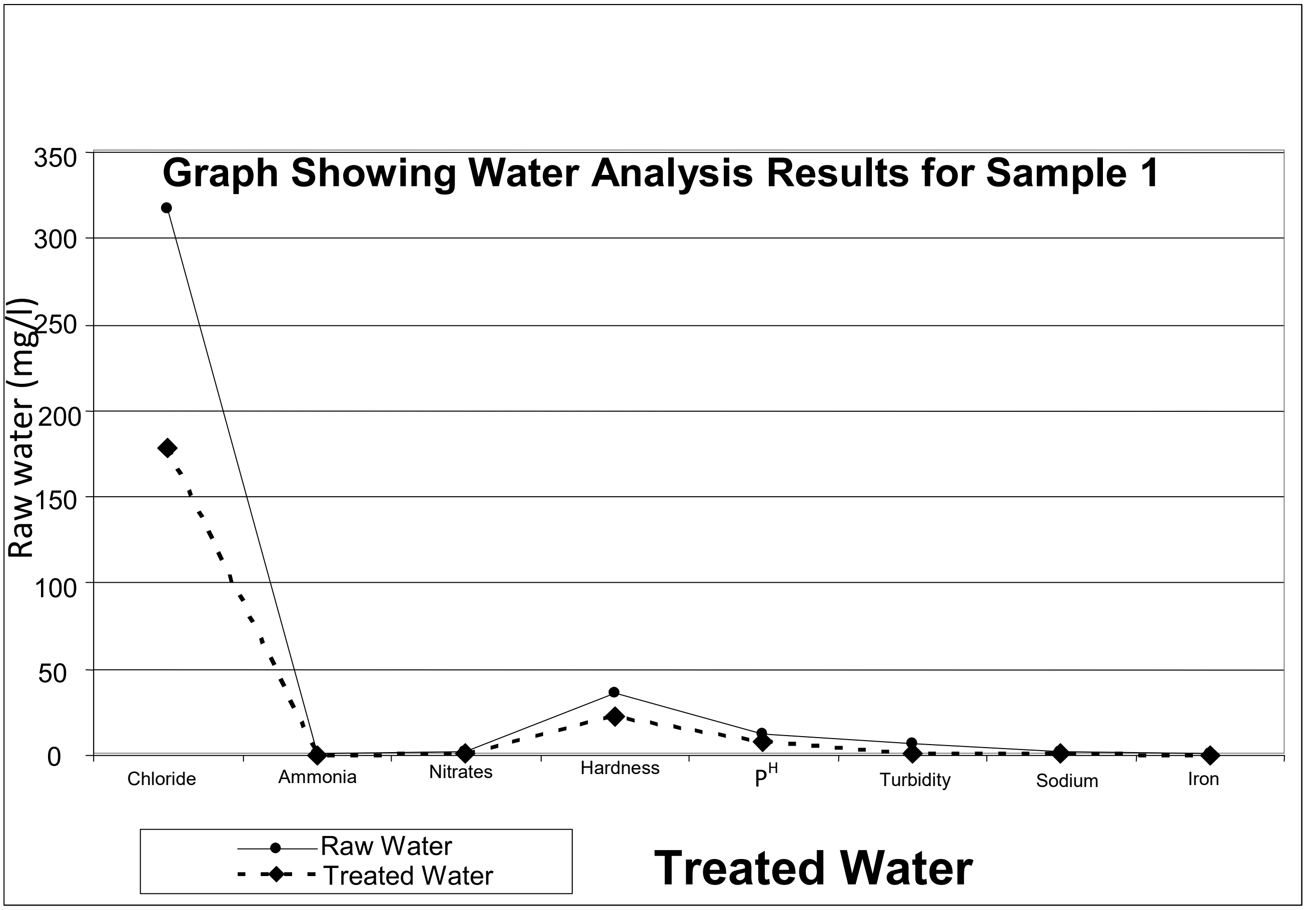


Fig. 4.1 Graph showing water analysis result of sample 1

The turbidity of the treated water sample was within the permissible limit. The mean chloride content of the treated water sample did not exceed the maximum tolerance limit (600mg/l) required for drinking water (see Figure 4.2).

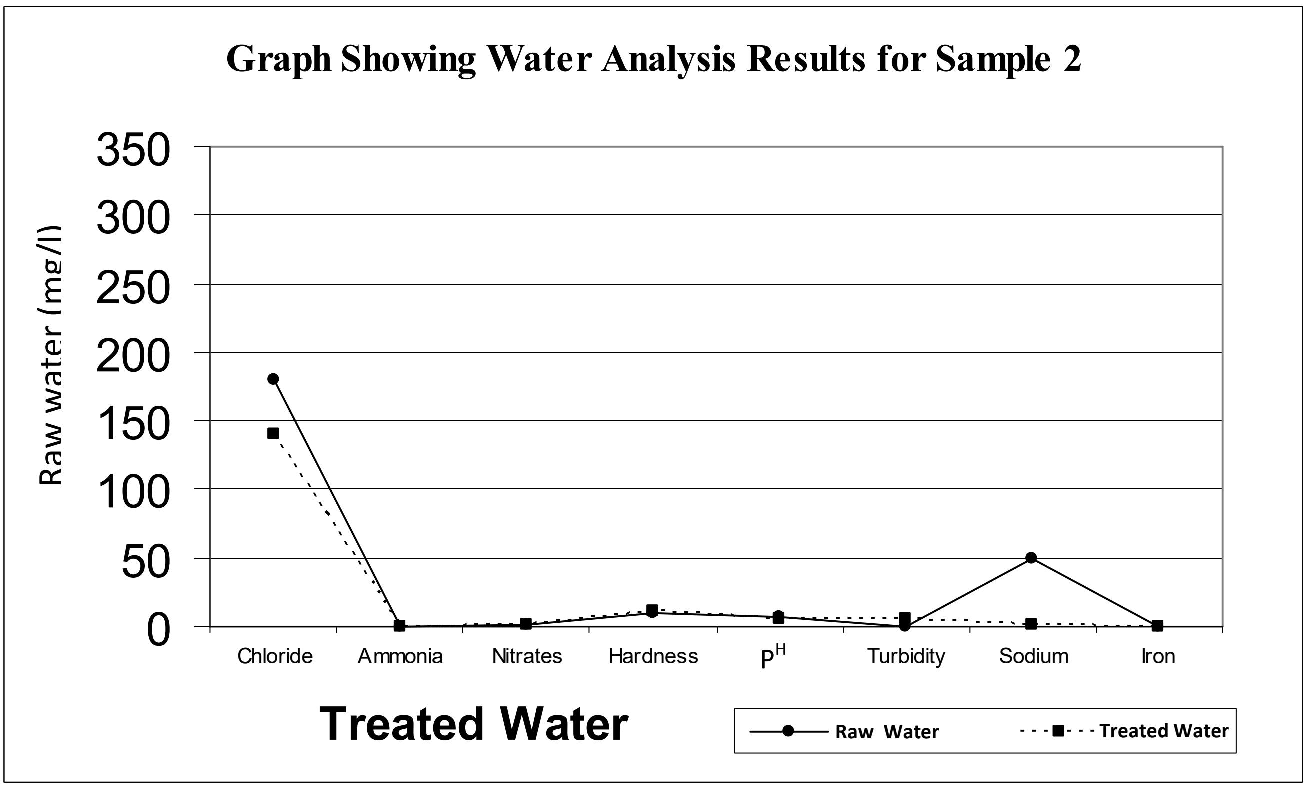


Fig. 4.2 Graph showing water analysis result of sample 2

In the analyzed water sample the concentration of nitrite and nitrate were within the permissible limit. The reduced concentration of nitrate might have been due to the removal of nitrate salt during the filtration process. According to FEPA (1991) "the major sources of nitrate pollution are domestic waste, industrial waste, sewage, sluge etc" the treatment method adopted by Owerri water co-operation is therefore effective in removing nitrate contaminants.

The concentration of the total dissolved solids (TDs), chloride, sodium, sulphide and turbidity of the water were below the permissible and desirable limit for domestic water supply, implying that the treatment process adopted by the co-operation is effective in bringing down the concentration of the parameters (see Figure 4.3).

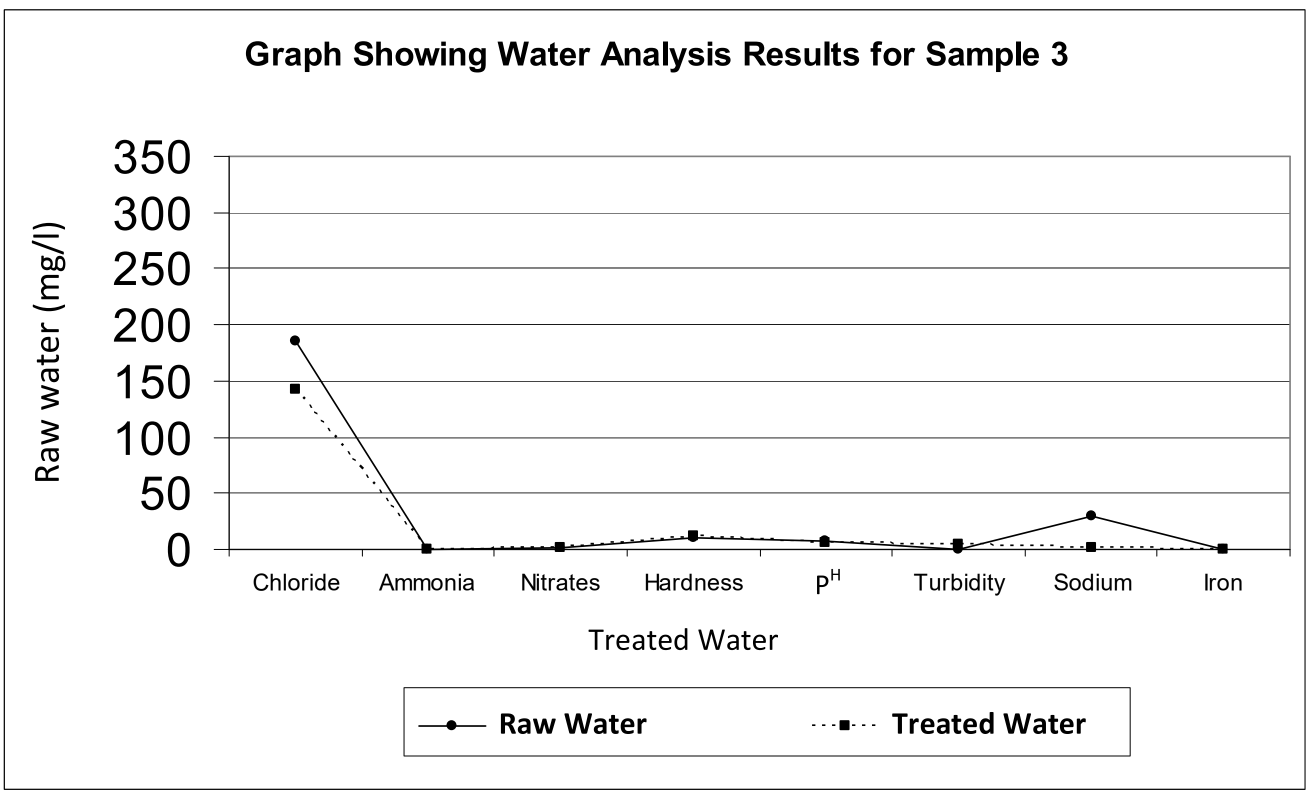


Fig. 4.3 Graph showing water analysis result of sample 3

The concentration of ammonia in the treated water samples were found to be within the permissible limits for drinking water. The measured pH of the treated water sample within the limit.

The iron content of the treated water sample was found to be within the permissible limit of drinking water quality. Therefore the water sample is not polluted with respect to iron (see Figure 4.4).

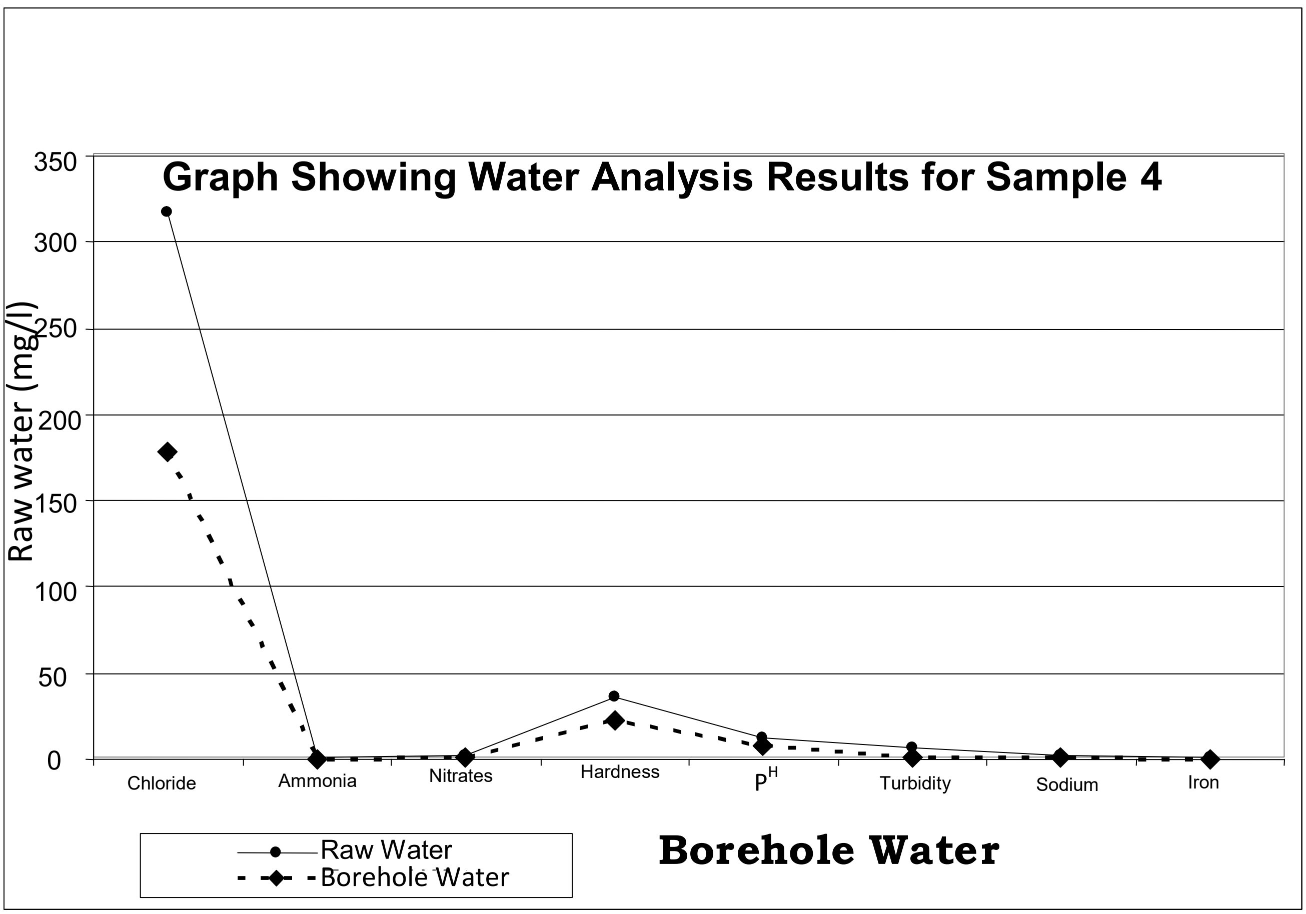


Fig. 4.4 Graph showing water analysis result of sample 4

The concentration of the total dissolved solids (TDs), chloride, sodium, sulphide and turbidity of the water were below the permissible and desirable limit for domestic water supply, implying that the treatment process is effective in bringing down the concentration of the parameters (see Figure 4.5).

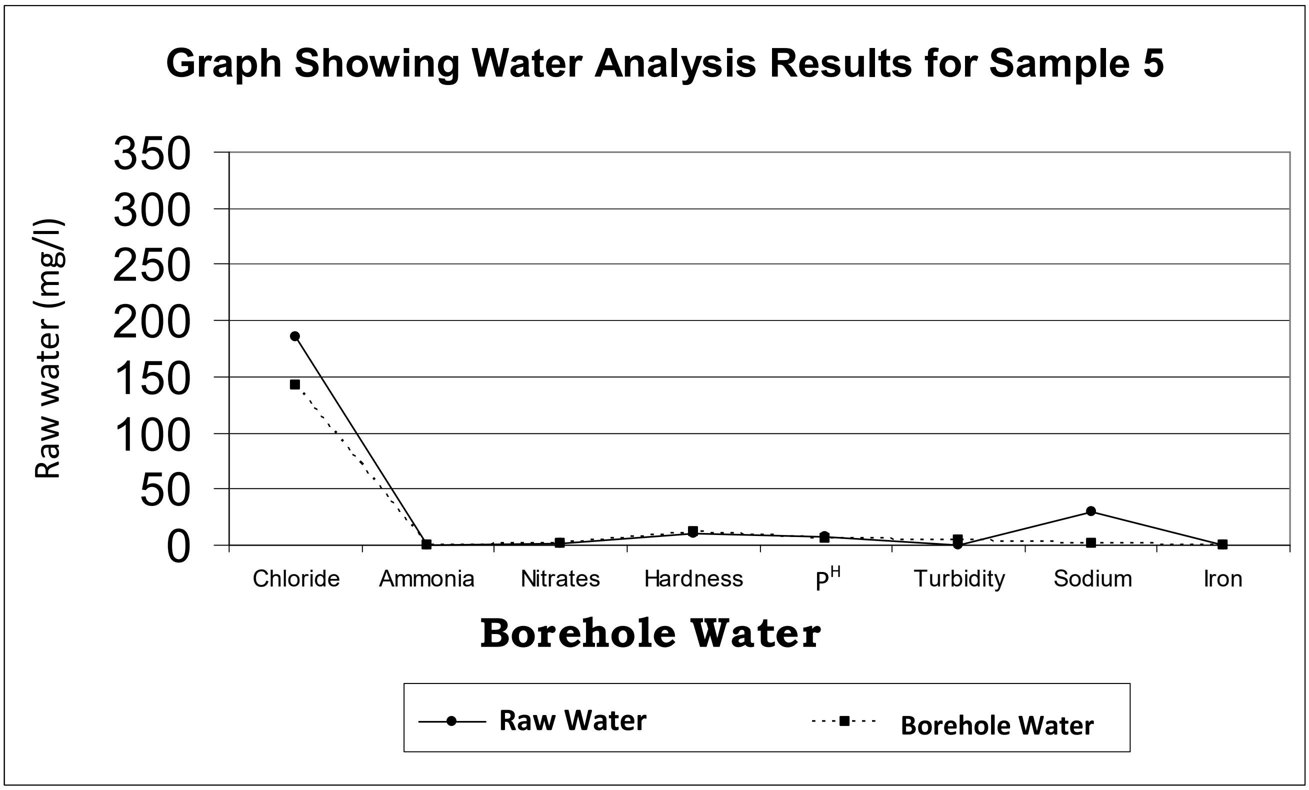


Fig. 4.5 Graph showing water analysis result of sample 5

The turbidity of the borehole water sample was within the permissible limit. The mean chloride content of the borehole water sample did not exceed the maximum tolerance limit (600mg/l) required for drinking water (see Figure 4.6).

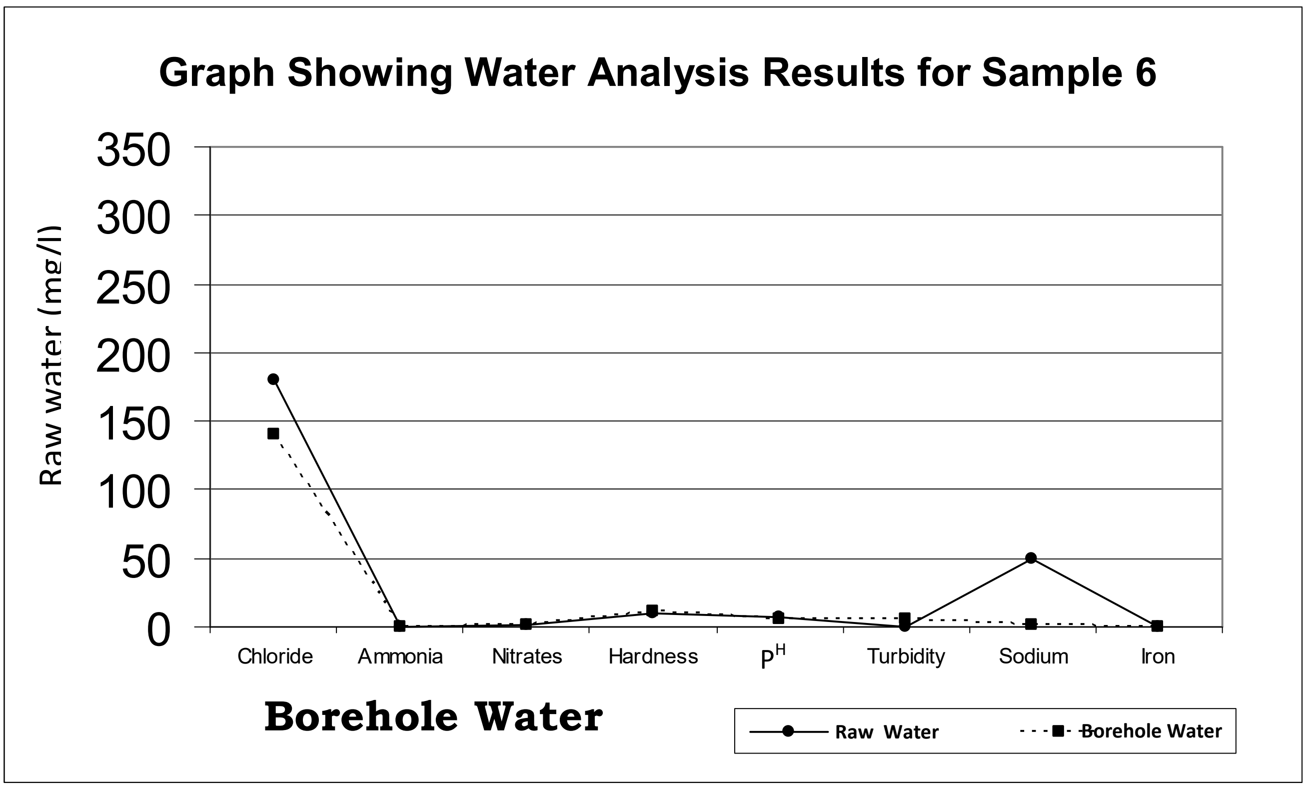


Fig. 4.6 Graph showing water analysis result of sample 6

In the analyzed water sample the concentration of nitrite and nitrate were within the permissible limit. The reduced concentration of nitrate might have been due to the removal of nitrate salt during the filtration process. According to FEPA (1991) "the major sources of nitrate pollution are domestic waste, industrial waste, sewage, sludge etc" the treatment method is therefore effective in removing nitrate contaminants.

### 4.2.3 Treatment Efficiency

Treatment efficiency of any water process unit can be evaluated using Equation (4.1);

$$\text{Treatment efficiency} = \left(\frac{Raw\ water - Treated\ water}{Raw\ water}\right)100\% \quad \ldots\ldots\ldots\ldots \ (4.1)$$

Average removal efficiency of aeration process of sample 1 – 3

= (15.4 + 15.5 + 29.1)%/3 = 20%

Average removal efficiency of sedimentation process of sample 1 – 3

= (18.0 + 28.0 + 8.03)%/3 = 21.3%

Average removal efficiency of filtration process of sample 1 – 3

= (9.1 + 25.0 + 36.4)%/3 = 23.5%

Therefore, the average removal efficiency of the three treatment process units is:

= (20 + 21.3 + 23.5)%/3 = 21.6%

Average distribution of sample 1-3

$$= \quad (42 + 36.8 + 42.1)\%/3 \quad = \quad 40.3\%$$

In effect, the sedimentation, filtration and aeration units need to be upgraded to improve the quality of water distributed within Owerri metropolis.

The removal efficiencies of the physicochemical parameters, major ions for samples 1-3 are presented in bar graphs (Figs 4.4-4.9) for quick assessment of the distributions.

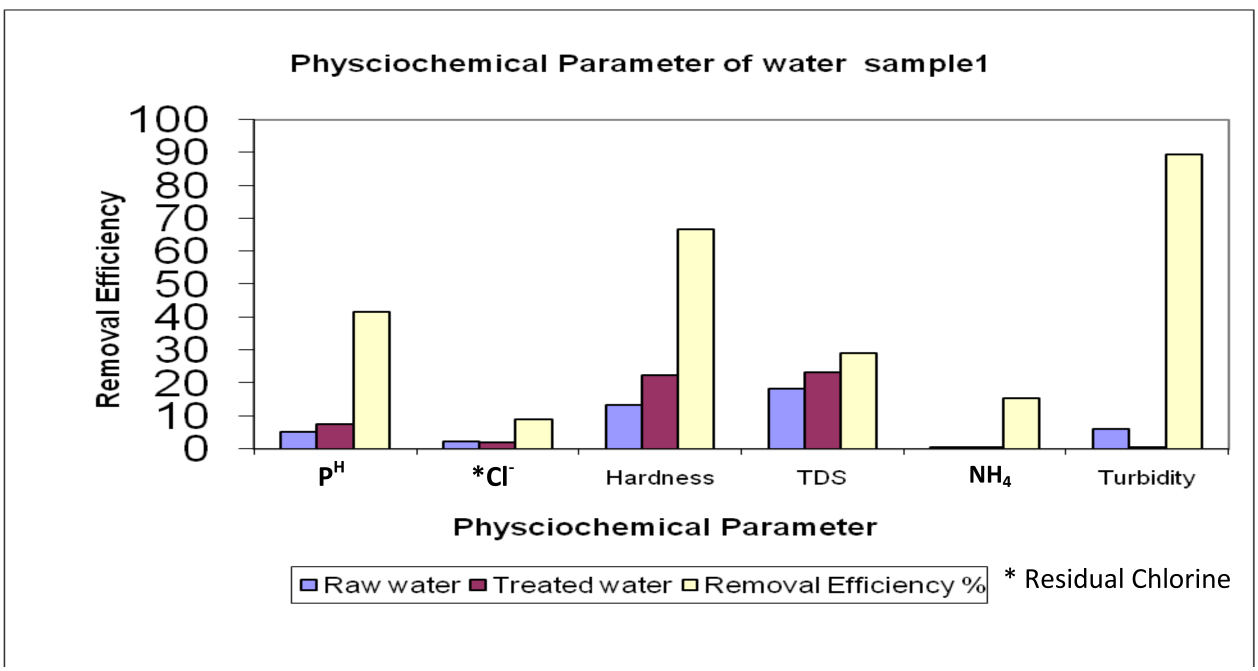


Fig 4.7 Chart showing physciochemical parameter of sample 1

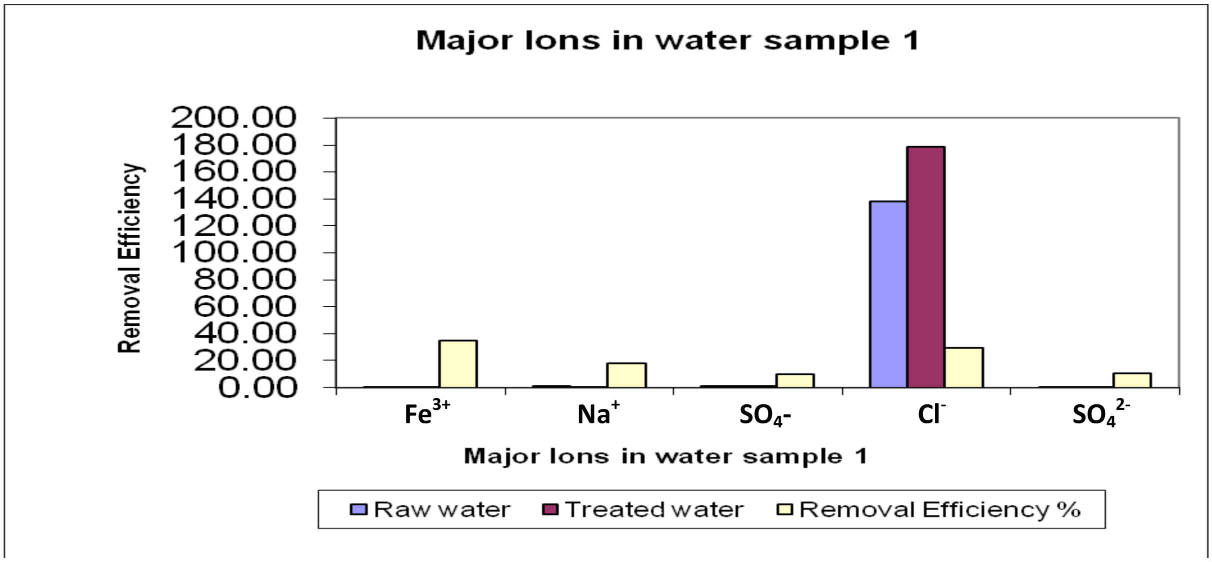


Fig 4.8 Chart showing major ion of sample 1

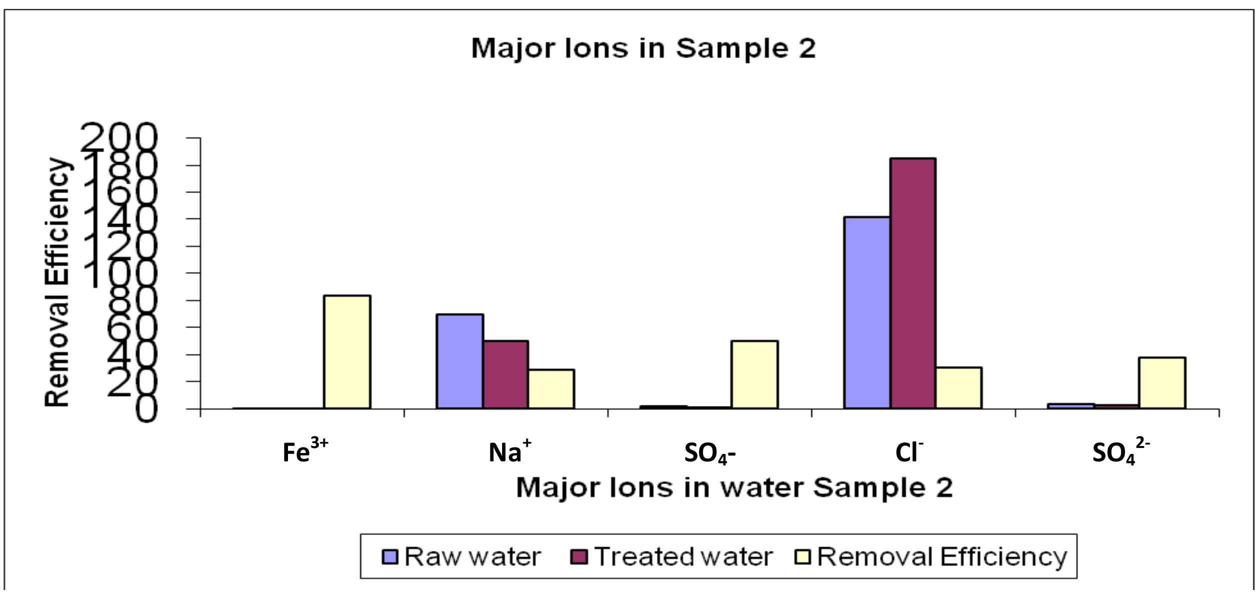


Fig 4.9 Chart showing major ion of sample 2

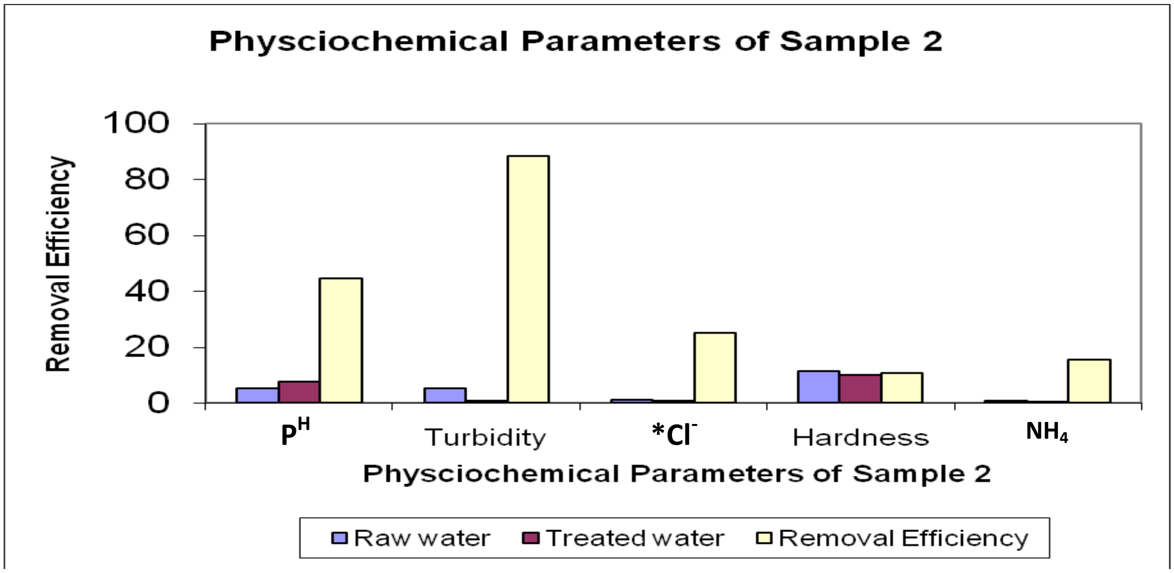


Fig 4.10 Chart showing physciochemical parameter of sample 2

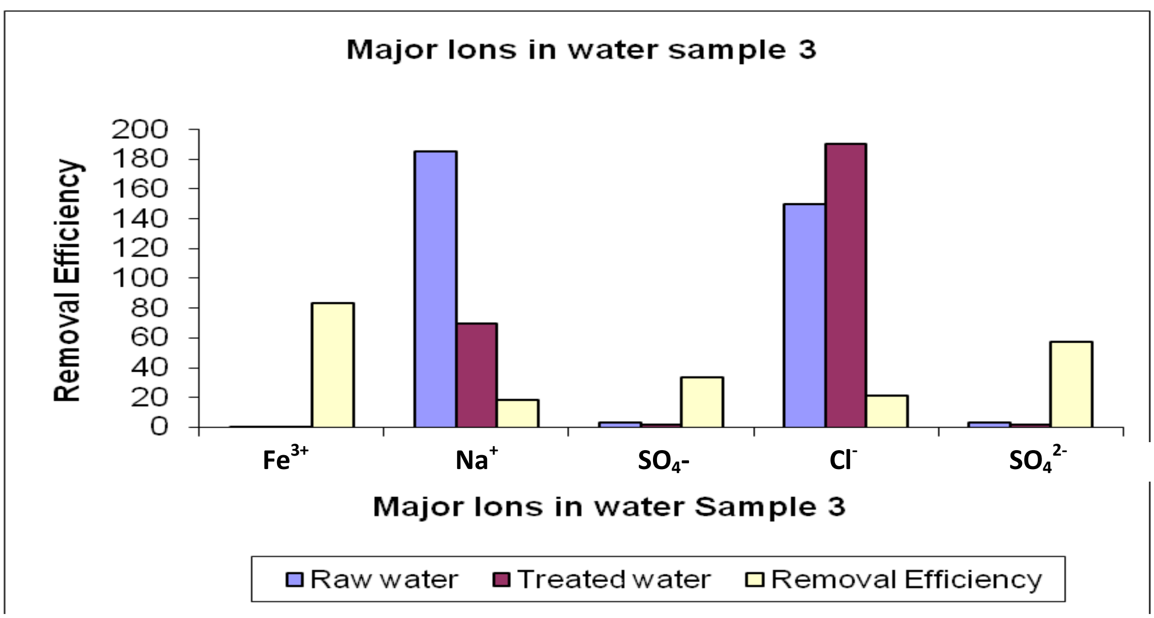


Fig 4.11 Chart showing major ion of sample 3

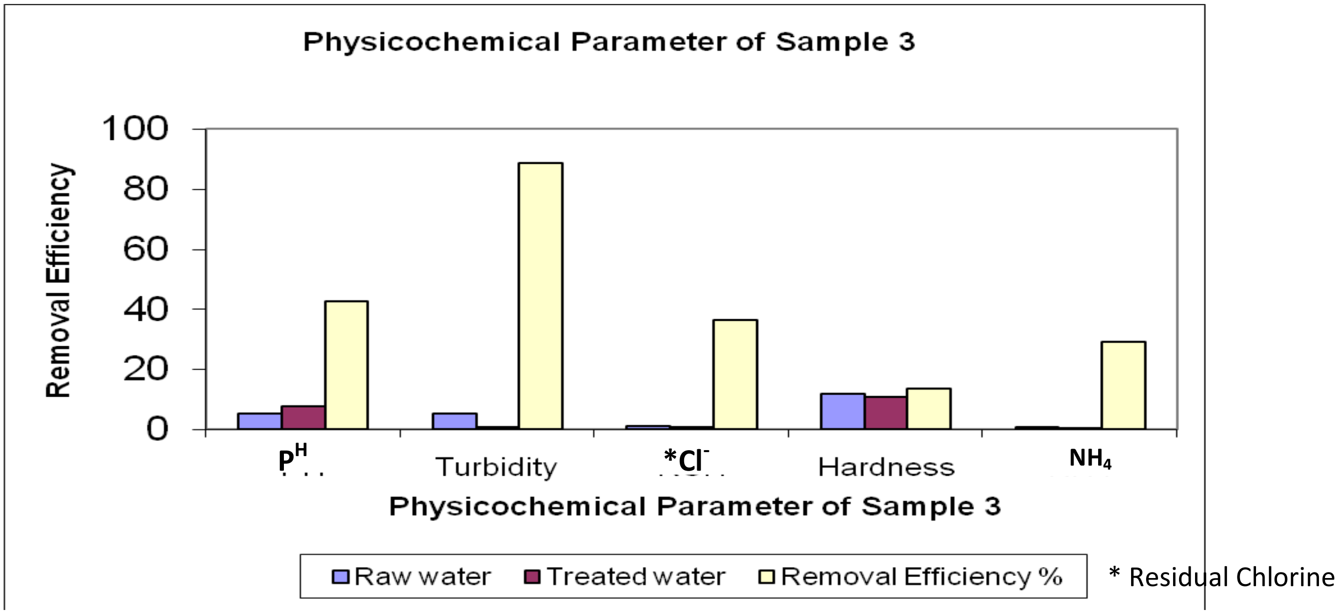


Fig 4.12 Chart showing physciochemical parameter of sample3

Average removal efficiencies for samples 1-3 with respect to physicochemical parameters are represented in Fig. 4.10 as bar charts for quick comparison.

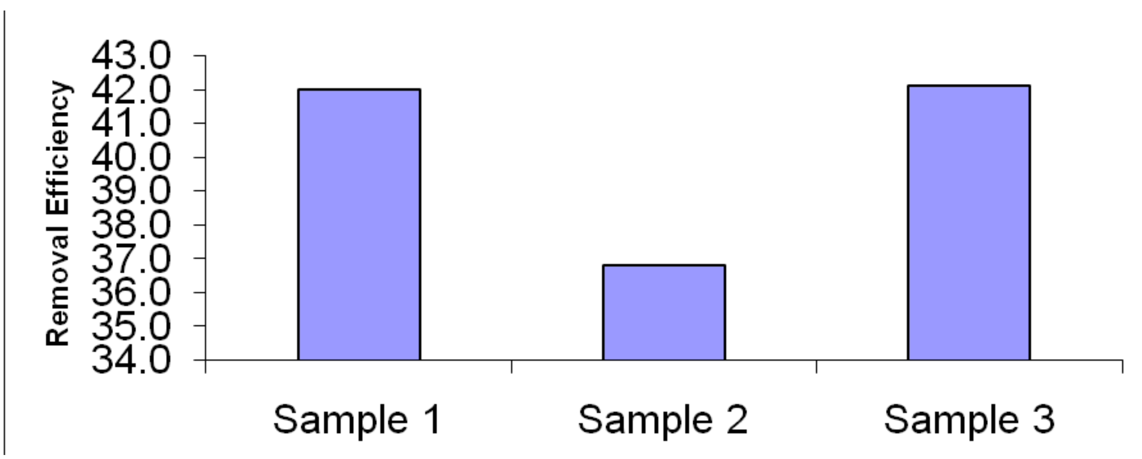


**Fig 4.13 Average distribution of physciochemical parameters for sample 1 -3**

## CHAPTER FIVE

## CONCLUSION AND RECOMMENDATIONS

### 5.1 CONCLUSION

The study showed that, Otamiri River as a source of drinking water requires minimal treatment processes. However, Nworie River as a source of drinking water for Owerri Municipal water supply system may require a state of the art water treatment plant. The use of boreholes as source of drinking water for Owerri Municipal water supply system will be the best in terms of quality. The lack of adequate funding has also been identified as a problem by operators for the supply of potable water to consumers. The mean levels for free chlorine (Cl), sodium (Na), sulphate ($S0_4^-$), nitrate and nitrite ($N0_2^-$) did not exceed the maximum tolerance limits required by WHO standard for drinking water. The $P^H$ was within the standard limit required. The mean levels for turbidity, ammonia and iron of the treated water sample were within the permissible limits, (see Tables 4.1 – 4.16), there is need for adequate funding to improve the quality of water supplied to consumers.

The evaluation of removal efficiency shows that the treatment plant is performing at 40.3%.

## 5.2 RECOMMENDATIONS

Based on the study and site visits to the study area (Owerri Water Treatment Plant), it is recommended that:

1. Evaluation of plant performance should be carried out yearly;
2. Backwashing of the filter bed should be carried out every six months;
3. The Owerri water treatment plant should be upgraded;
4. Evaluation of treatment plant should be carried out every three years; and
5. Weeds/water hyacinth of the source water and/or radial gate should be cleared monthly.
6. There should be proper funding by government for the treatment plant.
7. Nworie River requires a state of the art water treatment plant.

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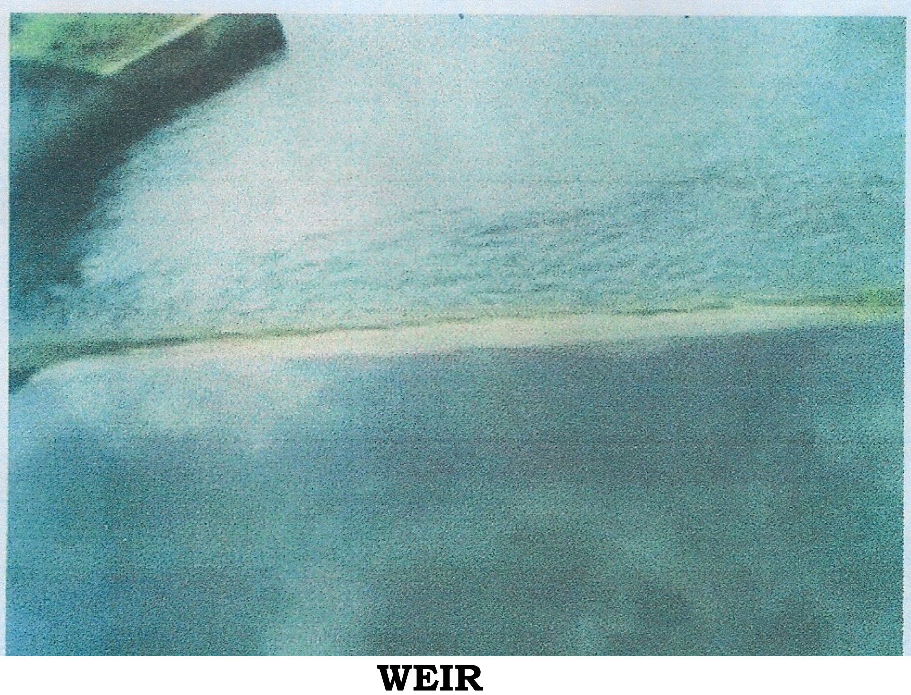
## APPENDICES

# APPENDIXES 1 AND 2

COLLECTION OF WATER SAMPLE



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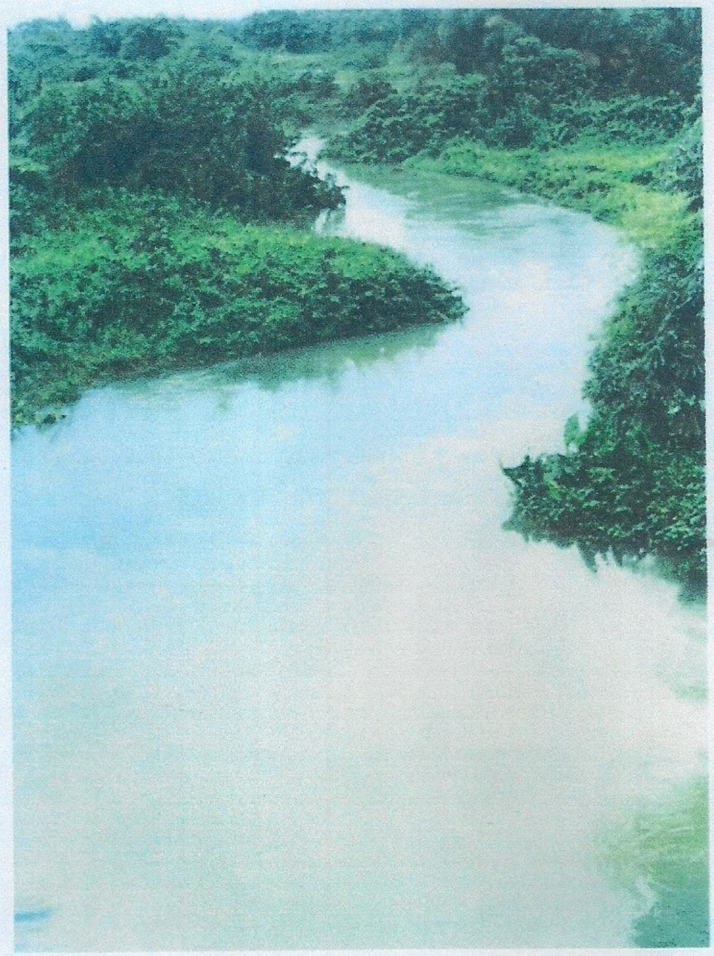
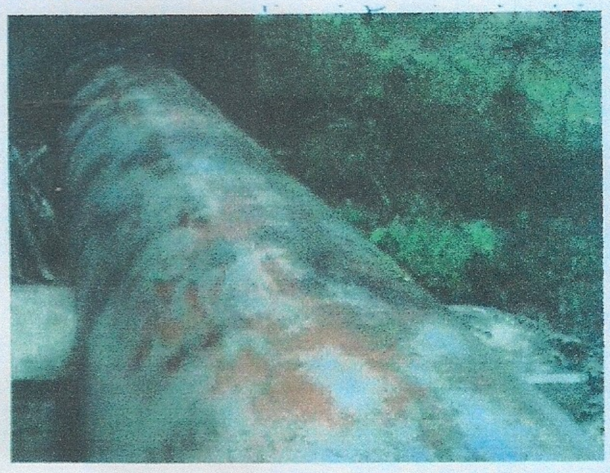
## APPENDIXES 3, 4 AND 5



OTAMIRI RIVER

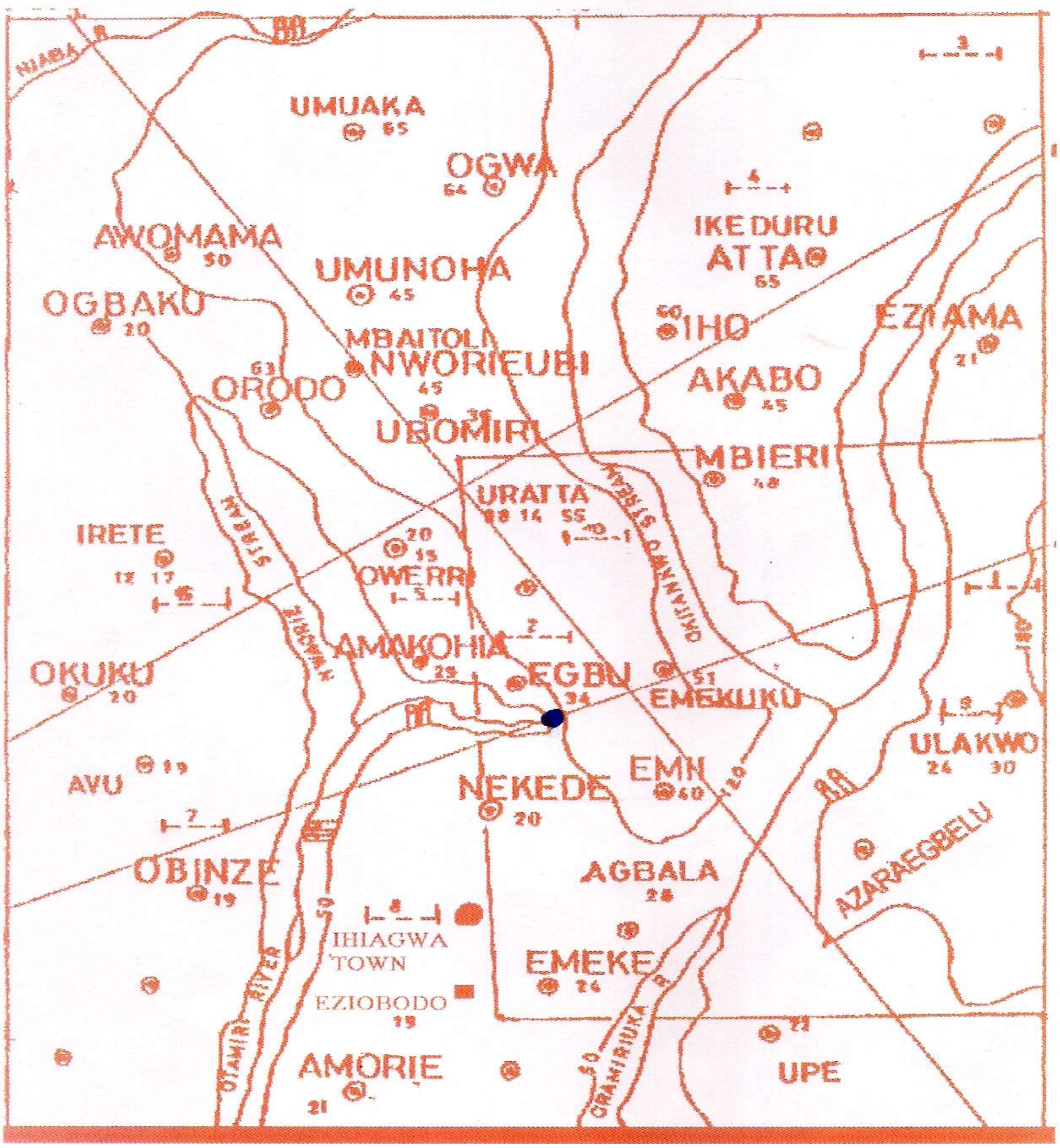
ELEVATED WATER TANK



0.9 METER PIPE

APPENDIX 6

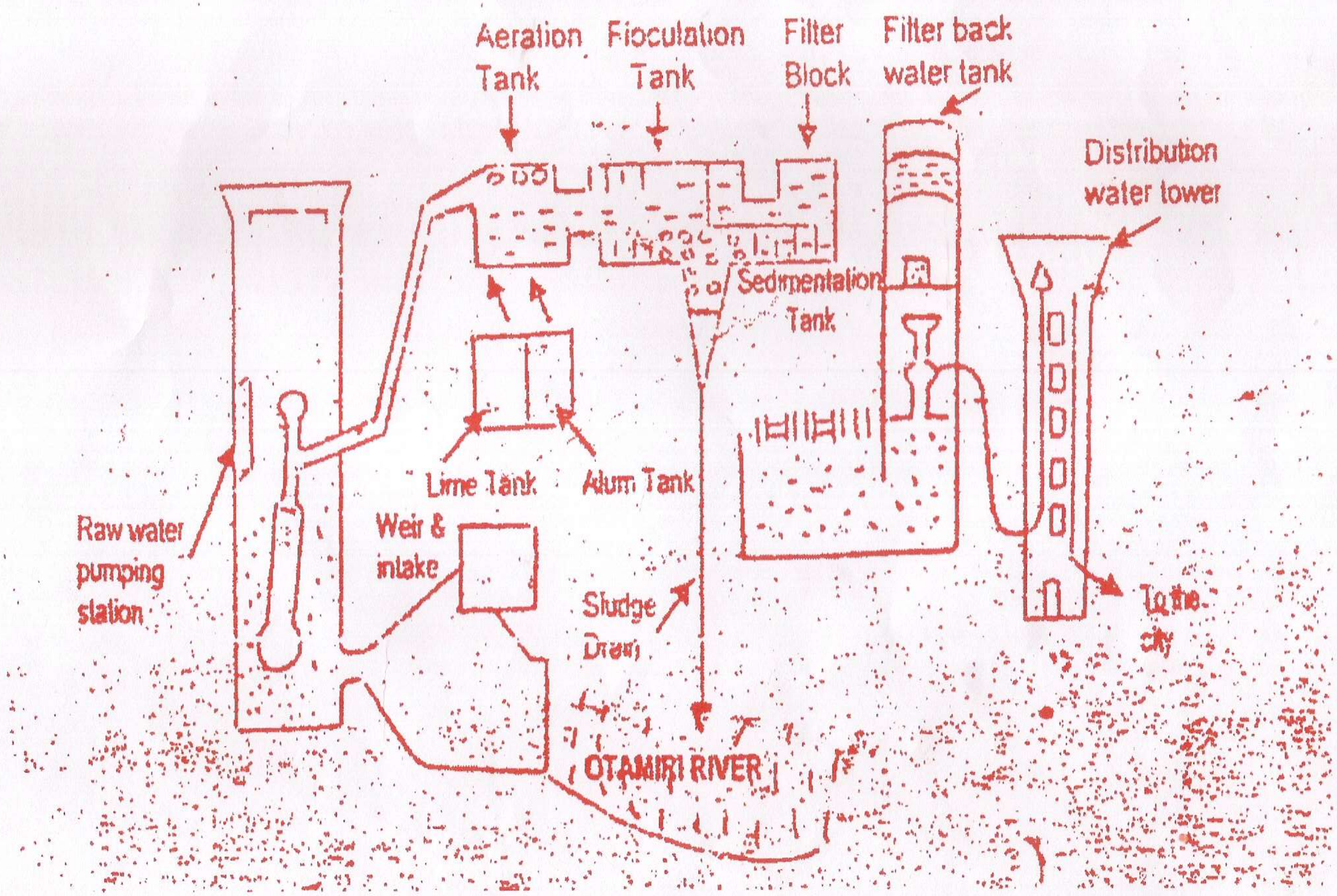
# MAP OF OWERRI SHOWING LOCATION OF WATER TREATMENT PLANT




**SOURCE: Imo State Water Corporation**

# Appendix 7

FLOW SHEET OF PROCESS IN LARGE SCALE WATER TREATMENT PLANT




**SOURCE: Imo State Water Corporation**