COMPARATIVE ANALYSIS OF WATER SAMPLES FROM THREE (3) DIFFERENT SOURCES (GALVANIZED IRON ROOFING SHEET, BOREHOLE AND WELL)

(A Case Study of Bosso, Minna Niger State)

BY

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

FEBRUARY, 2010

TITLE

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

FEBRUARY, 2010

DECLARATION

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

19/02/2010

Hashim, Muniru Muhammad | Date

CERTIFICATION

This project entitled "Comparative Analysis of Water Samples from Three (3) Different Sources (Galvanized Iron Roofing Sheet, Borehole and Well) (A Case Study of Bosso, Minna Niger State)" by Hashim Muniru Muhammad, meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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External Examiner Date

DEDICATION

This project is dedicated to Almighty Allah for giving me the strength and life to handle this thesis. Also this project is dedicated to my parents Alh. Alhassan Usman Hashim and Hajiya Maimunat Hashim and may Allah crown their efforts towards my success with Al-jannah Firdausi. (Ameen).

ACKNOWLEDGEMENTS

All praise is to Almighty Allah for giving me good health and the opportunity to reach this stage of my life, all thanks be unto Allah.

Secondly, my sincere gratitude goes to my family for their loving support, my parents who rendered their financial support to pursue this programme to this extent and to my brothers and sisters for their unending support too.

This acknowledgement will be incomplete without expressing my gratitude to my outstanding supervisor Mr. John Jiya Musa, who was of great assistance while we were carrying out this research work. I will forever remain grateful to him for contributing his time and assistance tirelessly. And also thank him for his advice, encouragement and criticism on this project from start to finish.

Also, my special gratitude goes to my lecturers in the department of Agricultural and Bioresources Engineering for their cooperation and understanding. I also feel highly indebted to a lot of my friends whose companionship and support contributed immensely to the success of this work.

Lastly, my sincere gratitude goes to the entire family members of Rtd. Justice Mamman Kolo for all their unending support throughout my stay in minna.

ABSTRACT

This study assesses the level of potability of rainwater samples harvested from a catchments roof in Bosso LGA in Niger state, Nigeria. To achieve this goal a physiochemical analysis was carried out on 3 water samples collected from galvanized iron roofing sheets, a well and a borehole. The harvested rainwater sample was analyzed as recommended by World Health Organization (WHO) and federal ministry of environment in Nigeria and the results were compared with that of the well, borehole and the WHO guidelines for drinking water. The result revealed that most of the physiochemical characteristics of rainwater samples were generally below the WHO threshold, as such the rainwater characteristics showed satisfactory concentration in Bosso community. Samples gotten from galvanized iron roof sheets, well, and borehole were analyzed for major physical and chemical water quality parameters and the results gotten from the 3 samples were pH (7.2, 6.6 and 7.5), alkalinity (48.7, 52, and 81.1), electrical conductivity (EC) (176, 104, and 230), total dissolved solids (TDS) (88, 52, and 115), total hardness (TH) (55, 39, and 93), colour (4.0, 8.4, and 3.3), Temperature (23.2, 23.2, and 23.2), Zn (6, 4 and -), sulphate (0.9, 29, and 26), turbidity (2.1, 6.7 and 1.8), iron (0.14, 0.21, and 0.03) and TSS (0, 2.8 and 0). Thus, the rainwater from these rural communities should be harvested, stored for human consumption and for other uses by the inhabitants. But treatment is needed in terms of their pH, TSS, TDS, Fe, colour, temperature, alkalinity, turbidity, hardness. Similarly, significant differences exist amongst the water samples collected from the 3 source. Thus, rainwater from these sources should be purified before consumption.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

The liquid which descends from the clouds in rain, and which forms rivers, lakes, seas, etc. Pure ordinary water (H_2o) consists of hydrogen (11.1888 percent) by weight and oxygen (88.812 percent). It has a slightly blue color and is very slightly compressible. At its maximum density at 39.2 °F or 4 °C, it is the standard for the specific gravities of solids and liquids. Its specific heat is the basis for the calorie and the B.T.U. units of heat. It freezes at 32 °F or O°C" (Webster's dictionary).

Though we talk a great deal about "pure water," the phrase is more of a designation than an actuality. Actually, "pure water" (H_2o) occurs so rarely, that for all intents and purposes, it is a non-existent liquid.

"Pure water" has different connotations to individuals in various fields. The bacteriologist, for example, is apt to regard "pure water" as a sterile liquid, that is, one with no living bacteria in it. The chemist, on the other hand, might well classify water as "pure" when it possesses no mineral, gaseous or organic impurities. It is obvious that "pure water" as described in this paragraph is likely to be found only in laboratories and even there only under ideal conditions.

The United States Environmental Protection Agency (EPA) provides practical standards for water in terms of its suitability for drinking (or potability) in the Primary Drinking Water Regulations and for aesthetic considerations in the Secondary Drinking Water Regulations.

In its Drinking Water Regulations, the United States Environmental Protection Agency (U.S.EPA) takes into consideration adequate protection of water against the effects of contamination, both through natural processes and through artificial treatment. The Standards list requirements for bacterial count, physical and chemical characteristics.

It is almost impossible to find a source of water that will meet basic requirements for a public water supply without requiring some form of treatment. In general, the requirements for a public water supply may be considered as follows:

1. That it shall contain no disease-producing organisms.
2. That it be colorless and clear.
3. That it be good-tasting, free from odors and preferably cool.
4. That it be non-corrosive.
5. That it be free from objectionable gases, such as hydrogen sulfide, and objectionable staining minerals, such as iron and manganese.
6. That it be plentiful and low in cost.

While the presence of coli form bacteria and toxic chemical content in water supply would cause water to be classified as unsafe to drink, other factors such as taste, odor, color and mineral content have a certain aesthetic effect - which can cause a water to be rejected as a usable supply.

There are tremendous variations in the quality of water from area to area. Review of the maps at the end of the article gives some indication of the variations. These, however, are only broad general indications of the differences. Even within a specified area significant differences may be noted.

In some cases there are variations in the quality of water in a given area, even on a day to day basis. Why do such variations occur?

The answer can be traced to the fact that water is a solvent. Water is aptly described as "the universal solvent." Scientists generally agree that it is one of the best solvents available.

As a result of its solvent action, water dissolves at least a portion of everything it touches. It dissolves metals, rocks, waste matter, gases, dust and numerous other foreign substances and may contain appreciable amounts of these dissolved materials. (www.freedrinkingwater.com)

Water contamination containing toxic substances are generated by a wide variety of chemical processes, as well as by a number of other common household and agricultural applications. In this context, galvanized roofing sheets and their chemicals are toxic recalcitrant compounds, which may accumulate in the environment. The inadequate management of these effluents can have harmful consequences to human health. Man realized from the very beginning that water is about the most essential element for satisfaction of all his basic needs (Odjugo and Konyeme, 2008).

An accessible source of potable water helps in lifting the standard of living to an acceptable level.

However, with the era of industrial revolution, which began in the 16th century, and pollution explosion of the 20th and 21st century that concentrated more people in the urban areas, both the ground water and surface water have been found to be highly polluted mainly with inorganic pollutants such as chemical and industrial waste. (Odjugo and Konyeme, 2008).

As urban population increases, human activities also increase and the need for water increases. With the unprecedented rate of growth in world population, the unavailability of this essential fluid of life in adequate quantity and good quality delays development. (Yayock, 2007).

Underground sources of water are used for a variety of different purposes wherever human habitation occurs, as in the case of Bosso Minna in Niger State, Nigeria. Scarcity of conventional sources of water in arid and semi arid regions has promoted the search of additional sources of water such as deep ground water, Treated waste water, and brackish water. Water resources management in arid and semi-arid region is complex, multifaceted task, because of the need to integrate many hydrological, environmental, economic, social, and managerial factors. Water intended for human consumption must be free from organisms and concentration of chemical substances that may be health hazards.

1.1.1 Sources of Water

Rain and Glacier are the main sources of water, and they are classified under two main categories based on its location. These two categories are surface water and underground water. Both have its own characteristics; the most important of these characteristics are accessibility, quality, and quantity. Water from these sources flow from over the surface to form lakes, ponds, reservoirs, rivers, canals, creeks, and are termed as surface water. Surface water is easily contaminated with bacteria and organic substances harmful to health. The water which gets absorbed into the ground to be tapped as springs or wells, shafts or infiltration galleries, are termed as groundwater, and it is the most highly demanded among other Natural resources.

1.1.2 Water Contamination

Ground water contamination is the result of polluted water infiltrating through the soil and rock and and eventually reaching the ground water. This process might take many years and might take place at a distance from a well where the contamination is found. Once the ground water is contaminated, it is very difficult to remediate. No doubt that the new technologies will always reduce the pollution level. (Geetha *et al*, 2008)

Water is necessary to life on earth. All organisms contain it; some live in it; some drink it. Plants and animals require water that is moderately pure, and they cannot survive if their water is loaded with toxic chemicals or harmful microorganisms. People who ingest polluted water can become ill, and, with prolonged exposure, may develop cancers or bear children with birth defects.

According to recent news and reports, most tap and well water in the U.S. are not safe for drinking due to heavy industrial and environmental pollution. Toxic bacteria, chemicals and heavy metals routinely penetrate and pollute our natural water sources making people sick while exposing them to long term health consequences such as liver damage, cancer and other serious health conditions. We have reached the point where all sources of our drinking water, including municipal water systems, wells, lakes, rivers, and even glaciers, contain some level of contamination.

1.2 Statement of Problem

Since precipitation is the major source of water, some of the problems that arise in ground water around residential areas in this part of the world where galvanized roofing sheets made out of metals are used, includes chemical pollutants from the coating of the metal against rust and physical pollutants from the environment.

Acid rain occurs when sulfur dioxide and nitrogen oxides in the atmosphere react with oxygen in the air to form sulfuric acid (H_2SO_4) and nitric acid (HNO), which falls to the surface as rain, snow or dust. To be considered acid, precipitation has to have a pH of 5.0 or lower. Sulfur dioxide (SO_2) from human sources comes primarily from smelters and coal burning power plants. Hot sulfur dioxide also originates from natural sources. Nitrogen oxides come primarily from automobile exhaust and other combustion processes, and some is created by lightening and soil microbes, flaring of gases and other industrial processes; house hold with wood-burning stoves, also emit SO_2 and NO_x into the atmosphere. Acid ran also contains in additional to sulfur dioxide and nitrogen dioxide, heavy metals, carbonmonoxide and photochemical oxidants. Reactions between these substances strengthen their damaging effect, which is referred to as synergistic effect. Because an electrolyte is a necessity for corrosion, roofing sheets tend to corrode, where acid rain water and/or condensation cannot run off or becomes trapped. Sulfur dioxide is the main pollutant in respect to corrosion, but others take their toll, including Nitrogen oxide, carbon dioxides, ozone etc. The reaction between roofing sheets and pollutants are very complex and many variables are involved. Deposition of pollutants onto surface depends on atmospheric concentrations of the pollutants and the climate around the surface. Once the pollutants are on the surface, interactions will vary depending on the amount of exposure, the reactivity of different materials and the amount of moisture present. (Abdulkarim *et al*, 2009)

Galvanizing simply means coating metal with zinc that will react with the corroding substances more readily than the iron does and thus, while being consumed, protect the iron. It is also satisfactory, but expensive. In the presence of corrosive solutions, an electric potential is set up between the iron and the zinc, causing the zinc to dissolve but protecting the iron as long as any zinc remains.

The impact of the rain on these roofing materials causes Corrosion, which is the partial or complete wearing away, dissolving, or softening of any substance by chemical or electrochemical reaction with its environment. The term corrosion specifically applies to the gradual action of natural agents, such as air or salt water, on metals. The most familiar example of corrosion is the rusting of iron, a complex chemical reaction in which the iron combines with both oxygen and water to form hydrated iron oxide. The oxide is a solid that retains the same general form as the metal from which it is formed but, porous and somewhat bulkier, is relatively weak and brittle.

1.3 Objective of Study

- The main objective of this case study is to assess the quality of water collected from galvanized roofing sheets and assess if the contamination affects the ground water collected from wells and bore holes in the area, and compare the results with FAO and WHO acceptable limits.
- To suggest methods of treatment of contaminated underground water for domestic and agricultural purposes.

1.4 Scope of Work

This study provides information about the chemical and physical contamination of water samples collected from three (3) sources;

- From galvanized roofing sheets
- From well
- From bore hole

1.5 Research Question

The research questions include the following;

- What is water contamination?
- What are the properties of the water collected from the galvanized iron roof?
- What are the concentrations of metal constituent in the groundwater?

- What are the impacts of these metals on human health?

CHAPTER TWO

LITERATURE REVIEW

2.0 Rainwater Harvesting

'Rainwater harvesting' is a widely used term covering all those techniques whereby rain is intercepted and used 'close' to where it first reaches the earth. The term has been applied to arrangements to cause rainfall to percolate the ground rather than run off its surface, to forms of flood control, to the construction of small reservoirs to capture run-off water so that it can be used for cattle or micro-irrigation and to the collection of run-off from roofs and other impermeable surfaces. Thus, roof water harvesting is a subset of rainwater harvesting, albeit an important one. (Thomas, and Martinson, 2007)

Rainwater harvesting is the gathering, or accumulating and storing, of rainwater. Rainwater harvesting has been used to provide drinking water, water for livestock, water for irrigation or to refill aquifers in a process called groundwater recharge. Rainwater collected from the roofs of houses, tents and local institutions, or from specially prepared areas of ground, can make an important contribution to drinking water. In some cases, rainwater may be the only available, or economical, water source. Rainwater systems are simple to construct from inexpensive local materials, and are potentially successful in most habitable locations. Roof rainwater is usually of good quality and does not require treatment before consumption. Household rainfall catchment systems are appropriate in areas with an average rainfall greater than 200mm per year, and no other accessible water sources (Rainwater Harvesting, Wikipedia 2009).

Rainwater harvesting is still the only source of potable. Water for rural communities where there are no water supplies networks. Even in some areas where potable water is supplied by networks, harvested rainwater is still a significant supplemental resource for domestic uses especially during summer season when low quantity of water is supplied. Currently in Jordan, roof top rainwater harvesting is being practiced for drinking water, domestic uses, and livestock and for garden irrigation (MWI, 2009)

2.1 Rainwater Harvesting For Domestic Purposes

Catchment refers to the prepared surface area from which rainwater is collected. The catchment can be the roof-top area of households, buildings or dedicated ground area.

2.1.1 Roof Catchment Systems

This is the most common type of catchment and is usually the roof of houses or buildings. The effective roof area and the type of roof material influence the efficiency of collection and the water quality. Galvanized corrugated iron sheets, corrugated plastic or tiles all make good catchment surfaces. However, roofs made of asbestos or painted with lead based paints should be avoided. Roofs should also be free from over-hanging trees to prevent entry of bird and animal faeces as well as decomposing leaves. Properly and maintained roofs are the best choice as a collection surface, because their isolated location protects rainwater from pollution.

2.1.2 Ground Catchment Systems

These are normally employed where suitable roof surfaces are not available. The advantage is that water can be collected from a larger area and is useful in low rainfall regions. The disadvantage is runoff is easily contaminated and the underground tanks are less assessable for maintenance and cleaning. Ground catchments systems are less suitable for collecting drinking water.

2.1.3 Rock Catchment Systems

These are generally constructed for communal supplies in areas where unjointed massive rock outcrops provide suitable catchment surfaces. (Sundaravadivel *et al*, 2007)

2.2 Water Quality and Health Risk

As rainwater may be contaminated, it is often not considered suitable for drinking without treatment. However, there are many examples of rainwater being used for all purposes — including drinking — following suitable treatment.

Rainwater harvested from roofs can contain animal and bird faeces, mosses and lichens, windblown dust, particulates from urban pollution, pesticides, and inorganic ions from the sea (Ca, Mg, Na, K, Cl, SO_4^{2-}), and dissolved gases (CO_2, NO_x, SO_x). High levels of pesticide have been found in rainwater in Europe with the highest concentrations occurring in the first rain immediately after a dry spell; the concentration of these and other contaminants are reduced significantly by diverting the initial flow of water to waste as described above. The water may need to be analyzed properly, and used in a way appropriate to its safety. In the Gansu province for example, harvested rainwater is boiled in parabolic solar cookers before being used for drinking. In Brazil alum and chlorine is added to disinfect water before consumption. So-called "appropriate technology" methods, such as solar water disinfection, provide low-cost disinfection options for treatment of stored rainwater for drinking (Rainwater Harvesting, Wikipedia 2009).

Rainwater is relatively free from impurities except those picked up by rain from the atmosphere, but the quality of rainwater may deteriorate during harvesting, storage and household use. Wind-blown dirt, leaves, faecal droppings from birds and animals, insectsand contaminated litter on the catchment areas can be sources of contamination of rainwater, leading to health risks from the consumption of contaminated water from storage tanks. Poor hygiene in storing water in and abstracting water from tanks or at the point of use can also represent a health concern. However, risks from these hazards can be minimized by good design and practice. Well designed rainwater harvesting systems with clean catchments and storage tanks supported by good hygiene at point of use can offer drinking-water with very low health risk, whereas a poorly designed and managed system can pose high health risks. Microbial contamination of collected rainwater indicated by E. coli (or, alternatively, thermotolerants coliforms) is quite common, particularly in samples collected shortly after rainfall. Pathogens such as Cryptosporidium, Giardia, Campylobacter, Vibrio, Salmonella, Shigella and Pseudomonas have also been detected in rainwater. However, the occurrence of pathogens is generally lower in rainwater than in unprotected surface waters, and the presence of non-bacterial pathogens, in particular, can be minimized. Higher microbial concentrations are generally found in the first flush of rainwater, and the level of contamination reduces as the rain continues. A significant reduction of microbial contamination can be found in rainy seasons when catchments are frequently washed with fresh rainwater. Storage tanks can present breeding sites for mosquitoes, including species that transmit dengue virus.

Rainwater is slightly acidic and very low in dissolved minerals; as such, it is relatively aggressive. Rainwater can dissolve heavy metals and other impurities from materials of the catchment and storage tank. In most cases, chemical concentrations in rainwater are within acceptable limits; however, elevated levels of zinc and lead have sometimes been reported. This could be from leaching from metallic roofs and storage Rainwater lacks minerals, but some minerals, such as calcium, magnesium, iron and fluoride, in appropriate concentrations are considered very essential for health. Although most essential nutrients are derived from food, the lack of minerals, including calcium and magnesium, in rainwater may represent a concern for those on a mineral-deficient diet. In this circumstance, the implications of using rainwater as the primary source of drinking-water should be considered. The absence of minerals also means that rainwater has a particular taste or lack of taste that may not acceptable to people used to drinking other mineral-rich natural waters. Water quality should be managed through development and application of WSPs that should deal with all components from catchment areas to point of supply (www.who.int/water_sanitation_health).

Acid rain occurs when sulfur dioxide and nitrogen oxides in the atmosphere react with oxygen in the air to form sulfuric acid (H_2SO_4) and nitric acid (HNO), which falls to the surface as rain, snow or dust. To be considered acid, precipitation has to have a pH of 5.0 or lower. Sulfur dioxide (SO_2) from human sources comes primarily from smelters and coal burning power plants. Hot sulfur dioxide also originates from natural sources. Nitrogen oxides come primarily from automobile exhaust and other combustion processes, and some is created by lightening and soil microbes, flaring of gases and other industrial processes; house hold with wood-burning stoves, also emit SO_2 and NO_x into the atmosphere. Acid ran also contains in additional to sulfur dioxide and nitrogen dioxide, heavy metals, carbon monoxide and photochemical oxidants. Reactions between these substances strengthen their damaging effect, which is referred to as synergistic effect. Because an electrolyte is a necessity for corrosion, roofing sheets tend to corrode, where acid rain water and/or condensation cannot run off or becomes trapped. Sulfur dioxide is the main pollutant in respect to corrosion, but others take their toll, including Nitrogen oxide, carbon dioxides, ozone etc. The reaction between roofing sheets and pollutants are very complex and many variables are involved. Deposition of pollutants onto surface depends on atmospheric concentrations of the pollutants and the climate around the surface. Once the pollutants are on the surface, interactions will vary depending on the amount of exposure, the reactivity of different materials and the amount of moisture present. (Abdulkarim *et al*, 2009)

2.2.1 Nitrate: Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. The nitrate ion (NO_3^-) is the stable form of combined nitrogen for oxygenated systems. Although chemically unreactive, it can be reduced by microbial action. The nitrite ion (NO_2^-) contains nitrogen in a relatively unstable oxidation state. Chemical and biological processes can further reduce nitrite to various compounds or oxidize it to nitrate. Nitrite can also be formed chemically in distribution pipes by Nitrosomonas bacteria during stagnation of nitrate-containing and oxygen-poor drinking-water in galvanized steel pipes or if chloramination is used to provide a residual disinfectant and the process is not sufficiently well controlled.

Nitrates and nitrites are nitrogen-oxygen chemical units which combine with various organic and inorganic compounds. Once taken into the body, nitrates are converted to nitrites. Infants below six months who drink water containing nitrate in excess of the maximum contaminant level (MCL) could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome. This health effects language is not intended to catalog all possible health effects for nitrate. Rather, it is intended to inform consumers of some of the possible health effects associated with nitrate in drinking water when the rule was finalized. EPA has set an enforceable regulation for nitrate, called a maximum contaminant level (MCL), at 10 mg/L or 10 ppm.

The major sources of nitrates in drinking water are runoff from fertilizer use; leaching from septic tanks, sewage; and erosion of natural deposits. The following treatment method(s) have proven to be effective for removing nitrate to below 10 mg/L or 10 ppm: ion exchange, reverse osmosis, electrodialysis (WHO, 2007).

Groundwater contains nitrate due to leaching of nitrate with the percolating water. Groundwater can also be contaminated by sewage and other wastes rich in nitrates. The nitrate content in the study area varied in the range 0.041 mg/L to 1.271 mg/L and found within the prescribed limit. (V.T. Patil *et al*, 2009)

2.2.2 Fluoride (F): Fluorine is a common element that does not occur in the elemental state in nature because of its high reactivity. It accounts for about 0.3 g/kg of the Earth's crust and exists in the form of fluorides in a number of minerals, of which fluorspar, cryolite and fluorapatite are the most common. The oxidation state of the fluoride ion is -1. Bone disease (pain and tenderness of the bones); Children may get mottled teeth .Water additive which promotes strong teeth; source is usually from erosion of natural deposits; discharge from fertilizer and aluminum factories. Many epidemiological studies of possible adverse effects of the long-term ingestion of fluoride via drinking-water have been carried out. These studies clearly establish that fluoride primarily produces effects on skeletal tissues (bones and teeth). Low concentrations provide protection against dental caries, especially in children. The pre- and post-eruptive protective effects of fluoride (involving the incorporation of fluoride into the matrix of the tooth during its formation, the development of shallower tooth grooves, which are consequently less prone to decay, and surface contact with enamel) increase with concentration up to about 2 mg of fluoride per litre of drinking-water; the minimum concentration of fluoride in drinking-water required to produce it is approximately 0.5 mg/litre (WHO, 2004).

Excessive fluoride intake can have negative consequences on bone, teeth and the brain. Too much of the ion can lead to skeletal fluorosis, a condition in which teeth have weak enamel and bones have poor mineralization.

Exposure to high levels of fluoride may also alter brain development, according to recent studies of Chinese populations. Studies from rural China, albeit done with inappropriate controls, suggest fluoride may harm the developing brain. Young children are the most vulnerable to the neurodevelopmental effects from too much fluoride (Xiang *et al.* 2003).

2.2.3 Chlorides (Cl^-): Are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$).Sodium chloride is widely used in the production of industrial chemicals such as caustic soda, chlorine, sodium chlorite, and sodium hypochlorite. Sodium chloride, calcium chloride, and magnesium chloride are extensively used in snow and ice control. Potassium chloride is used in the production of fertilizers. A normal adult human body contains approximately 81.7 g chloride. On the basis of a total obligatory loss of chloride of approximately 530 mg/day, a dietary intake for adults of 9 mg of chloride per kg of body weight has been recommended (equivalent to slightly more than 1g of table salt per person per day). For children up to 18 years of age, a daily dietary intake of 45 mg of chloride should be sufficient. A dose of 1 g of sodium chloride per kg of body weight was reported to have been lethal in a 9-week-old child. Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, e.g. in congestive heart failure. Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Little is known about the effect of prolonged intake of large amounts of chloride in the diet. As in experimental animals, hypertension associated with sodium chloride intake appears to be related to the sodium rather than the chloride ion.

Chloride increases the electrical conductivity of water and thus increases its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts, thus increasing levels of metals in drinking-water. In lead pipes, a protective oxide layer is built up, but chloride enhances galvanic corrosion. It can also increase the rate of pitting corrosion of metal pipes. Chloride concentrations in excess of about 250 mg/litre can give rise to detectable taste in water, but the threshold depends upon the associated cations. Consumers can, however, become accustomed to concentrations in excess of 250 mg/litre. No health based guideline value is proposed for chloride in drinking-water (WHO, 2004).

The chloride concentration serves as an indicator of pollution by sewage. People accustomed to higher chloride in water are subjected to laxative effects. In the present analysis, chloride concentration was found in the range of 16.9 mg/L to 447.9 mg/L. (V.T. Patil *et al*, 2009)

2.2.4 Iron: Is the second most abundant metal in the earth's crust, of which it accounts for about 5%. Elemental iron is rarely found in nature, as the iron ions Fe^{2+} and Fe^{3+} readily combine with oxygen- and sulfur-containing compounds to form oxides, hydroxides, carbonates, and sulfides. Iron is most commonly found in nature in the form of its oxides. Iron is used as constructional material, inter alia for drinking-water pipes. Iron oxides are used as pigments in paints and plastics. Other compounds are used as food colours and for the treatment of iron deficiency in humans. Various iron salts are used as coagulants in water treatment. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day. The average lethal dose of iron is 200–250 mg/kg of body weight, but death has occurred following the ingestion of doses as low as 40 mg/kg of body weight. Autopsies have shown haemorrhagic necrosis and sloughing of areas of mucosa in the stomach with extension into the submucosa. Chronic iron overload results primarily from a genetic disorder (haemochromatosis) characterized by increased iron absorption and from diseases that require frequent transfusions. Adults have often taken iron supplements for extended periods without deleterious effects, and an intake of 0.4–1 mg/kg of body weight per day is unlikely to cause adverse effects in healthy persons. Anaerobic groundwater may contain iron (II) at concentrations up to several milligrams per litre without discoloration or turbidity in the water when directly pumped from a well. Taste is not usually noticeable at iron concentrations below 0.3 mg/litre, although turbidity and colour may develop in piped systems at levels above 0.05–0.1 mg/litre. Laundry and sanitary ware will stain at iron concentrations above 0.3 mg/litre. Iron is an essential element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day (WHO, 2004).

2.2.5 Sulphates: occur naturally in numerous minerals, including barite ($BaSO_4$), epsomite ($MgSO_4 \cdot 7H_2O$) and gypsum ($CaSO_4 \cdot 2H_2O$). Sulfates and sulfuric acid products are used in the production of fertilizers, chemicals, dyes, glass, paper, soaps, textiles, fungicides, insecticides, astringents and emetics. They are also used in the mining, wood pulp, metal and plating industries, in sewage treatment and in leather processing. Aluminum sulfate (alum) is used as a sedimentation agent in the treatment of drinking-water. Copper sulfate has been used for the control of algae in raw and public water supplies. Ingestion of 8 g of sodium sulfate and 7 g of magnesium sulfate caused catharsis in adult males. Cathartic effects are commonly reported to be experienced by people consuming drinking-water containing sulfate in concentrations exceeding 600 mg/litre, although it is also reported that humans can adapt to higher concentrations with time. Dehydration has also been reported as a common side-effect following the ingestion of large amounts of magnesium or sodium sulfate. There are subpopulations that may be more sensitive to the cathartic effects of exposure to high concentrations of sulfate. Children, transients and the elderly are such populations because of the potentially high risk of dehydration from diarrhea that may be caused by high levels of sulfate in drinking-water (WHO, 2004).

2.2.6 Zinc (Zn): occurs in small amounts in almost all igneous rocks. The principal zinc ores are sulfides, such as sphalerite and wurzite. The natural zinc content of soils is estimated to be 1–300 mg/kg. Zinc is used in the production of corrosion-resistant alloys and brass, and for galvanizing steel and iron products. Zinc oxide, used in rubber as a white pigment, for example, is the most widely used zinc compound. Peroral zinc is occasionally used to treat zinc deficiency in humans. Zinc carbonates are used as pesticides. Acute toxicity arises from the ingestion of excessive amounts of zinc salts, either accidentally or deliberately as an emetic or dietary supplement. Vomiting usually occurs after the consumption of more than 500 mg of zinc sulfate. Mass poisoning has been reported following the drinking of acidic beverages kept in galvanized containers; fever, nausea, vomiting, stomach cramps, and diarrhea occurred 3–12 hours after ingestion. Food poisoning attributable to the use of galvanized zinc containers in food preparation has also been reported; symptoms occurred within 24 h and included nausea, vomiting, and diarrhea, sometimes accompanied by bleeding and abdominal cramps. Manifest copper deficiency, which is the major consequence of the chronic ingestion of zinc, has been caused by zinc therapy (150–405 mg/day) for coeliac disease, sickle cell anaemia, and acrodermatitis enteropathica. Impairment of the copper status of volunteers by dietary intake of 18.5 mg of zinc per day has been reported. Zinc supplementation of healthy adults with 20 times the recommended dietary allowance for 6 weeks resulted in the impairment of various immune responses. Gastric erosion is another reported complication of a daily dosage of 440 mg of zinc sulfate. Daily supplements of 80–150 mg of zinc caused a decline in high-density lipoprotein cholesterol levels in serum after several weeks, but this effect was not found in some other studies. In an Australian study, no detrimental effect of 150 mg of zinc per day on plasma copper levels was seen in healthy volunteers over a period of 6 weeks. Acute toxic effects of inhaled zinc have been reported in industrial workers exposed to zinc fumes; the symptoms include pulmonary distress, fever, chills, and gastroenteritis. In a small-scale study on zinc-refinery workers, no evidence was found of increased mortality from any type of cancer. In subjects with low baseline levels of serum zinc, no significant difference in the risk of death from cancer or cardiovascular diseases, as compared with those with high baseline levels, was observed (WHO, 2004).

2.2.7 Total Dissolved Solids (TDS): is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. No recent data on health effects associated with the ingestion of TDS in drinking-water appear to exist; however, associations between various health effects and hardness, rather than TDS content, have been investigated in many studies. In early studies, inverse relationships were reported between TDS concentrations in drinking water and the incidence of cancer, coronary heart disease, arteriosclerotic heart disease, and cardiovascular disease. Total mortality rates were reported to be inversely correlated with TDS levels in drinking-water. It was reported in a summary of a study in Australia that mortality from all categories of ischaemic heart disease and acute myocardial infarction was increased in a community with high levels of soluble solids, calcium, magnesium, sulfate, chloride, fluoride, alkalinity, total hardness, and pH when compared with one in which levels were lower. No attempts were made to relate mortality from cardiovascular disease to other potential confounding factors (WHO, 2004).

2.2.8 The pH: of a solution is the negative common logarithm of the hydrogen ion activity:

pH = −log (H+)

In dilute solutions, the hydrogen ion activity is approximately equal to the hydrogen ion concentration. The pH of water is a measure of the acid–base equilibrium and, in most natural waters, is controlled by the carbon dioxide–bicarbonate–carbonate equilibrium system. An increased carbon dioxide concentration will therefore lower pH, whereas a decrease will cause it to rise. Temperature will also affect the equilibria and the pH. In pure water, a decrease in pH of about 0.45 occurs as the temperature is raised by 25 °C. In water with a buffering capacity imparted by bicarbonate, carbonate and hydroxyl ions, this temperature effect is modified. The pH of most drinking-water lies within the range 6.5 – 8.5. Natural waters can be of lower pH, as a result of, for example, acid rain or higher pH in limestone areas. The effects of acids and alkalis depend on the strength of the acid or alkali and the concentration. Strong concentrated acids or alkalis are corrosive, whereas dilute and weak acids and alkalis are not corrosive. pH alone is not the primary determinant of adverse effects, and in water, acids and alkalis are normally extremely dilute. The pH of stomach fluid, which contains hydrochloric acid, is between 1.0 and 3.5, with a mean of approximately 2.0, and there is a range of commonly encountered foods that are also of low pH. These include lemon juice, with a pH of 2.4, and vinegar, with a pH of 2.8. Because these are weak acids, they pose no threat to health from their consumption. A direct relationship between human health and the pH of drinking water is impossible to ascertain, because pH is so closely associated with other aspects of water quality, and acids and alkalis are weak and usually very dilute. However, because pH can affect the degree of corrosion of metals as well as disinfection efficiency, any effect on health is likely to be indirect and due to increased ingestion of metals from plumbing and pipes or inadequate disinfection (WHO, 2004).

2.2.9 Turbidity: Is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches. Source of contaminant is by Soil runoff (WHO, 2004).

2.2.10 Aluminium (Al): Aluminum is the most abundant metallic element and constitutes about 8% of the Earth's crust. It occurs naturally in the environment as silicates, oxides, and hydroxides, combined with other elements, such as sodium and fluoride, and as complexes with organic matter. Aluminum metal is used as a structural material in the construction, automotive, and aircraft industries, in the production of metal alloys, in the electric industry, in cooking utensils, and in food packaging. Aluminum compounds are used as antacids, antiperspirants, and food additives. Aluminum salts are also widely used in water treatment as coagulants to reduce organic matter, colour, turbidity, and microorganism levels. The process usually consists of addition of an aluminum salt (often sulfate) at optimum P^H and dosage, followed by flocculation, sedimentation, and filtration. Symptoms including nausea, vomiting, diarrhea, mouth ulcers, skin ulcers, skin rashes, and arthritic pain were noted. It was concluded that the symptoms were mostly mild and short-lived. No lasting effects on health could be attributed to the known exposures from aluminum in the drinking-water (WHO, 2004).

2.2.11 Total Hardness (TH)

Hardness is the property of water which prevents the lather formation with soap and increases the boiling points of water. Hardness of water mainly depends upon the amount of calcium or magnesium salts or both (V.T. Patil *et al*, 2009)

2.2.12 Electrical Conductivity (EC)

Electrical conductivity is a measure of water capacity to convey electric current. It signifies the amount of total dissolved salts.

.2.3 System Risk Assessment

Important factors in collecting and maintaining good quality rainwater include proper design and installation/construction of rainwater harvesting systems. Materials used in the catchment and storage tank should be suitable for use in contact with drinking-water and should be non-toxic to humans. Rainwater can be harvested using roof and other above-ground catchments and stored in tanks for use. The roof catchment is connected with a gutter and down-pipe system to deliver rainwater to the storage tank. The quality of rainwater is directly related to the cleanliness of catchments, gutters and storage tanks. Rooftop catchment surfaces collect dust, organic matter, leaves and bird and animal droppings, which can contaminate the stored water and cause sediment buildup in the tank. Care should also be taken to avoid materials or coatings that may cause adverse taste or odour, and some metals can dissolve to give high concentrations in water. Regular cleaning of catchment surfaces and gutters should be undertaken to minimize the accumulation of debris. Wire meshes or inlet filters should be placed over the top of down-pipes to prevent leaves and other debris from entering storages. These meshes and filters should be cleaned regularly to prevent clogging. The first flush of rainwater carries most contaminants into storages. A system is, therefore, necessary to divert the contaminated first flow of rainwater from roof surfaces. Some devices and good practices are available to divert the first foul flush of rainwater. Automatic devices that prevent the first 20–25 litres of runoff from being collected in storages are recommended. If diverters are not available, a detachable down-pipe can be used manually to provide the same result. Even with these measures in place, storages will require periodic cleaning to remove sediment. Storages without covers or with unprotected openings will encourage mosquito breeding and sunlight reaching the water will promote algal growth. Covers should be fitted, and openings need to be protected by mosquito-proof mesh. Cracks in the tank and withdrawing of water using contaminated pots can contaminate stored water. Storages should preferably be fitted with a mechanism such as a tap or outlet pipe that enables hygienic abstraction of water. Some households incorporate cartridge filters or other treatments at the point of consumption to ensure better quality of drinking-water and reduce health risk. (www.who.int).

2.4 The Growing Role of Roofwater Harvesting

Water professionals are becoming increasingly worried about water scarcity. The UN World Water Development Report of 2003 suggests that population growth; pollution and climate change are likely to produce a drastic decline in the amount of water available per person in many parts of the developing world. Domestic Roof water Harvesting (DRWH) provides an additional source from which to meet local water needs. In recent years, domestic rainwater harvester systems have become cheaper and more predictable in performance. There is a better understanding of the way to mix domestic rainwater harvester with other water supply options, in which domestic rainwater harvester is usually used to provide full coverage in the wet season and partial coverage during the dry season as well as providing short-term security against the failure of other sources. Interest in domestic rainwater harvester technology is reflected in the water policies of many developing countries, where it is now cited as a possible source of household water. Rainwater systems deliver water directly to the household, relieving the burden of water-carrying, particularly for women and children. This labour-saving feature is especially crucial in communities where households face acute labour shortages due to the prolonged sickness or death of key household members, increasingly as a result of HIV/AIDS, coupled with a reduction in the availability of labour due to education and migration (Thomas, and Martinson, 2007).

2.4.1 Groundwater Recharge

Rainwater may also be used for groundwater recharge, where the runoff on the ground is collected and allowed to be absorbed, adding to the groundwater. In the US, rooftop rainwater is collected and stored in sump. In India this includes Bawdis and johads, or ponds which collect the run-off from small streams in wide area. In India, reservoirs called tankas were used to store water; typically they were shallow with mud walls. Ancient tankas still exist in some places.

2.5 The Basic Roofwater Harvesting System

Rain falls onto roofs and then runs off. The run-off is extremely variable – for the typically 99% of each year that it is not raining, run-off flow is zero. However if the run-off is channeled into a tank or jar, water can be drawn from that store whenever it is needed, hours, days or even months after the last rainfall. Moreover as the jar is generally located immediately next to the building whose roof the rain fell on, roof water harvesting is used to supply water to that very building, with no need for the water to be carried or piped from somewhere more distant. The essential elements of a roof water harvesting system, as shown in Figure 2.1, area suitable roof, a water store and a means of leading run-off flow from the first to the second. In addition, some rainwater harvesting systems have other components to make them easier to manage or to improve the quality of the water (Thomas, and Martinson, 2007).

Plate 2.1 Picture of a simple domestic Rainwater harvesting system in Bosso Minna, Niger state.

2.5.1 The Roof

Roofs are made of a variety of materials and most, with the exception of those made from grass/reed and potentially toxic materials, are suitable as rainwater catchment surfaces. The typical roofing materials are metal sheets, ceramic tiles, rock slate and Ferro cement. Probably the most common form of roofing in the Pacific Islands is corrugated galvanized steel sheets. Galvanizing protects the steel from corroding by coating with zinc compounds. Metal sheet roofs are comparatively smooth and are less likely to retain contamination (e.g. dust, leaves, bird droppings) than rougher concrete tile roofs. They may also get hot enough in the tropical Pacific islands to sterilize themselves. Metals such as zinc, copper and lead, can be present at quite high levels in rainwater that has come into contact with metallic roofs (e.g. galvanized iron for zinc) or fittings (lead and copper flashings). Fortunately zinc has a low toxicity to humans, so that run-off water from the common galvanized steel roofs should not exceed WHO permitted zinc. Lead materials are sometimes still used at roofing joints and this may result in hazardous levels of lead in water collected. Therefore lead fittings are not recommended. The collection of water from metallic roofs in islands where acidic rain is present should be cautioned as more corrosion and leaching of metals from roofs will occur under these conditions. Metal roofs that are visibly corroded should preferably be repaired or replaced. However, the iron in rain runoff from a rusting roof is unlikely to cause any health problems although it may be unsightly. Roofing material is often supplied with a paint coating or sometimes painting is performed on site. Certain types of paints may leach toxic compounds so they should be checked for suitability before a roof is painted. New acrylic-based paints designed for exterior and roof use in the tropics are recommended, and their suitability for drinking water collection should be queried. Paints containing lead, chromate, tar/bitumen, fungicides or other toxins should not be used as they may create a risk to health and/or may impart an unpleasant taste to the water. After repainting of a roof, the runoff water from the first rainfall should be prevented from entering the storage tank and discarded or used for non-drinking purposes. The safety of water harvested from 'asbestos' (asbestos-reinforced cement mortar) roofs has been queried, but the consensus is that the danger of developing cancer from ingested asbestos is very slight. The danger from inhaled asbestos dust is however sufficiently high that working with asbestos sheeting, for example sawing it, without special protection is now generally banned. It is recommended that any tree branches overhanging the roof are trimmed to minimize the amount of leaves and bird droppings falling onto the roof. Rodents and mongooses should not be able to get onto the roof as they may introduce pathogenic bacteria to the water. Leaves and other debris should be cleaned off roofs and out of gutters at least once a month. The more you do to keep a roof clean, the better the water quality will be. (Luke, 2005)

2.5.2 Historical Background Of Galvanized Roofing Sheet

Galvanized metal was named after the Italian scientist, Luigi Galvani. In 1783 he had a dissected frog on the same table he was using while conducting an experiment on static electricity. When he touched the sciatic nerve of the dead frog with his metal scalpel, the frog's leg moved. He called it "animal electricity," but his fellow scientists referred to it as galvanizing. It was in 1923 that the first piece of galvanized metal was used by the Baldwin brothers. They constructed the Gleaner Combine Harvester, the first harvester to be self-propelled. It was also the first time galvanized metal was used in construction.

2.5.3 Significance

Galvanized metal has many uses in today's world. Due to the type of processing it undergoes, it is considered to be the most durable and reliable steel to use in the world of construction. It has been shown that galvanized metal can be recycled and re-used, even after sixty years or more of prior use. It is a product that many opt for when constructing large buildings because of its ability to resist rust and corrosion from natural elements, and has proven itself much stronger than average steel which has a tendency to weaken over time.

2.5.4 Function

Galvanized metal goes through a processing which involves a piece of steel or metal being submerged in melted zinc. It is during this process of galvanizing that the zinc chemically reacts to the molecules in the metal, permanently bonding it to the metal. The zinc provides protection against rust and corrosion that the natural elements have a tendency to cause; elements that weaken unprocessed steel or metal. It is because of this that galvanized metal is used in the construction of warships and submarines, large buildings found in the big cities, roof tops and housing, and as vents for heating and cooling systems. Not only is it a reliable construction source, it is also inexpensive, given the fact that it can be reused multiple times.

2.5.5 Types

Galvanized metal comes in many forms: Sheet metal which is used for roof tops and machinery. Steel structures which are used to build guard rails and large buildings. Heating and cooling fans and vents which are used in air ducts. Pipes which are used as underground water pipes. And cable wire which is used for cranes.

2.4.6 Considerations

Galvanized metal can be painted, but it requires a primer made especially for it. You need to be sure that the surface of the metal is free of alkaline build-up and then add the metal primer. You can then paint it with latex paint. Any oil or alkyd based paints should not be used; they do not mix well with the chemicals found in galvanized metal. Also, any product containing galvanized metal should not be used for any form of food preparation or storage. The acids found in food could dissolve in the zinc, making the person eating the food extremely ill.

2.5.7 Warning

Many illnesses, some life threatening, can occur as a result of exposure to high levels of zinc. Since zinc is the main chemical in galvanized metal, precautions need to be taken. Galvanized metal workers are at a higher risk than many. While small amounts of zinc are acceptable, high levels like those found in galvanizing plants are not. Occupational Safety and Health Administration (OSHA) has regulated the amount of zinc these workers can be exposed to in a day due to the fact that it can be deadly. If over-exposure has occurred, the initial symptoms would be nausea, vomiting, and stomach cramps. More serious symptoms include a low blood pressure, jaundice, fever, and seizures. If any of the symptoms occur, give the

The rainwater reaching a roof in a year can be estimated as the annual rainfall times the roof's plan area, but in the tropics only about 85% of this water runs off the roof. The remaining 15% is typically lost to evaporation and splashing. If the rain falls mainly as light drizzle, as in some more temperate countries, even more than 15% will be lost in this way through slow evaporation. Often, and especially in areas of low annual rainfall, the available roof area is not big enough to capture enough water to meet all the water needs of people in the building. In this case, either the roof must be extended, or roof water harvesting can only be one of a number of sources of water to meet need. In fact, getting water from more than one source is the usual practice in most rural areas of developing countries, and is reviving in popularity in richer countries (Thomas, and Martinson, 2007).

2.5.8.2 The Path Of Contamination

When considering the water quality of a roof water system, it is useful to observe the complex path a contaminant must follow in order to enter a human being. The usual paths are shown in Figure 2.2.

Roof water harvesting generally represents a hostile environment for microbiological contaminants and presents a number of barriers to chemical contaminants. The primary means of tank contamination is through water washed in from the roof, although the main reason for most outbreaks of reported disease is direct entry to water in the tank either via a vector, such as a rat, lizard or insect, or because of an accident. Material washed in from the roof can come from several sources:

• By far the largest contribution will come from material that has accumulated on the roof or is blown onto the roof during a storm. Accumulated material may have been blown onto the roof by the wind, stirred up by passing vehicles, dropped from overhanging trees or deposited by an animal (or person) with access to the roof.

• If the roof is made of decayed materials, the roof itself can contribute to the dirt load. This is particularly true of low-quality roof materials such as thatch or tar sheets, though asbestos sheeting and galvanised iron (particularly if it is rusty) can also add material to incoming water.

• Passage of water along unclean gutters may add further debris (Thomas, and Martinson, 2007).

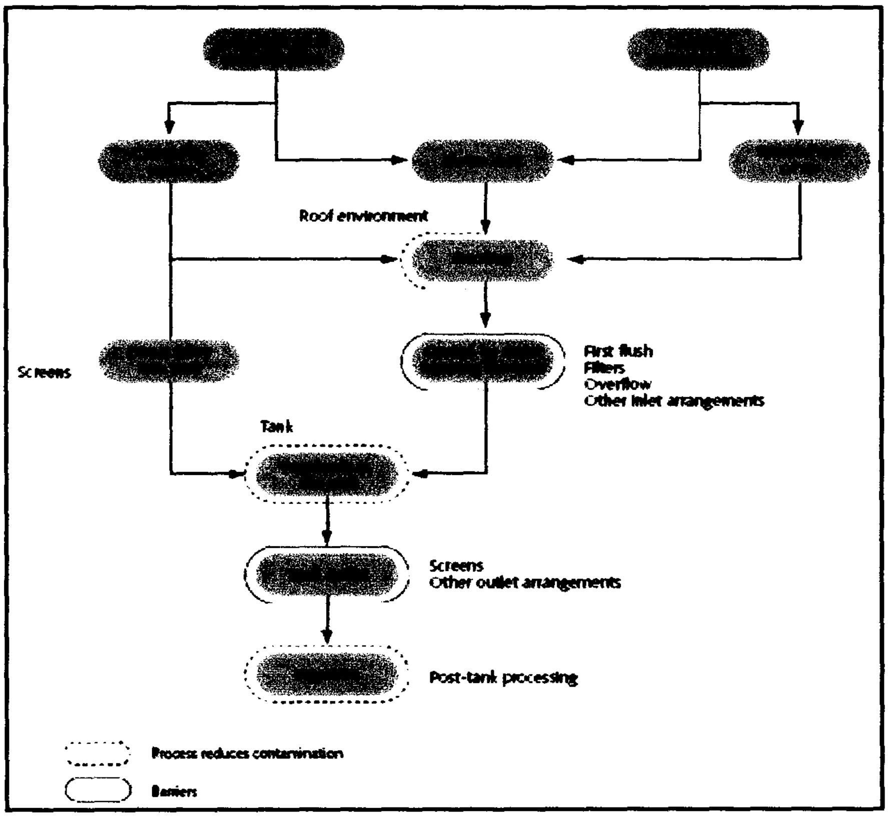

Figure: 2.2 Contamination paths for roof water harvesting

2.5.8.3 Factors Affecting Runoff

Considering the short length of building roofs, a theoretical analysis of the first flush of roof runoff was conducted based on the kinematic wave and pollutant erosion equations. This mathematical derivation with analytical solutions predicts pollutant mass first flush (MFF), mean concentration of initial runoff (MCIF), mean concentration of roof runoff (MCRR) with diversion of initial portion and residual mass available on the bed surface (RS) after the entire runoff under the condition of constant excess rainfall. And the effects of the associated influencing factors (roof length, roof gradient, roof surface roughness, rainfall intensity, rainfall duration, and erosion coefficients) on them were discussed while the values of parameters referred to the previous studies.

The results showed that for roofs whose length is shorter than 20 m, both the increase in roof length and roof gradient and the decrease in roof surface roughness result in larger MFF and MCIF and smaller MCRR and RS, which is beneficial to water reuse and pollution reduction. The theoretical relationship between the first flush and the influencing factors may aid the planning and design of roof in terms of rainwater utilization or diffuse pollution control (Biao, and Tian, 2009).

Table: 2.1. Characteristics of roof types

Type	Run-off coefficient	Notes
Galvanised Iron Sheets	>0.9	• Excellent quality water. Surface is smooth and high temperatures help to sterilise bacteria
Tile (glazed)	0.6 – 0.9	• Good quality water from glazed tiles. • Unglazed tile can harbour mould • Contamination can exist in tile joints
Asbestos Sheets	0.8 – 0.9	• New sheets give good quality water • No evidence of carcinogenic effects by ingestion • Slightly porous so reduced run-off coefficient and older roofs harbour moulds and even moss
Organic (Thatch, Palm)	0.2	• Poor quality water (>200 FC/100 ml) • Little first-flush effect • High turbidity due to dissolved organic material which cannot easily be filtered or settled out

2.6 Guttering

The arrangement for leading water from the roof to the water store is usually called 'guttering' or 'gutters and downpipes'. The gutters are open channels carrying water sideways under the edge of the roof to a point just above the water store; the downpipes are tubes leading water down from the gutters to the entrance of the water store. There are many ways of achieving the transfer of water from roof to store – for example in Northern China the run-off is allowed to fall from the roof edge onto a paved courtyard and there led towards an underground tank. However guttering is the most popular method because it helps keep run-off water clean (Thomas, and Martinson, 2007).

Table 2.2: The following table describes some of the roofing choices available.

Roof Type	House Style	Advantages	Disadvantages
Composition (asphalt shingles) 	Can be used on any house from contemporary to historic. False thatched roof with the wrapped roof edge on 1920s Tudor style.	• inexpensive • ranges from low-cost 3-tab shingle to architectural shingles with extra durability and style • many colors, types, and manufacturers • suitable for most residential applications • easy to repair • fire resistant	• relatively short life-span (15–30 years) • scars easily when hot • subject to mildew and moss • environmentally unfriendly
Wood shingles or shakes 	Bungalows, ranch, contemporary, cottage, historic	• natural look weathering to a soft grey • offers some insulation value • blends in with the environment • easy to repair or replace • long lasting if maintained (30–50 years)	• expensive • usually requires professional installation • high maintenance • tends to rot, split, mold, and mildew • poor fire rating unless presure treated
Metal (steel, aluminum, tin, copper) 	Bungalows, ranch, contemporary, cottage, historic (virtually all)	• available in different looks including cedar shingles, slate, or standing seam • many colors • light weight • durable • long life span (at least 50 years)	• may be difficult to install • can be expensive • may need periodic painting

		• low maintenance • can be installed over existing roofs • excellent performance in high wind, hail and rain • environmentally friendly	
Tile (concrete, clay) 	Mediterranean, Italian, French Eclectic, Spanish Eclectic, Beaux Arts, Mission, and Prairie. May also be attractive on some contemporary or ranch style homes.	• non-combustible • many colors and styles • attractive • fireproof • easy to maintain • extremely durable when maintained	• expensive • heavy • used primarily in new buildings because of weight and structural requirements • installation and repairs can be tricky • fragile; walking on roof may break tiles
Slate 	Colonial, French, Italianate, Exotic Revivals, Chateauesque, Beaux Arts	• beautiful, distinctive appearance • fireproof • long life span • low maintenance	• very expensive • requires specialized installation • heavy • fragile • high maintenance
Concrete (fiber reinforced)	Virtually any style of home	• many colors and styles including shakes, tile, and stone • relatively lightweight • fire and insect resistant; meet many of the more restrictive fire codes • low maintenance • extremely durable • resource efficient	• can be expensive • uneven quality among products

2.7 Storage Systems

Storage facility: There are various options available for the construction of these tanks with respect to the shape, size and the material of construction.

Shape: Cylindrical, rectangular and square.

Material of construction: Reinforced cement concrete, (RCC), ferrocement, masonry, plastic (polyethylene) or metal (galvanized iron) sheets are commonly used.

Position of tank: Depending on space availability these tanks could be constructed above ground, partly underground or fully underground. Some maintenance measures like cleaning and disinfection are required to ensure the quality of water stored in the container (Rainwater harvesting.org).

The tank or jar used to store water in a roof water harvesting system is usually its most expensive component. If we choose to make it very large, the system will make the best use of the water running off the roof but will incur a high cost. If we choose a very small tank, the system will be cheap but will waste quite a lot of the available water because the tank will sometimes overflow. So 'sizing a tank' means choosing the best compromise between good performance and low cost. Often there are only a few tank sizes available, so sizing means choosing which of these offers the best value. Sizing can be done by custom (use the size everyone else in the district has been using for years), or by price alone (use the biggest tank you can afford) or by some sort of calculation. This chapter presents ways of calculating what size is best for in a particular house. That 'best size' is not the same for all houses, but depends upon the climate, the roof size, the number of people living in the house, the way the household manages its rainwater supply and the household's wealth (Thomas, and Martinson, 2007).

The time that water spends in the tank provides opportunities for purifying processes such as sedimentation and bacterial die-off to take place, increasing water quality over time. If, however, the tank is poorly designed, built or maintained, storage may conversely provide further opportunities for pollution. If light is allowed to enter the tank, (particularly if it is open-topped) an active ecosystem may develop in the tank resulting in stagnant water of very poor quality. Once the water has resided in a well designed tank for some time, it should be safe for drinking without further treatment, although some feel safer if the water is further treated. Rainwater is soft and has a very low turbidity so it makes an excellent candidate for many household treatment processes such as boiling, SODIS or biosand filters (Thomas, and Martinson, 2007).

2.7.1 System Sizing

It is important that the system is sized to meet the water demand throughout the dry season. Generally speaking, the size of the storage tank should be big enough to meet the daily water requirement throughout the dry season. In addition, the size of the catchment area or roof should be large enough to fill the tank.

Plate 2.3: A storage tank made of galvanised iron sheets

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

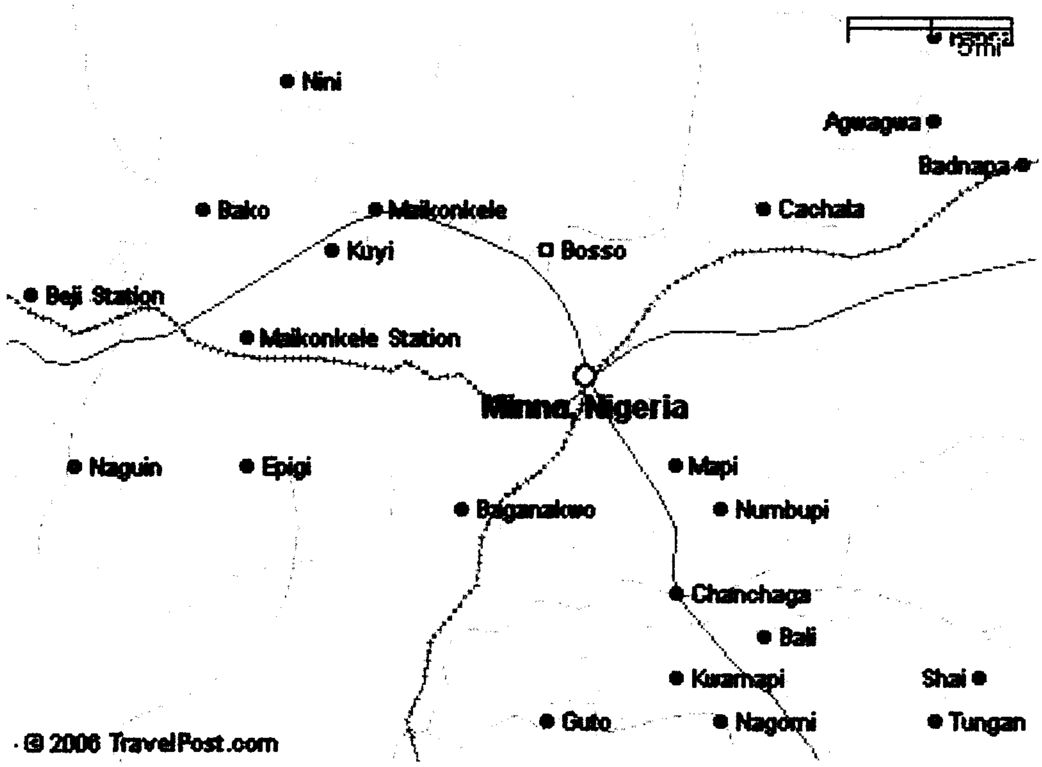

Figure 3.1: An Abridge Map of Niger State Showing the Study Site

Figure 3.1 shows the position of the project study area on a map (abridged Niger State map). Niger state is situated in the middle belt of the federal republic of Nigeria. It lies in the savanna zone of the tropics between latitude (8^0 10^1N and 11^0 30^1N) and longitude (3^0 30^1E and 7^0 30^1E).

3.1.1 Climate

Its climate is influenced mainly by the rain-bearing South West monsoon winds from the oceans and the dry dusty or harmattan North East winds (air masses) from the Sahara desert.

There are mainly the rainy and the dry seasons. The rainy season begins in April and ends in October and the dry season starts in November and ends in March.

3.2 Data Collection and Analysis

In Task 1, roofing materials that are commonly used in Minna, Niger state for rainwater harvesting were identified to be galvanized metal sheets.

In Task 2, three water samples from the selected sites were collected during May 2009 and taken in pre-cleaned polyethylene bottles that have been cleaned and rinsed carefully, given a final rinse with de-ionized or distilled water and sterilized properly. Samples were collected that are representative of the water being tested; sample ports were flushed or disinfected and aseptic techniques was used to avoid sample contamination. Sampling bottles were kept closed until it is to be filled. After removing stopper or cap, the containers were filled with water and the caps were replaced immediately in order to avoid contamination as much as possible.

The samples after collection were immediately placed in dark boxes and processed within 24 hours of collection with no preservatives added.

The three locations where samples were collected are

- Galvanized rooftop (A)
- Well (B)
- Bore hole (C)

In task 3, samples were taken and analyzed for quality parameters (pH, alkalinity, Hardness, turbidity, TDS, COD, NO_3, NH_4, PO_4, Pb, Fe, Cr, Al, F, Cl, Cu, Colour, hardness, Zn, SO_4, Mn). Additionally, these samples were tested for contamination of biological and microbiological contents. TCC, E.Coli bacteria.

3.3 Physiochemical Analysis

The sample test was carried out at the Niger state water board by a laboratory technologist. The procedures for the physiochemical analysis are described below.

3.3.1 Alkalinity

100ml of the sample was measured into a conical flask and drops of phenolphthalein indicator were added. 3 drops of methyl orange were added to the solution when colour change was not noticed until there was change in colour which was yellow. The resultant yellow colour solution was titrated with against diluted sulphoric acid until a pink colour was observed.

3.3.2 Total Hardness (TH)

Fill the sample chamber to the 12.9 ml line with the water sample. Add 5 drops of Hardness Reagent to the water sample and swirl to mix. Add one Hardness Reagent, cap and shake tube to dissolve tablet. A red color will develop. Fill the titrator with Hardness Reagent in the manner described in lab. While gently swirling the sample, titrate with Hardness Titration Reagent until the color changes from red to clear blue. Read test results where the plunger tip meets the titrator scale. Each minor division = 4 ppm.

3.3.2.1 Calcium Hardness

Fill the Titration Chamber to the 12.9 ml line with the water sample to be tested. Add 6 drops of Sodium Hydroxide Reagent to the test sample. Cap, and swirl to mix. Add one Calcium Indicator Tablet to the test sample, cap and shake to dissolve the tablet. A red color will appear. Titrate with Hardness Titration Reagent as described in the Total Hardness Test. The titrating reagent is added until the red color changes to blue. The results are read as described in the Total Hardness Test and expressed as Calcium Hardness in ppm $CaCO_3$.

3.3.2.2 Magnesium Hardness

Magnesium Hardness is determined by subtracting Calcium Hardness from Total Hardness. (Calcium Hardness + Magnesium Hardness = Total Hardness).

3.3.3 Iron (Fe^{2+} and Fe^{3+})

Rinse the test tube with the water to be tested, and fill to the 5 ml line. Add five drops of iron Reagent 1 Solution. Cap the tube and shake to mix the solution. Using the 0.05 g. measuring spoon add one level measure of iron Reagent 2. Cap tube and shake to dissolve powder. Let stand 3-5 minutes for maximum color development. Insert the test tube in the Comparator and match the test sample color against the color standards. Express as ppm Iron.

3.3.4 Chloride (Cl^-)

Fill the sample titration chamber to the 15 ml line with the water sample to be tested. Add one drop of Phenolphthalein Indicator to the sample. If the solution remains colorless, proceed to step 3. If the sample turns pink, add Sulfuric Acid 0.5N, one drop at a time, mixing after each drop, until the pink color disappears. Add 3 drops of Chloride Reagent to the sample in the titration chamber. Place the cap on the chamber and swirl to mix. A yellow color will develop. Fill the titrator with Chloride Reagent in the manner described in the instruction manual. Insert the titrator in the center hole of the cap. Titrate with Chloride Reagent until the yellow color is permanently changed to a salmon color. Be careful not to overshoot the endpoint. Read the test results in ppm Chloride where the plunger tip meets the titrator scale. Each minor division = 4 ppm.

3.3.4.1 High Chloride Readings

For high chloride readings, the sample being tested must be diluted carefully with deionized water to bring it within the range of the test procedure. The results are multiplied by the dilution factor.

3.3.5 Nitrate (NO_3^-)

Fill a test tube to the 5 ml line with the water sample. Add one Nitrate Tablet .Cap and mix until tablet dissolves. Add one Nitrate CTA Tablet. Cap and mix until tablet dissolves. Wait 5 minutes. Insert Nitrate-Nitrogen Octa-Slide into the Octa-Slide viewer. Insert test tube into viewer. Match sample color to one of the color standards. Record as mg/L Nitrate-N. Nitrate-N may be converted to Nitrate by multiplying by results by 4.4.

3.3.6 pH

Fill test tube to the 5 ml line. Add 10 drops of pH Indicator solution and shake. Place test tube in Comparator and compare with color standard.

3.3.7 Sulfide

Fill test tube to 5 ml line with water sample. Add 15 drops of Sulfide Reagent. Cap, and gently invert to mix. Add 3 drops of Sulfide Reagent. Cap and mix. In the presence of sulfide these two reagents combine to form Methylene Blue. After 1 minute, use the dropper to add 1 ml of Sulfide Reagent. Cap and mix. This reagent is added prior to making the color comparison to offset any color due to the presence of ferric iron. Place the test tube in the Sulfide Comparator and compare color to standards. Results are expressed in ppm Sulfide.

3.3.8 Electrical Conductivity

The temperature of the water sample was adjusted close to 20^{0}C, the conductivity cell was washed with a volume of the sample and then filled completely to ensure that no air bubbles adheres to the electrodes, and processed according to manufacturer's instructions. Since the instrument does not automatically compute for temperature differences, the electrical conductivity observed was multiplied by 1/ (1-0.0022(20-t)). Where t is the sample temperature (^{0}C).

3.3.9 Total Dissolved Solids (TDS)

The empty dish was weighed and 100ml of the water sample was poured into the dish and evaporate on a water bath. The concentration was dried in an oven at 150^{0}C for 30 minutes. The dish was cooled in desiccators and weighed. The increase in weight over the empty dish represents the total dissolved solids. The cycle of drying was repeated until accountant weight was obtained and recorded.

3.3.10 Colour

The colour of the sample, were observed by filling one clean test tube with distilled water and another with water sample and comparison was made between the two solution and the colour was noted.

3.3.11 Suspended Solids (mg/l)

The filter was washed in filter holder under suction with successive small volumes of laboratory water. The filter paper was removed and placed in the Aluminum dish and oven at 105°C for 1hr cool in desiccators and weighed. The procedure was repeated until the drift is less than 0.5mg. This filter was placed and dumped with laboratory water and the accurate volume of well-mixed water sample (100-500ml) and filter under slight suction then the filter was removed and dried in the oven at 105°C for 1hr and recorded.

CHAPTER FOUR

4.0 RESULT AND DISCUSSIONS

4.1 Results

The results of the physiological analysis carried out on water samples gotten from these three (3) sources, galvanized rooftops (A), borehole water (B) and shallow well (C) are presented in Table 4.1 below

Table 4.1: Physiochemical Analysis of Water samples.

S/N	PARAMETERS	SAMPLE A (galvanized roof)	SAMPLE B (well)	SAMPLE C (borehole)
1	Electrical conductivity (us/cm)	176	104	230
2	Total dissolved solid (mg/L)	88	52	115
3	Temperature in lab. (^{0}C)	23.2	23.2	23.2
4	Suspended solids (mg/L)	0	2.8	0
5	Turbidity (NTU)	2.1	6.7	1.8
6	Colour	4.0	8.4	3.3
7	pH	7.2	6.6	7.5
8	Iron	0.14	0.21	0.03
9	Sulphate (mg/L)	0.9	29	26
10	Nitrate as Nitrogen (mg/L)	6.1	5.2	4.7
11	Nitrate (mg/L)	28.0	24.1	23.1
12	Total hardness (mg/L)	55	39	93
13	Hardness (ca) as $caco_3$	22.1	16.3	38.8
14	Hardness (mg)	34.5	25.0	58.3
15	Total Alkalinity (mg/L)	48.7	52	81.1

16	Zinc (mg/L)	6	4	-

The table below represents the Comparism of both results from water sample analysis and WHO's Guidelines for drinking water quality in 2006. Results would be discussed in order to see if the results of water samples taken is in line with the WHO's allowable limits.

Parameter	SAMPLE A (galvanized roof)	SAMPLE B (well)	SAMPLE C (borehole)	WHO guideline
pH	7.2	6.6	7.5	6.5 to 8.5
Total dissolved solids (mg/ l)	88	52	115	500
Total suspended solids	0	2.8	0	*
Sulphates (mg/ l)	0.9	29	26	250
Turbidity (NTU)	2.1	6.7	1.8	5
Colour	4.0	8.4	3.3	15
Nitrates (as NO_3-N mg/ l)	6.1	5.2	4.7	10
Total Alkalinity (mg/L)	48.7	52	81.1	100
Iron (mg/ l)	0.14	0.21	0.03	0.3
Hardness (Ca) (mg/ l)	22.1	16.3	38.8	200
Hardness (Mg) (mg/ l)	34.5	25.0	58.3	200

Electrical conductivity us/cm)	176	104	230	1000
Total hardness(CaCO3 mg/l)	55	39	93	500
Zinc (mg/L)	6	4	-	3.0

* no WHO guideline

TABLE 4.2: WHO's guidelines for drinking water quality

4.2 Discussion of Parameters

4.2.1 Electrical Conductivity (US/CM).

Electrical Conductivity (EC), also called specific conductance, is a measure of ability of water sample to convey an electric current and it is related to the concentration of ionized substance in water.EC Were 176, 104, and 230 for samples of 'A' galvanized rooftop rainwater, 'B' shallow well and 'C' borehole samples. These values, when compared to the guidelines were below the 1000uS/cm World Health Organization (WHO) limits. It therefore poses no salinity problem and there is no restriction on the use of the water consumption. Conductivity can be used as an approximate measure of the total concentration of inorganic substances in water. Conductivity is often used to express the mineral content of water sample. It is an important measurement in waters destined for various uses; irrigation, drinking, food industry and industrial boilers.

4.2.2 Total Dissolved Solids (TDS) (mg/L)

Total Dissolved Solids of the samples were 88, 52, and 115 respectively for the three samples collected. They are compared to the guidelines and were found to be below the 500mg/L WHO limits. Hence the water does not pose any threat. Total Dissolved Solid is generally satisfactory for domestic use and many industrial purposes.

4.2.3 Temperature in Lab (°C)

The temperature of water is an important parameter because of its effect on chemical reactions and reaction rates, and aquatic life. Temperatures were 23.2, 23.2, and 2320 respectively, which is lower than the WHO limits. Therefore the water temperature will not cause harm to aquatic life and other beneficial uses. Optimal temperatures for bacterial activity are in range from 25 to 35°C. Aerobic digestion and nitrification stops when the temperature rises to 50°C.

4.2.4 Suspended Solids (mg/L)

Suspended solids were 0, 2.8 and 0 respectively, suspended solids of both samples taken from galvanized roof (A) and borehole (C) were found to be 0 and that of sample B was seen to be present as 2.8, this is due to screening process that takes place through the soil particles in wells. All three samples are compatible for domestic purposes because WHO does not state any limit for maximum allowance, note: the lower the values of this parameter the lower the contamination of water.

4.2.5 Turbidity (NTU)

Turbidity is the degree to which water looses its transparency due to the presence of suspended particulates. Turbidity values obtained were 2.1, 6.7 and 1.8 respectively; from the result obtained in sample 'B' has turbidity above WHO recommendation which poses threats of absorbing heat from the sunlight, making turbid waters becomes wormer, and so reducing the concentration of oxygen in the water.

In most waters, turbidity is due to colloidal and extremely fine dispersions.

4.2.6 Colour (pt.Co).

Colour was 4.0, 8.4, and 3.3 for all three samples analysis and they are found to be lower than world health organization standard which is 15. Therefore by this WHO standard it clear that the three water samples are good for domestic activities.

4.2.7 pH

The pH is a measure of the acidity or alkalinity of the water. The pH obtained was 7.2, 6.6 and 7.5 respectively; In general, water with pH <7 is considered acidic and with a pH >7 is considered alkaline or basic, Most of the waters are slightly alkaline due to presence of carbonates and bicarbonates. The normal pH range value of WHO is 7.0-8.5, and it is recommended for drinking and other domestic uses and also for agricultural purposes.

4.2.8 Iron Content (mg/L)

Iron content obtained was 0.14, 0.21, and 0.03 respectively; these values when compared to the guidelines and were found below 0.3mg/l WHO limits. Water for domestic and industrial use is generally required to contain less than 0.2-0.3mg/l. Despite being the second most abundant element on earth's crust iron is present in relatively small amount in natural waters. High concentration of iron is not known to have any adverse health effects; however they may lead to other problem.

4.2.9 Sulphate (mg/L)

Sulphate (SO_4^{2-}) is a major ion occurring in water, the main natural source of sulphate in surface and ground water is the processes of chemical weathering and dissolution of sulphur-containing minerals, predominantly gypsum ($CaSO_4.2H_20$). Other natural sources are the oxidation of sulfides and elemental sulfur, and the decomposition of animal and plant residues. Sulphate values obtained were 0.9, 29, and 26 respectively; it was observed that the values obtained were very low compared to guideline of WHO 200mg/l limits allowing it to be safe for usage.

4.2.10 Nitrates

The presence of nitrate ions in unpolluted surface is due mainly to processes in the water body itself, such as nitrification. The nitrate content of drinking water is rising at an alarming rate in both developed and developing countries owing largely to lack of proper sewage treatment, and excessive fertilizer application. The WHO drinking water guideline is 50mg/l no adverse effects have been observed with water concentration <20-30mg/l, expect for mathaemoglobinemia in infants. Nitrate in drinking water is a major health concern because of its toxicity, especially to young children.

Nitrogen compounds are of interest to environmental engineers because they are both essential nutrients, beneficial to living organisms, and pollutants. With potentially harmful consequences. Nitrogen pollution can exist in seven different oxidation states and its environmental chemistry is consequently quite complex. Nitrogen pollution can have potentially harmful effects in surface and ground waters, and these are causing considerable current concern. Nitrate of Nitrogen values obtained were 6.1, 5.2, and 4.7 respectively and nitrate are as follows 28.0, 24.1 and 23.1 respectively; these values when compared to the guideline were below the 50mg/l WHO limits.

4.2.11 Total Hardness (Ca) and Hardness (Mg)

The hardness of water is characterized by its ability to form lather with soap. Total hardness is defined as the sum of Ca and Mg concentrations expressed as calcium carbonate in mg/l or ppm. Hardness (Ca) is due to magnesium in the water only. Total hardness of (Ca and Mg) values obtained was 22.1, 16.3 and 38.8 respectively, and 34.5, 25.0 and 58.3 respectively.

The values obtained from the total hardness do not exceed WHO limit therefore it is good for consumption, no guide by WHO to compare the calcium and magnesium hardness.

4.2.12 Total Alkalinity

Total alkalinity is the total concentration of bases in water expressed as parts per million (ppm) or milligrams per litre (mg/l) of calcium carbonate ($CaCO_3$). Total alkalinity values obtained are as follows 48.7, 52, and 81.1 respectively. Water with high total alkalinity is not always hard, since the carbonates can be brought into the water in the form of sodium or potassium carbonate. An important environmental aspect of alkalinity in natural water is the capacity to neutralize acidity originating from atmospheric decomposition. Although alkalinity has a little public health significance, highly alkaline waters are unpalatable and are not used for domestic water supply. But all the results obtained proved no harm since it is below WHO limits. The lower the alkalinity, the more likely water is to be corrosive. Water with high alkalinity (greater than 150mg/l) may cause scale (lime) buildup in plumbing.

4.2.13 Zinc

Zinc content obtained was 6, 4, and 0 respectively; these values when compared to the guidelines, it was noticed that sample from galvanized iron roof and well sample were found above 3.0mg/l WHO limits.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The results from the physiochemical analysis of water samples collected from galvanized rooftop, borehole and well shows that the water is pure and wholesome free from high concentration of contaminants and can be used for drinking, domestic or agricultural purpose. This was arrived at, after the comparism of these water samples contamination concentrations with the WHO maximum permissible limits for contamination. However, the simple first flush was effective in eliminating bacteriological contamination, Rainwater was of higher quality than water supplied by a water utility, borehole and shallow well water.

High zinc concentration in the roof water was attributed to the galvanised iron sheets used for roofing and rain guttering.

It was therefore possible to harvest rainwater that could meet the WHO guidelines as long as materials used to construct RWH systems were carefully selected to avoid contamination of the rainwater. Simple disinfection methods such as boiling and chlorination are recommended if water is to be used for drinking purposes.

5.2 Recommendations

Roof catchment systems channel rainwater that falls onto a roof into storage via a system of gutters and pipes. The first flush of rainwater after a dry season should be allowed to run to waste as it will be contaminated with dust, bird droppings etc. Roof gutters should have sufficient incline to avoid standing water. They must be strong enough, and large enough to carry peak flows. Storage tanks should be covered to prevent mosquito breeding and to reduce evaporation losses, contamination and algal growth. Rainwater harvesting systems require regular maintenance and cleaning to keep the system hygienic and in good working order (Rainwater Harvesting, Wikipedia 2009).

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