DOMESTIC WATER TREATMENT IN IKOLE EKITI USING MORINGA OLEIFERA SEED POWDER

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BY

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ABSTRACT

Most people living in rural communities, have no access to good domestic water for consumption. The inhabitants depends on rain water, well water and sometimes surface water for consumption. Improper treatment of water gotten from these sources, can lead to the spread of water borne diseases, because, sometimes the water gotten from these sources are turbid. Although, some inhabitants use alum to treat the water so as to make the water clear. But excessive usage of alum to treat water can induce Alzheimers disease. It is in this light that this research was carried out to confirm the effectiveness of powder extracted from mature-dried Moringa oleifera seeds, a cheap and readily available local coagulant, on water quality. Four water samples were gotten from each of the rain water, hand dug well and borehole water sources. The physical, chemical, and biological characteristics of the water was examined using alum and moringa seed powder respectively. It was observed that the physical characteristics such as the appearance, odour, total solids and turbidity of the water samples was improved upon addition of alum and moringa seed extract respectively, but the seed extract proved more efficient in treating the water samples. As for the chemical characteristics of the water samples, addition of alum further reduced the pH of the water and made the water more acidic. Also, the nitrate, iron, sulphate, B.O.D, dissolved oxygen the water got reduced. It was also observed that chemical parameters such as electrical conductivity, total alkalinity, chloride, magnesium and calcium hardness was increased, and in some instances beyond the permissible limits. Addition of Moringa seed extract was observed to improve the chemical characteristics of the water samples. The pH of the water was stabilized. Parameters such as electrical conductivity, nitrate, total alkalinity, chloride, magnesium and calcium hardness, iron and sulphate was reduced. Also, the dissolved oxygen and B.O.D was increased. Lastly, the biological parameter such the the bacteria count remain unchanged upon addition of alum and moringa seed extract respectively. Findings from this study indicate that Moringa oleifera, a natural coagulant, can be a potentially viable substitute to alum in treatment of water.

DEDICATION

This report is dedicated to Almighty God for the wisdom and strength he gave to me since the period I gained admission into this citadel of learning.

CERTIFICATION

This is to certify that this project was written by AKANJI, OPEYEMI OLALEKAN (CVE/13/1053) under my supervision and is approved for its contribution to knowledge and literary presentation. All sources of information are specifically acknowledged by means of references, in partial requirements for the award of Bachelor of Engineering (B.Eng) degree in Civil Engineering, Federal University Oye-Ekiti.

26/03/2019

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Date

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Date

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I owe my life to God Almighty: my source of sustenance, help and protection. I thank Him for providing for my needs and also for protecting me from all unseen evil.

My acknowledgement also goes to my parents Oba and Olori Akanji. I pray they live to eat the fruit of their labour. I also thank all my family, most especially my brother Ayodeji, for the love and support given to me.

Finally, I thank my supervisor Dr (Mrs). O.I Ndububa for her encouragement and constructive criticisms. To my lecturers and fellow students, I say thank you.

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CHAPTER ONE

INTRODUCTION

Drinking water is a basic human need, including food, shelter and clothing. The lack of safe drinking water is a leading cause of morbidity and mortality, especially in local communities where waterborne diseases are prevalent and persistent due to low quality surface source waters. Appropriate treatment technology can render this poor water resource into safe potable water; however, conventional technology may not be appropriate for those communities in terms of economics, availability, and operational constraints.

It can be concluded from the findings of Bartram *et al.* (2005) that safe water and adequate sanitation are basic to the health of every person on the planet, yet many people especially in Africa and Asia do not have access to this fundamental need. An important step towards resolving this global crisis is to understand its magnitude: how many people lack access to safe drinking-water and sanitation (WHO and UNICEF, 2000).

Also, WHO (2008) showed that The Millennium Development Goal 7, Target 7C calls on countries to "Half by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation". According to WHO (2008), population forecast suggests that, an additional 784 million people worldwide will need improved drinking water sources for the MDG target to be met. From 1990 to 2006, approximately 1.56 billion people gained access to improved drinking-water sources. Currently 87% of the people of the world drink water from improved sources, as compared to 77% in 1990. Improved drinking water coverage in sub-Saharan Africa is still considerably lower than in other regions. The work of WHO (2008) showed that it has increased from 49% in 1990 to 58% in 2006, which means that an additional 207 million Africans are now using safe drinking water.

In their own work, Rondinelli (1991) showed that despite widespread recognition of the importance of improved water and sanitation and heavy investment by international donors and governments in developing countries in extending water supply systems, more than half the population of rural areas still lack access to clean drinking water. Due to this distressed situation people in rural areas are forced to use traditional sources that are polluted (WHO and UNICEF, 2000). According to WHO (2003) contaminated drinking water and inadequate supplies of water for personal hygiene and poor sanitation are responsible for about 4 billion cases of diarrhoea each year that cause 2.2 million deaths, mostly among children under the age of five.

1.1 Effects of inadequate water supply

The effects of inadequate water supply and sanitation cannot be ignored. The economic, social and health effects retard to a greater extent the development of affected people.

1.1.1 Health

In the investigation conducted by Billig *et al.* (1999), water and sanitation improvements, in association with hygiene behaviour change, can have significant effects on population and health by reducing a variety of disease conditions such as diarrhoea, intestinal helminths, guinea worm, skin diseases, cholera, trachoma and typhoid. Verheyen (1986) in his findings concluded that studies have reported that diarrhoea, dysentery and malaria are the causes of high rate of mortality in these countries. In their own work Billig *et al.* (1999) said that improvements in health as a result of improved water and sanitation provision can, in turn, lead to reduced morbidity and mortality and improved nutritional status.

1.1.2 Education

According to UNDP (2006), water-related diseases cost 443 million school days each year, equivalent to an entire school year for all seven-year-old children in Ethiopia. Almost half of these days are lost due to intestinal parasites transmitted through water and faecal material. More than 150 million children of school going age are severely affected by the intestinal helminths such as roundworm, whipworm and hookworm. UNDP (2006) concluded that children with infections are twice as likely to be absent from school as those without and they perform poorly even when in school.

1.1.3 Economic

Beyond the human waste and suffering, the global deficit in water and sanitation is undermining prosperity and retarding economic growth. Productivity losses linked to this deficit is retarding the efforts of millions of the world's poorest people to work their way out of poverty and holding back development of these countries. Less attention has been paid to the economic costs of the crises in water and sanitation and to the implications of these costs for poverty and prosperity (UNDP, 2006).

1.2 Causes of water scarcity

1.2.1 Population increase

It can be concluded from the findings of (Acquah, 1997) that in some European countries and in the United States, water consumption has not increased substantially since the 1970s however, in Africa and other developing countries consumption is increasing while water resources are being degraded.

Increase in population has led to an increase in pollution and degradation of the environment raising huge challenges for policy makers (Acquah, 1997). Since this increase is faster than infrastructural development, demand for freshwater in these regions are extremely high. Goundern (1997) suggested that the rapid increase in population and urbanization, particularly the conversion of watersheds into residential facilities and farmlands is leading to depletion of water resources.

1.2.2 Pollution

The quality of freshwater is threatened because of pollution by domestic, industrial and agricultural wastes. The amount of domestic and industrial waste water that flows into the world's rivers in a year amounts to about 450 Km^3. Acquah (1997) demonstrated that farming close to river banks and uncontrolled discharge of waste into freshwaters pose significant threat to water quality in rural and urban areas.

1.2.3 Deforestation

Uncontrolled deforestation, especially in watersheds leads to disturbances of water resources and in the extreme case, the drying up of rivers and streams. According to the FAO, on the average stream water takes 16 days to be fully replaced. The annual burning of vegetation at watersheds has devastating effects on water resources. Nsiah-Gyabaah (2001) postulated that another factor accelerating and intensifying water shortage is drought caused by the greenhouse effects and global warming.

1.3 Need for water treatment

About one billion people do not have healthy drinking water. More than six million people (about two million people) die because of diarrhoea which is caused by the polluted water. Developing countries pay a high cost to import chemicals including Polyaluminium chloride and alum (Martyns *et al.*, 1989). This is the reason why these countries need low cost methods requiring low maintenance and skill. The work of Vickers *et al.* (1995) showed that nowadays, Inorganic coagulants (e.g., aluminium sulphate, ferric chloride and calcium carbonate) and synthetic organic polymers (e.g., polyaluminium chloride (PACl) and polyethylene mine) are common coagulants used in this treatment. Among all the available coagulants, including other inorganic and organic chemicals, aluminium salts are the most widely used worldwide because of their effectiveness and competitive cost. However the sludge obtained from treatments using aluminum salts leads to disposal, problems such as aluminium accumulation in the environment. Moreover some studies have reported that residual aluminium sulphate (alum) and polyaluminium chloride may induce Alzheimer's disease. Whereas the synthetic organic polymers such as acrylamide have neurotoxic and carcinogenic effects (Lee *et al.*, 2009).

Moringa oleifera is a tree of Moringaceae family with 14 species. This is the species belonging to the south of India which is the most famous one among all species. The advantages of Moringa oleifera usage in water treatment will be mentioned later in the paper. The extract of oleifera seed removes the 50% to 60% of hardness as well as 99% turbidity. It can be concluded from the work of Jahn (1988) that coagulating active element in extracts is a cationic dimeric protein with molecular weights of 6-14 kDa and isoelectric point. Extract efficiency of Moringa oleifera seed for turbidity removal equals that of alum. Proteinase active element extracted from Moringa oleifera seeds by dialysis and Ion exchange is 34 times more effective than that extracted by distilled water.

The mechanism of coagulation with Moringa oleifera that extracted with distilled appears to consist of adsorption and neutralization of the colloidal charges. Some studies reported that coagulation efficiency of Moringa oleifera can be improved by extraction of its active agents with sodium chloride solution. The natural coagulants are readily available, affordability, Eco-friendly and low cost. According to Tzouponas and Zoubolis (2010), chemical coagulants produce secondary contaminants, and Natural coagulants are nontoxic and food grade nature. This improvement was apparently due to the salting in mechanism proteins solubility as the salt ionic strength increases. However the active agents in their extraction methods were predominantly caused by the lower molecular weight compound.

1.4 Need for study

The need of using natural coagulant such as seeds of Moringa oleifera (Drumstick seed) as water treatment materials are cost-effective. Naturally occurring coagulants are usually presumed safe for human health. While the commercial coagulants are effective only at certain pH range and good flocculation may not be possible in some water.

1.5 Objective of research

The objective of this research is to:

1. To characterize the collected water samples gotten from different water sources.
2. To treat collected water samples by using Moringa seed powder and alum.
3. Evaluate and compare the performance and effectiveness of Moringa seed powder as a replacement to alum in water treatment systems.
4. To analyse and compare the treatment efficiency and the cost effectiveness of Moringa seed powder with alum.

1.6 Scope of study

This work will reduce the health threats arising from the consumption of residual aluminium present in water, such as Alzheimer's diseases and neurodegenerative illness, reduce production of large sludge volumes, reduce alteration of water pH, poor coagulation efficiency in cold weather will be minimized, sludge produced will be highly biodegradable and to reduce surface and ground water pollutant. So, the environmental friendly natural coagulants would present a viable alternative for the treatment of contaminated surface water which will be economical and efficient at domestic level. The use of natural coagulant as coagulant aid with synthetic coagulants can reduce the chemical costs and threats can be minimized.

CHAPTER TWO

LITERATURE REVIEW

Water is a precious natural resource vital for sustaining life. It is in a continuous circulation movement (i.e., hydrological cycle), and is not uniformly distributed in time and space. Due to its multiple benefits and the problems created by its excesses, shortages and quality deterioration, water, as finite resource requires special attention (Pinderhughes, 2004).

Water treatment usually comprises water clarification and disinfection processes. The work of AWWA (1990) showed that in conventional water treatment a series of processes including coagulation, flocculation, sedimentation, filtration and disinfection are often used. Kalibbala (2007) demonstrated that a combination of several processes is usually needed to improve the quality of raw water depending on the type of water quality problems present, the desired quality of the treated water, the costs of different treatments and the size of the water system.

Methods of water treatment from biological materials will indeed be effective in providing water at a very cheap and affordable price and at all times in every household. In the investigation conducted by Ghebremichael *et al.* (2005), one method that has been practised by people in some parts of the developing world is the use of locally available natural coagulants to improve turbidity and reduce bacteria in surface water.

2.1 Coagulation

Coagulation is the process by which the medium is destabilized such that particles are readily agglomerated. It is the process of chemically changing colloids, allowing them to form bigger particles by particle destabilization. The transformation from stable to unstable state is visible. In dispersed suspensions, floc or precipitate, formation can be observed due to destabilization whereas in more concentrated suspension dewatering of the suspension is observed. In their own work, Cornwell and Bishop (1983) said that Particle destabilization is achieved by double layer compression or physical enmeshment of colloids within the coagulant precipitates or via a chemical reaction or through chemical sorption.

Coagulants reduce the net electrical repulsive force at the surface of the metal precipitate particles. The purpose of adding coagulants to acidic drainage waters is to increase the number of flocs present in the treatment water. It can be concluded from the findings of Qasim *et al.* (2000) that as flocs density increases, inter particle contact increases due to Brownian motion, promoting agglomeration of colloidal particles into larger flocs for enhanced settling.

Treatment of water to remove turbidity is essential for large and small-scale production of drinking water. The work of Raghuwanshi *et al.* (2002) showed that the removal of turbidity in water treatment is essential because naturally suspended particles are transport vehicles for undesirable organic and inorganic contaminants, taste, odour and colour-imparting compounds and pathogenic organisms. The turbidity of water often results from the presence of colloidal particles that have a net negative surface charge. Thus, electrostatic forces prevent them from agglomerating, making it impossible to remove them by sedimentation without the aid of coagulants (Diaz *et al.*, 1999).

Coagulants are widely used in water treatment systems but are not commonly used at conventional acidic drainage treatment operations. The most common coagulants are aluminium and iron salts. In the investigation conducted by Faust and Aly (1999), Aluminium and iron coagulants react with bicarbonate alkalinity (HCO3-) in acid drainage, creating aluminium, ferric or ferrous hydroxide flocs which attract metals in solution through co-precipitation.

The high cationic charge of these two metal salts makes them effective for destabilising colloids. They act by neutralising the negative charges of the stable colloidal particles. Coagulants enhance particle collision and agglomeration of neutral particles to form dense flocs that can settle easily. In their own work, Amirtharajah and O'Melia (1990); (Gregory & Duan, 2001) concluded that destabilisation of colloidal particles in water is accomplished via adsorption and charges neutralisation, adsorption and inter-particle bridging, enmeshment in a precipitate and double layer compression. The formation of microflocs before and after the coagulants is added is shown in Figure 2.1.

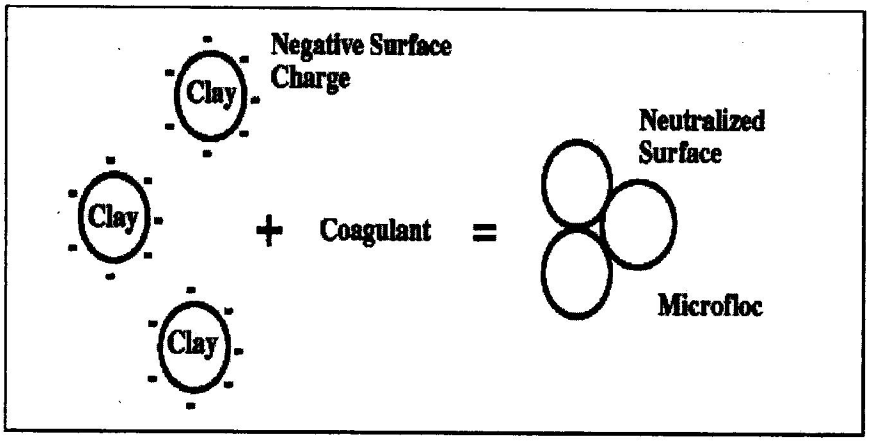

Figure 2.1 Formation of a Microfloc (Pillai.J, 2004)

2.2 Flocculation

Flocculation is the process that follows on from destabilization and forms aggregates ((i.e. flocs). According to (Gregory *et al.*, 1997), flocculation is the process of linking coagulated colloids in to contact with each other to form larger aggregates. This is generally considered to be a two stage process of particle transport and particle attachment (Amirtharajah & O'Melia, 1990). In the investigation conducted by Bratby (2006) flocculation occurs as soon as a coagulating agent is added.

It can be concluded from the findings of Skousen *et al.* (1996) that flocculation involves the combination of small particles by bridging the space between particles with chemicals. Essentially, coagulants aid in the formation of metal precipitate flocs, and flocculants enhance the floc by making it heavier and more stable. In their own work (Faust & Aly, 1999); Tillman (1996) said that flocculants are sometimes referred to as coagulant aids at water treatment operations.

Two main groups of flocculants exist: minerals which include activated silica, clays, and metal hydroxides and synthetic which include anionic, cationic, and non-ionic compounds. It can be concluded from the findings of Skousen *et al.* (1996) activated silica has been used as a flocculants since the 1930's to strengthen flocs and reduce the potential of deterioration. It is usually produced on-site by reacting sodium silicate with an acid to form a gel. When using activated silica, the resultant floc is larger, denser, more chemically stable, and settles faster than iron and aluminium flocs (Tillman, 1996).

Synthetic flocculants consist of polymers which produce negative (anionic), positive (cationic) or both (polyampholytes and non-ionic polymers). Polyampholytes are neutral but release both negative and positive ions when dissolved in water. The ions released from synthetic polymers (flocculants) adsorb to destabilized particles to form larger flocs. According to Tillman (1996) cationic polymers are most often used for charge neutralization and are usually used in conjunction with a metallic coagulant to reduce the dose required and amount of sludge produced. Anionic polymers dissolve in water to provide more reaction sites for positively charged coagulants. A drawback to using synthetic flocculants is that over-dosage may hinder their efficiency. Figure 2.2 shows the formation a floc from microfloc when anionic flocculants is used.

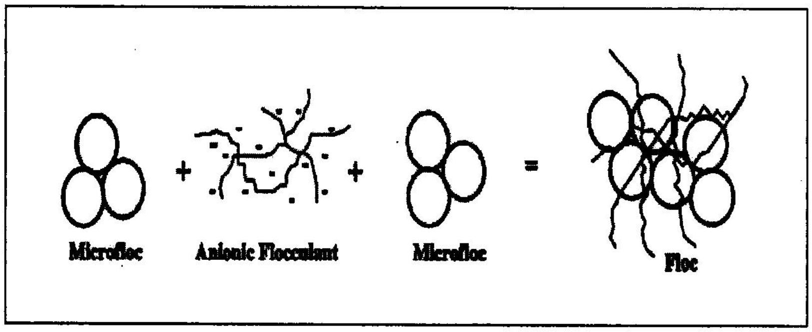

Figure 2.2: Formation of a Floc from Microfloc (Pillai.J 2004)

2.3 Chemical coagulants

2.3.1 Iron salts

Tillman (1996) concluded that iron coagulants are ferric sulphate ($Fe_2 (SO_4)_3$), ferrous sulphate ($FeSO_4$) and ferric chloride ($FeCl_2$). Iron compounds are generally cheaper, produce a heavier floc, and perform over a wider pH range than aluminium coagulants. However, iron coagulants are not used as much as aluminium due to staining equipment, corrosiveness, and they require more alkalinity than alum. Ferric sulphate is active over a wider pH range (4.0-6.0, 8.8-9.2) than ferrous sulphate (8.8-9.2) and produces heavier flocs which settle more quickly. Ferric chloride reacts in a manner similar to ferrous sulphate but is commonly used as an oxidant. In their own work Skousen *et al.* (1996) concluded that it is effective over a much greater pH range than aluminium sulphate, ferric sulphate, and ferrous sulphate. Although clarifications with iron salts are effective they are not mostly used in conventional treatments due to their colouring effect after coagulation (Peavey *et al.*, 1985).

2.3.2 Aluminium salts

Common aluminium coagulants include aluminium sulphate (alum), sodium aluminates, and polyaluminium chloride. Dry alum is available in several grades, with a minimum aluminium content expressed as 17 % of A12O3. Liquid alum is about 49 % solution, or approximately 8.3 % by weight aluminium as A12O3. Alum coagulation works best for a pH range of 5.5 to 8.0; however, actual removal efficiency depends on competing ions and chelating agent concentrations. Sodium aluminate is an alternative to alum and is available in either dry or liquid forms, containing an excess of base. Sodium aluminate provides a strong alkaline source of water-soluble aluminium, which is useful when adding sulphate ions is undesirable. It is sometimes used in conjunction with alum for controlling pH. Polyaluminum chloride (PAC), another aluminium derivative, is a partially hydrolyzed aluminium chloride solution. Although still not widely used, it has been reported to provide stronger, faster settling flocs than alum in some applications (Hahn & Kunte, 1990).

2.3.3 Lime

This is usually not considered as an effective coagulant because it does not produce flocs like salts of iron and aluminium. Cosidine (1974) concluded that it reacts with phosphorous and bicarbonate compounds in water to adjust pH causing precipitation of calcium carbonate and magnesium hydroxides.

2.3.4 Activated silica

The nature of interaction with suspended solids is somehow analoguos to that of polyelectrolytes but differs by lacking the long flexible chains and is therefore denser. They are usually referred to as weighting agents that promote settling of flocs. Dosages are about 20-60 % of alum dose used for coagulation. The work of Cosidine (1974) showed that they have been used with or without alum to achieve clarification in lime water-softening plants.

2.3.5 Polyelectrolyte

Polyelectrolytes are water-soluble organic polymers consisting of repeating units of smaller molecular weights chemically combined to form larger molecules of colloidal size each carrying electrical charges or ionized groups. In the investigation conducted by Hashimoto *et al.* (1991), they can be either natural or synthetic and can be used as both primary coagulants and coagulant aids. In their own work Gregory and

Duan (2001) demonstrated that polyelectrolyte primary coagulants are cationic with high charge density and low molecular weight, while synthetic polyelectrolyte coagulant aids have relatively high molecular weights and facilitate flocculation through inter-particle bridging.

According to Özacar and Şengil (2003), polyelectrolytes are more expensive than aluminium and iron salts in terms of material cost, overall operating costs can be lower because of reduced need for pH adjustment, lower sludge volumes, no increase in total dissolved solids in treated water and shorter settling time. However, they are not readily available and also costly for most parts of the developing world. Natural polyelectrolytes such as water-soluble proteins released from crushed seed kernels are potential alternatives to synthetic polyelectrolytes. The merits of natural polyelectrolytes over synthetic include safety to human health, biodegradability and a wide effective range of flocculation for various colloidal suspensions (Kawamura, 1991).

2.4 Alum as a chemical coagulant

Alum (Al2 (SO4)2.14H2O) is available commercially in industrialized countries in lumps, ground or liquid form. It is a basic product of the reaction between sulphuric acid and a mineral despite such as bauxite. Lump or ground alum whether purified or not contain not less than 9.0 % of available water-soluble aluminium as Al or 17 % as Al2O3 (AWWA, 1990).

Chemical coagulation with alum like any other form of coagulant is aimed at achieving the following objectives:

1. Removal of turbidity, inorganic or organic
2. Removal of harmful bacteria and pathogens
3. Removal of colour, taste, and odour producing substances.

Alum is a relatively inexpensive coagulant if local production is possible. In most developing countries, it is imported at substantially increased cost. Treatment plants in these countries must be designed so that alum consumption may be minimised. The dosage of alum may be reduced in some instances by

1. Direct filtration of low turbidity waters
2. Pre-treating excessively turbid river waters

3. Use of coagulant aids
4. Optimum pH adjustment

2.5 Factors affecting coagulation/flocculation

Coagulation and flocculation processes are dependent on numerous inter-related factors, which sometimes make optimisation of the processes cumbersome. Such factors include the characteristics of the water source, raw water pH, alkalinity and temperature, the type of coagulant and coagulant aids and their order of addition, dose rates of coagulants, the degree and time of mixing provided for chemical dispersion and flocs formation. For water with low alkalinity coagulant can consume virtually all of the available alkalinity, hence lowering the pH to a level that hinders effective treatment, while high alkaline waters may require additional chemicals to lower the pH to values favourable for coagulation (Kalibbala, 2007; Rossi & Ward, 1993).

The performance of the hydrolysing metal salts is significantly influenced by the pH of the solution and they have a good coagulation effect within a certain pH range of the water. The work of Gregory and Duan (2001) showed that the coagulation process in water treatment can be modified to facilitate the removal of dissolved organic matter which has been reported to occur optimally at pH 5-6 and at maximum rate at pH 4.

Low temperature affects the coagulation and flocculation process by altering the coagulant solubility, increasing the water viscosity and retarding the kinetics of hydrolysis reactions and particle flocculation. Poly-aluminium coagulants are more effective in cold water than alum, as they are pre-hydrolysed. In their own work Gregory *et al.* (1997) showed that to achieve effective coagulation, proper mixing is also necessary to allow active coagulant species to be transferred onto turbid water particles.

Proper mixing after addition of coagulants into raw water facilitates optimum removal of fine particles in the supernatant. This is because very fine particles become transformed into aggregates under good mixing condition (Kan *et al.*, 2002). It is commonly observed that particles are destabilised by small amounts of hydrolysing metal salts and that optimum destabilisation corresponds with the neutralisation of particle charge. Larger amounts of coagulants cause charge reversal so that the particles become positively charged and thus restabilisation occurs, which results in elevated turbidity levels. According to Gregory and Duan (2001) careful control of coagulant dosage is needed to give optimum destabilisation and this is determined to a large extent by the consistency of raw water quality.

2.6 Health risks associated with chemical coagulation and flocculation

The work of Driscoll and Letterman (1995) showed that water treatment chemicals are effective and used worldwide, scientific evidence shows that exposure to chemicals during coagulation with metal salts could be associated with adverse health effects. According to AWWA (1990), aluminium, which is the major component of aluminium sulphate (alum), polyaluminium chloride (PAC) and polyaluminium silica sulphate (PASS), could induce Alzheimer's disease and other similar related problems that are associated with residual aluminium in treated water. It can be concluded from the findings of Hashimoto *et al.* (1991) monomers of some synthetic organic polymers such as acrylamide have neurotoxicity and strong carcinogenic properties.

Disinfection of the clarified water prevents the growth of microorganisms both in the treatment plant and in the distribution system, thus protecting the public from water-borne diseases. Like chemical coagulants, disinfectants (chlorine in particular) combine with natural organic matter (NOM) that may be present in water to form trihalomethanes (THMs), which are carcinogenic and/or mutagenic by–products. In their own work Tokmak *et al.* (2004), demonstrated that THM cannot be removed by conventional treatment methods and thus water to be chlorinated should either be free from natural organics, or if NOM is present an alternative disinfectant should be used.

The search for disinfectants that are cheap, maintain acceptable microbiological quality and avoid chemical risks is one of the biggest challenges facing the water treatment industry (Bove *et al.*, 2002).

2.7 Natural materials as coagulants

The use of natural materials for treatment of drinking water in some parts of the world has been recorded throughout human history. However, these natural materials have not been recognised or duly supported due to lack of knowledge on their exact nature and the mechanism by which they function. As a consequence, the natural materials have been unable to compete effectively with the commonly used water chemicals (Ndabigengesere & Narasiah, 1998).

Traditionally, treatment of turbid surface water sources is carried out at household level using local materials of plant or animal origin. It can be concluded from the findings of Jahn (2001) that rural people in Sudan and Malawi, who depend on muddy water from rivers or intermittent streams, natural rain ponds and artificial rain-water catchments for domestic water supply, treat water fetched from such sources using *Moringa* seeds and other plant and soil materials.

2.8 Socio-economic importance of moringa oleifera

It can be concluded from the findings of Scoones *et al.* (1992) that studies from around the world illustrate how wild resources often form an integral part of livelihood wild resources provide materials for utensils and construction, and contribute to improved diets and health, food security, income generation, and genetic experimentation.

Moringa oleifera is one of the most useful tropical trees. The relative ease with which it propagates through both sexual and asexual means and its low demand for soil nutrients and water makes its production and management easy. According to Foidl *et al.* (2001), introduction of this plant into a farm which has a bio diverse environment can be beneficial for both the owner of the farm and the surrounding eco-system.

2.9 Ecology and cultivation

Moringa oleifera is a drought-resistant species mainly growing in semi-arid tropical and subtropical areas. It is found up to 1000 m altitude and in areas with annual rainfall of 750 - 2,250 mm. The work of Rashid *et al.* (2008) showed that while it grows best in dry sandy soil, it is adaptable to various soil conditions from pH 4.5 to 8. According to Odee (1998), the tree is also known for its resistance to drought and diseases and has been found to grow 6-7m in one year in areas receiving less than 400 mm mean annual rainfall.

In the investigation conducted by Duke (1983), a plant in cultivation starts bearing pods 6–8 months after planting while regular bearing commences after the second year. The tree can bear for several years.

2.10 Common uses of moringa

2.10.1 Nutritional

The work of Rams (1994) showed that Moringa leaves and fruit pods are rich sources of calcium and iron, and good sources of vitamins A, B, and C and of protein including good amounts of the sulphur-containing amino acids, methionine and cystine. Both young and older leaves are edible, though older ones are milder and tender. They can be cooked in soups or boiled. Young pods may be also cooked. Immature seeds are often cooked and eaten as a fresh vegetable, while mature seeds can be dried and roasted. The flowers can be cooked or oven-dried and steeped as tea. Dried leaves can be stored as future soup or sauce supplements (Davis, 2000).

2.10.2 Medicinal uses

Moringa oleifera is valued mainly for its tender pods, which are relished as vegetable but all its parts: bark, root, fruit, flowers, leaves, seeds and even gum - are of medicinal value. They are used in the treatment of ascites, rheumatism, venomous bites and as cardiac and circulatory stimulants. Donkor (1996), showed that fresh root of the young tree (as also the root bark) is used internally as stimulant, diuretic and anti-lithic and externally applied as a plaster or poultice to inflammatory swellings.

2.10.3 Seed oil

Moringa seeds contain about 35% oil. This oil is often extracted for cooking and in rare cases, even lubrication purposes. It can be used in salads, soap making, and burns without smoke (Von Maydell, 1986).

In their own work, Abdulkarim *et al.* (2005) concluded that the characteristics of Moringa oleifera seed oil are especially desirable, because of the current trends of replacing polyunsaturated vegetable oils with monounsaturated fatty acids. It can be concluded from the findings of Foidl *et al.* (2001) that the oil has the capacity to absorb and retain volatile substances and is therefore valuable in the perfume industry.

2.10.4 Water purification

According to Jahn (1984), attracting attention in recent decades is the use of the dried, crushed seeds as a coagulant. Even very muddy water can be cleared when crushed seeds are added. Solid matter and some bacteria will coagulate and then sink to the bottom of a container, after which the cleaned water is poured off and boiled (Gupta & Chaudhuri, 1992).

Current studies have shown that Moringa seeds and pods are effective in the removal of heavy metal and volatile organic compounds in the aqueous system. It can be added in oxidation lagoons of wastewater treatment units to coagulate algae as well. The work of Akhtar *et al.* (2006) showed that the algae are removed by sedimentation, dried and pulverized, and then used as protein supplement for livestock.

Based on the reviewed works, it is shown that extensive research has confirmed that Moringa seeds is effective for turbidity removal in water, but few research work has been done on the effect of Moringa seed on the physical, chemical and biological parameters of water. Therefore, this research work is based on the effect of Moringa seeds on the physical, chemical and biological parameters of water.

2.11 Water treatment process

Drinking water treatment involves a number of combined processes (Figure 2.3) based on the quality of the water source such as turbidity, amount of microbial load present in water and the others include cost and availability of chemicals in achieving desired level of treatment. Generally drinking water treatment protocols consist of two major steps: coagulation/flocculation and disinfection. Commonly alum (aluminium sulphate) is used as a coagulation agent, as it is efficient and relatively cost-effective in developed countries; while, disinfection is achieved by the addition of chemical disinfectants like chlorine-based compounds (Ida, 2013).

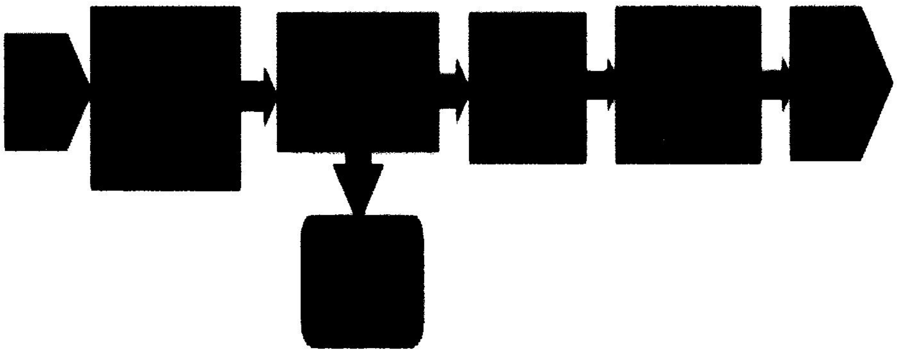

Figure 2.3: Conventional Water Treatment Process

CHAPTER THREE

METHODOLOGY

3.1 Study area

The area studied are Odi-Olowo, Otunja, Usin, and Ilotin, located in Ikole- Ekiti Local Government, Nigeria. The Local Government is predominantly a homogenous society and carefully populated by Ekiti speaking people of the South West Zone of Nigeria. Ikole (also called Ikole-Ekiti) is a local government area and city in the hilly state of Ekiti. The city has a population of 168,436 (according to the 2006 census) living on a landmass of about 321 square kilometres. The local government area consists of twenty four towns and villages such as Ikole, Ijesha Isu, Ootunja, Ara, Irele, and a host of others. Ikole has a thriving timber-based economy and you will easily sawmills lining the streets of Ikole. The location of Ekiti state on the map of Nigeria is shown in Figure 3.1.

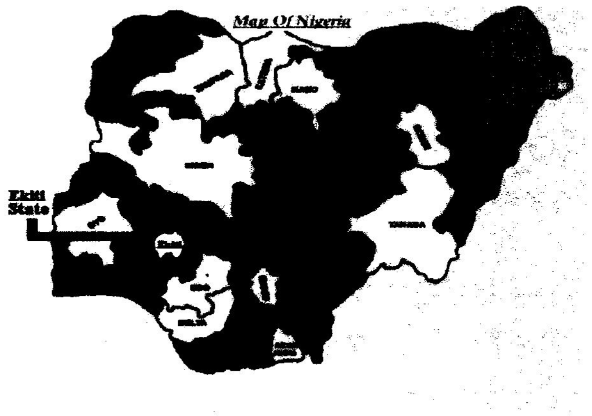

Figure 3.1: Position of Ekiti State on the Map of Nigeria

Also, Figure 3.2 shows the map of the Ekiti State showing all the local government area of the state.

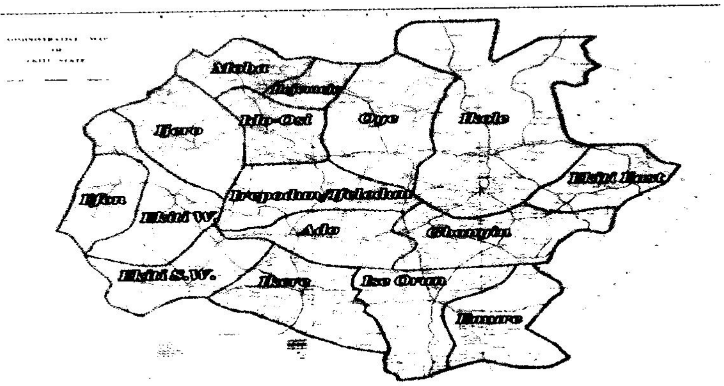

Figure 3.2: Map of Ekiti State showing all Local Government Area of the State

3.2 Materials

3.2.1 Conventional coagulants

In this Study, Aluminium sulphate (Alum) is to be used as a conventional coagulant and the stock solution (1 % strength) was prepared by adding 0.2 grams of Alum to 1000 ml of distilled water.

3.2.2 Natural coagulants

Dried Moringa oleifera seeds will be used for the experimental purposes. Seeds from the pods were removed and good quality seeds selected for the study. The winged seeds were shelled to extract kernels which were ground into a fine powder using a blender. The dried seeds were then grinded to fine powder and stored in plastic containers. Plate 3.1 and 3.2 shows the picture of a moringa tree and moringa seeds respectively.

Plate 3.1: Moringa Tree

Plate 3.2: Moringa Seed

3.3 Methodology

The Figure 3.3 below shows an overview of the procedures involved in carrying out the analysis.

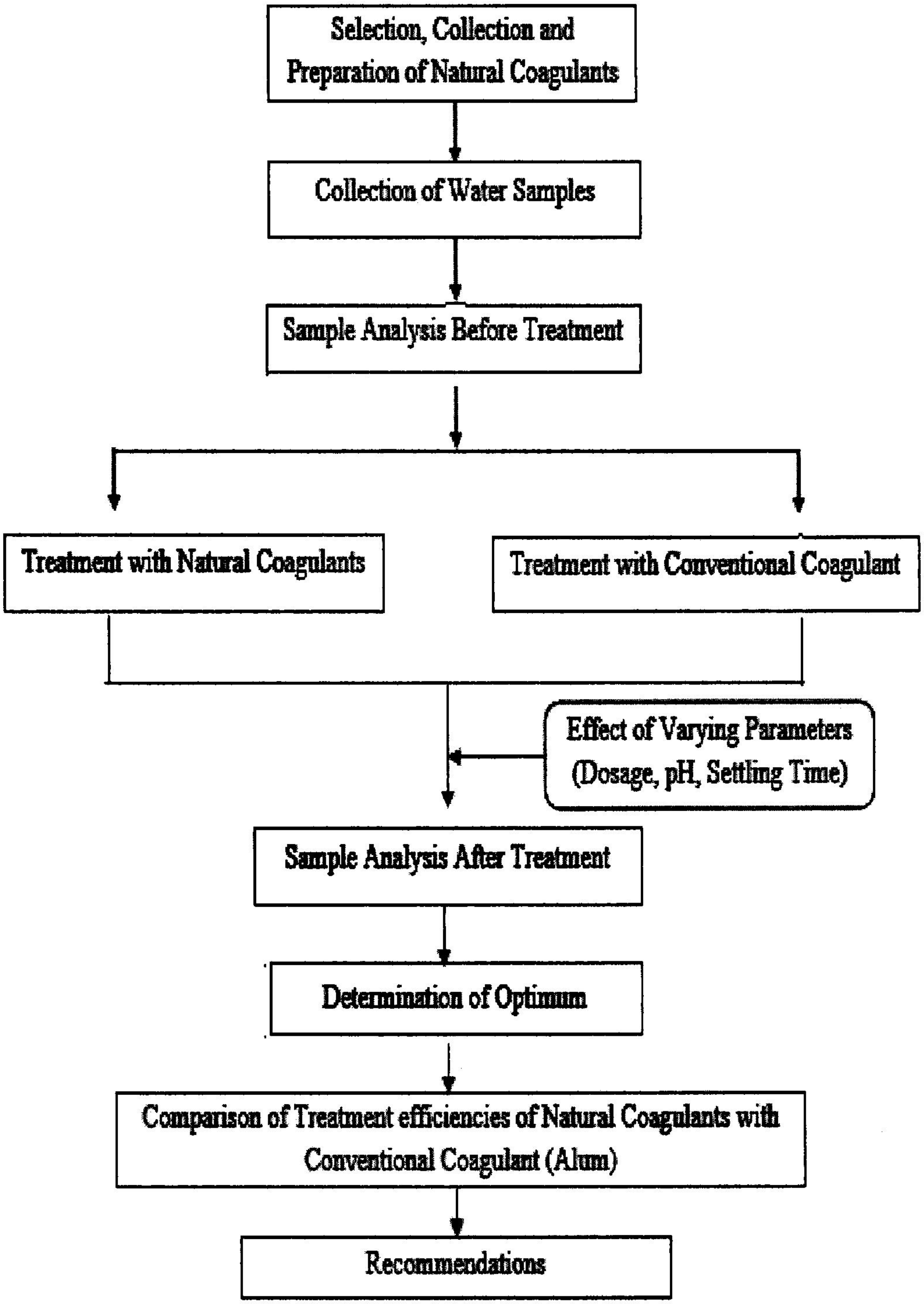

Figure 3.3: An Overview of Methodology

3.3.1 Collection of natural coagulants

The selected seeds were obtained from the local market and thoroughly washed with tap water to remove the sticks adhered on their surfaces and stored for preparation.

3.3.2 Preparation of natural coagulants

The collected seeds were dried at room temperature or in sunlight until its moisture content was completely removed. The dried seeds were then grinded to fine powder and stored in plastic containers. The fine powder was then sieved, using a 1.18m sieve. Then 0.2g of the sieved Moringa powder is then soaked in 500ml of distilled water for about 30 minutes to 1 hour. The solution is then filtered using a filter paper. Plate 3.3 and 3.4 below shows the moringa oleifera seeds when de-husked and grinded respectively.

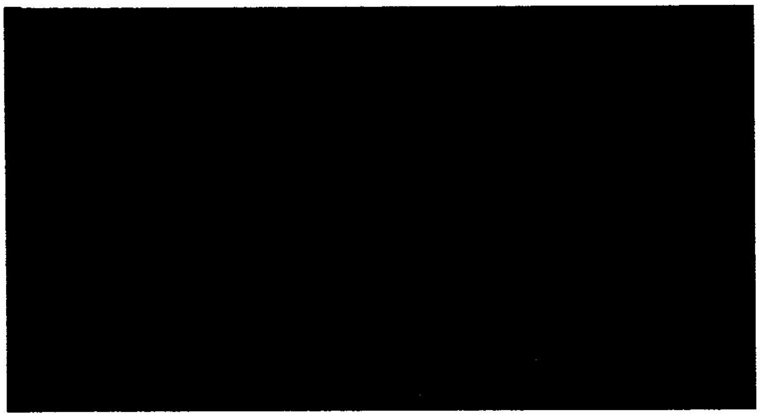

Plate 3.3 Moringa oleifera de-husked seed kernels

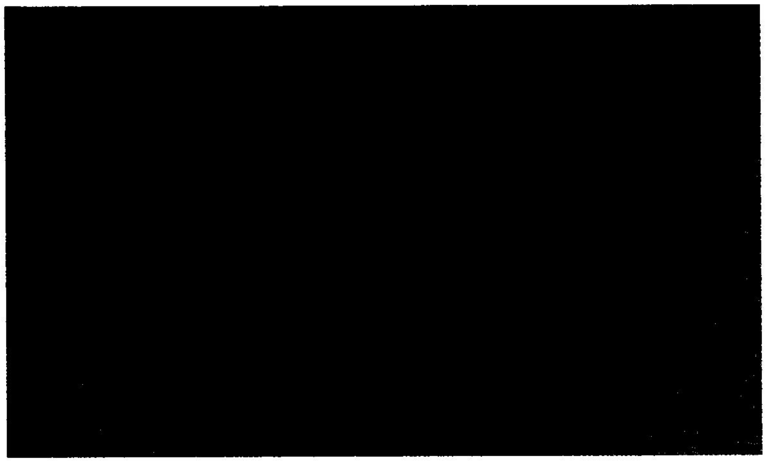

Plate 3.4 Moringa Oleifera seed powder

3.3.3 Collection of water samples

The required amount of water samples were collected from three (3) different sources, that is, the rain water, hand dug well and hand pump/borehole source. Four samples were collected from each of the sources. That is to say, four different samples were collected from different location for each of the source. This mean that twelve samples were collected in all, and their coordinates was taken. The physical conditions of the well was analysed, and also the water sample was analysed based on its colour and odour. The details of the samples collected can be seen in Table 3.1.

Sample collection was done in the wet season. Manual sampling with a plastic container in compliance with established standard norms was adopted. Labels were used to prevent sample misidentification. Sample preservation was done in tune with WHO guidelines with minimum possible time lapse between collection and analysis.

Table 3.1: Details of Sample Source

Sample No	Type of source	Location	Latitude (N)	Longitude (E)	Comment
Sample 1	Rain Water	Mpado Hostel	7.798909 N7°47’56”	5.492716 E5°29’33”	Colourless Odourless
Sample 2	Rain Water	Otunja	7.79202 N7°47’31”	5.48745 E5°29’14”	Colourless Odourless
Sample 3	Rain Water	Usin	7.79669 N7°47’48”	5.48843 E5°29’18”	Colourless Odourless
Sample 4	Rain Water	Ilotin	7.79601 N7°47’45”	5.49236 E5°29’32”	Colourless Odourless
Sample 1	Hand Dug Well	Mpado Hostel	7.798909 N7°47’56”	5.492716 E5°29’33”	Slightly Cloudy Unpleasant
Sample 2	Hand Dug Well	Gigonu House	7.798909 N7°47’56”	5.492716 E5°29’33”	Slightly Cloudy Odourless
Sample 3	Hand Dug Well	Olamide House	7.797449 N7°47’50”	5.501307 E5°30’04”	Slightly Cloudy Unpleasant

Sample 4	Hand Dug Well	CAC Ibudo	7.798909 N7°47'56"	5.492716 E5°29'33"	Slightly Cloudy Unpleasant
Sample 1	Hand Pump	Iya-Ibo House	7.798909 N7°47'56"	5.492716 E5°29'33"	Colourless Odourless
Sample 2	Bore Hole	Alayerogun Street	7.79202 N7°47'31"	5.48745 E5°29'14"	Colourless Odourless
Sample 3	Hand Pump	Ayeni Villa	7.79810 N7°47'53"	5.48778 E5°29'15"	Colourless Odourless
Sample 4	Hand Pump	Coded Villa	7.79776 N7°47'51"	5.48843 E5°29'18"	Colourless Odourless

3.3.4 Analysis of samples

Analysis of the collected ground water samples will be done in accordance with the procedures suggested in the Standard Analytical Procedure Manual for water samples which is based on 'Standard Methods for the Examination of Water and Wastewater' 19th edition, APHA, AWWA, wef 1995.

Analysis will be carried out on the physical, chemical, and biological properties of the water samples. The parameters analysed are listed below.

Physiochemical Parameters

1. Temperature
2. Appearance
3. Odour
4. Total Solids
5. Turbidity
6. Electrical Conductivity
7. pH
8. Nitrate
9. Total Alkalinity
10. Chloride
11. Magnesium Hardness
12. Calcium Hardness

13. Sulphate
14. Dissolved Oxygen
15. BOD

Micro-biological Parameters

a) Bacteria Count

3.3.5 Parameters and maximum allowable limits (nsdwq)

The Table 3.2 below shows the maximum permissible limits of each of the parameters to the tested as specified by NSDWQ and WHO.

Table 3.2: Physical, Chemical and Biological Parameters of Drinking Water

Parameters	**Unit**	**Max. Permitted Level**		**Health**
		NSDWQ	**WHO**	
Temperature	^0C	Ambient	Ambient	None
Appearance	-	Clear	Clear	None
Odour	-	Odourless	Odourless	None
Temperature	^{0}Cel	Ambient	Ambient	None
Total Solids	Mg/L	500	500	None
Turbidity	NTU	5	6	None
Electrical Conductivity	µS/cm	1000	1200	None
pH	-	6.5-8.5	6.5-8.5	None
Nitrate (NO_3)	mg/L	50	50	Cyanosis, and asphyxia (blue-baby syndrome) in infants under 3 months
Total Alkalinity	mg/L	250	250	None
Chloride (Cl)	mg/L	250	100	None
Magnesium (Mg^{2+})	mg/L	50	50	Consumer acceptability
Calcium (Ca^{2+})	mg/L	50	50	Consumer acceptability

Iron (Fe^{2+})	mg/L	0.3	0.3	None
Sulphate (SO_4)	mg/L	100	200	None
Dissolved Oxygen	mg/L	-	-	None
BOD	Mg/L	5	5	Stagnant water (outbreak of diseases)
Bacteria Count	cfu/mL	0	0	Urinary tract infections, bacteraemia, meningitis, diarrhea, (one of the main cause of morbidity and mortality among children), acute renal failure and haemolytic anaemia

3.3.6 Experimental procedure

Temperature: It was measured at the time of sample collection with a good mercury filled Celsius thermometer, having a scale marked for every 0.1°C.

pH: It was measured within 2 hr of sample collection because the pH of the sample can change due to carbon dioxide from the air dissolving in the sample water. A Systronics pH meter of 0.01 readability was used for the measurement of pH.

Turbidity: A conventional jar test apparatus was used to carry out the batch coagulation process for the treatment of water samples. It accommodates a series of six beakers together with six-spindle steel paddles. For each beaker, 1000 ml of sample was taken to which varying amount of coagulant dosage was added to the respective beakers followed by variation in pH and settling time. Then the apparatus was switched on and the speed of paddles was then adjusted to about 100 rpm thus rapid mixing of about 1 - 2 minutes was done. After rapid mixing, the speed of paddles was reduced to about 30 to 40 rpm followed by slow mixing for 20 minutes. After slow mixing, the apparatus was then switched off and the samples were allowed to settle for 10 - 60 minutes. The treated samples was analysed for alkalinity and turbidity level with respect to the effect of varying parameters and the removal efficiencies was obtained.

Eelectrical conductivity(EC): It was measured with Systronics conductivity meter. 0.01M KCl solution was used as the standard reference solution.

Total Dissolved Solids: It was calculated indirectly from electrical conductivity values in μS.

Total dissolved solids = 0.64 x EC (μS/cm)

Hardness: In total hardness determination, the water samples was first buffered to a pH of 10.0 with ammonia buffer and 2 or 3 drops EBT indicator will be added. The indicator reacts with calcium and magnesium ions to yield a wine red coloured complex. As EDTA was then added, it combines with free calcium and magnesium ions in the sample to produce EDTA – calcium and EDTA – magnesium complexes. When all free ions are used up, EDTA begins to break the red metal–indicator complex and combines with the free calcium and magnesium ions. Then the colour of the solution changes from wine red to pale blue.

Magnesium: It was determined as the difference between total hardness and calcium as $CaCO_3$.

Mg (mg/ l) = (Total hardness (as $CaCO_3$mg / l) – Calcium hardness (as mg $CaCO_3$/l)) x 0.243

Chloride: It was determined by argentometric method. 1.0ml of 5% potassium chromate solution was added to 20.0ml of the sample and titrated with standard 0.014N $AgNO_3$ solution till the colour changes to reddish brown.

mg Cl^-/l = (A-B) x N x 35450/vol. of sample
Where A = vol. of $AgNO_3$ consumed for sample
B = vol of $AgNO_3$consumed for blank
N = normality of $AgNO_3$

CHAPTER FOUR

RESULTS

The following results below was obtained when the four samples from the three water sources was tested in the laboratory. The results obtained include the physical, chemical and biological parameters of the water samples.

4.1 Physical chemical and biological analysis of the water samples

4.0.1 Physical chemical and biological analysis of rain water

Table 4.1, 4.2, 4.3, and 4.4 shows the physical, chemical and biological analysis of the rain water samples gotten from Mpado hostel, Otunja, Usin, and Ilotin respectively.

Table 4.1 Physical Chemical and Biological Analysis of Rain Water for Sample 1

Parameters	UNIT	Sample 1 (MPADO HOSTEL)			W.H.O	NSDWQ
		Raw sample	Moringa	Coagulant		
Temperature	^{0}C	24.2	24.2	24.2	Ambient	Ambient
Appearance	U	Clear	Clear	Clear	Clear	Clear
Odour	U	Odour less	Odour less	Odour less	Odourless	Odourless
Total Solids	Mg/l	4.5	1.1	1.32	500	500
Turbidity	NTU	0	0	0	6	0 – 5
E. Conductivity	µS/cm	400	300	1100	1000	1200
pH Value		5.8	6.3	5.7	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0	0	0	30	30
Total Alkalinity	Mg/l	73.2	24.4	73.4	250	250
Chloride Cl^{-2}	Mg/l	220	122.4	701.91	250	250
Magnesium Hardness Mg^{2+}	Mg/l	52	18	40	50	50
Calcium Hardness(Ca^{2+})	Mg/l	36	34	12	50	50
Iron (Fe^{2+})	Mg/l	0.04	0.01	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0	0	0	200	300
Dissolved Oxygen	Mg/l	18.2	20.2	16.3		

B.O.D	Mg/l	12.7	14.2	11.44		
Bacterial Count	Cfu/l	0	0	0	0	0

Table 4.2 Physical Chemical and Biological Analysis of Rain Water for Sample 2

Parameters	**UNIT**		**Sample 2 (OTUNJA)**		**W.H.O**	**NSDWQ**
		Raw sample	**Moringa**	**Coagulant**		
Temperature	^{O}C	25.4	25.4	25.4	Ambient	Ambient
Appearance	U	Clear	Clear	Clear	Clear	Clear
Odour	U	Odourless	Odourless	Odourless	Odourless	Odourless
Total Solids	Mg/l	3.2	0.8	0.98	500	500
Turbidity	NTU	1	0	0	6	0 – 5
E. Conductivity	µS/cm	500	400	2000	1000	1200
pH Value		5.9	6.5	4.8	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0	0	0	30	30
Total Alkalinity	Mg/l	48.8	22.4	48.8	250	250
Chloride Cl^{-2}	Mg/l	709	397	1966.5	250	250
Magnesium Hardness Mg^{2+}	Mg/l	30	20	26	50	50
Calcium Hardness(Ca^{2+})	Mg/l	38	20	15	50	50
Iron (Fe^{2+})	Mg/l	0.01	0	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0	0	0	200	300
Dissolved Oxygen	Mg/l	15	16.65	13.52		
B.O.D	Mg/l	10.58	11.85	9.35		
Bacterial Count	Cfu/l	0	0	0	0	0

Table 4.3 Physical Chemical and Biological Analysis of Rain Water for Sample 3

Parameters	UNIT		Sample 3 (USIN)		W.H.O	NSDWQ
		Raw sample	Moringa	Coagulant		
Temperature	^{O}C	22.4	22.4	22.4	Ambient	Ambient
Appearance	U	Clear	Clear	Clear	Clear	Clear
Odour	U	Odourless	Odourless	Odourless	Odourless	Odourless
Total Solids	Mg/l	14.2	3.6	4.13	500	500
Turbidity	NTU	0	0	0	6	0 – 5
E. Conductivity	µS/cm	400	300	1500	1000	1200
pH Value		5.7	6.1	4.9	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0	0	0	30	30
Total Alkalinity	Mg/l	73.2	48.8	73.2	250	250
Chloride Cl^{-}_{2}	Mg/l	652	321	1738.8	250	250
Magnesium Hardness Mg^{2+}	Mg/l	32	12	29	50	50
Calcium Hardness(Ca^{2+})	Mg/l	22	20	16.5	50	50
Iron (Fe^{2+})	Mg/l	0.04	0.01	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0	0	0	200	300
Dissolved Oxygen	Mg/l	17	18.87	15.32		
B.O.D	Mg/l	11.9	13.45	10.72		
Bacterial Count	Cfu/l	0	0	0	0	0

Table 4.4 Physical Chemical and Biological Analysis of Rain Water for Sample 4

Parameters	UNIT	Sample 4 (ILOTIN)			W.H.O	NSDWQ
		Raw sample	Moringa	Coagulant		
Temperature	^{0}C	22.7	22.7	22.7	Ambient	Ambient
Appearance	U	Clear	Clear	Clear	Clear	Clear
Odour	U	Odour less	Odour less	Odour less	Odourless	Odourless
Total Solids	Mg/l	3.2	0.7	1.04	500	500
Turbidity	NTU	0	0	0	6	0 – 5
E. Conductivity	µS/cm	700	300	1100	1000	1200
pH Value		5.6	6.2	5.1	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0	0	0	30	30
Total Alkalinity	Mg/l	73.2	36.6	75.2	250	250
Chloride Cl^{-2}	Mg/l	148	115	404.13	250	250
Magnesium Hardness Mg^{2+}	Mg/l	14	9	11	50	50
Calcium Hardness(Ca^{2+})	Mg/l	32	15	13.25	50	50
Iron (Fe^{2+})	Mg/l	0.03	0	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0	0	0	200	300
Dissolved Oxygen	Mg/l	13.1	14.54	11.8		
B.O.D	Mg/l	9.17	10.17	8.26		
Bacterial Count	Cfu/l	0	0	0	0	0

4.0.2 Physical chemical and biological analysis of hand dug well

Table 4.5, 4.6, 4.7, and 4.8 shows the physical, chemical and biological analysis of the hand dug well water samples gotten from Mpado hostel, Gigonu house, CAC Ibudo, and Olamide's hostel respectively.

Table 4.5 Physical Chemical and Biological Analysis of Hand Dug Well for Sample 1

Parameters	UNIT	Sample 1 (MPADO HOSTEL)			W.H.O	NSDWQ
		Raw sample	Moringa	Coagulant		
Temperature	^{0}C	25.7	25.7	25.7	Ambient	Ambient
Appearance	U	Slightly Cloudy	Clear	Clear	Clear	Clear
Odour	U	Unpleasant	Odourless	Odourless	Odourless	Odourless
Total Solid	Mg/l	8	2.2	2.5	500	500
Turbidity	NTU	9	1.1	2	6	0 – 5
E. Conductivity	µS/cm	1600	1200	2100	1000	1200
pH Value		6	6.7	5.6	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	4.25	0.78	4.25	30	30
Total Alkalinity	Mg/l	97.6	42.2	96.5	250	250
Chloride Cl^{-}_{2}	Mg/l	453.76	323	554.55	250	250
Magnesium Hardness Mg^{2+}	Mg/l	50	35	65	50	50
Calcium Hardness(Ca^{2+})	Mg/l	30	18.25	17	50	50
Iron (Fe^{2+})	Mg/l	0	0	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0.4	0.25	0	200	300
Dissolved Oxygen	Mg/l	7.5	8.32	6.75		
B.O.D	Mg/l	5.7	2.25	4.72		

Bacterial Count	Cfu/l	14	14	14	0	0

Table 4.6 Physical Chemical and Biological Analysis of Hand Dug Well for Sample 2

Parameters	**UNIT**	**Sample 2 (GIGONU HOUSE)**			**W.H.O**	**NSDWQ**
		Raw sample	**Moringa**	**Coagulant**		
Temperature	^0C	25.9	25.9	25.9	Ambient	Ambient
Appearance	U	Slightly Cloudy	Clear	Clear	Clear	Clear
Odour	U	Odourless	Odourless	Odourless	Odourless	Odourless
Total Solid	Mg/l	6	1.5	1.9	500	500
Turbidity	NTU	8	0.8	0.93	6	0 – 5
E. Conductivity	µS/cm	1300	1200	2400	1000	1200
pH Value		6.8	7.2	4	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	6.3	0.22	0	30	30
Total Alkalinity	Mg/l	61	45	68.8	250	250
Chloride Cl^{-2}	Mg/l	652.28	326.14	854.22	250	250
Magnesium Hardness Mg^{2+}	Mg/l	84	30	75	50	50
Calcium Hardness(Ca^{2+})	Mg/l	136	130	204	50	50
Iron (Fe^{2+})	Mg/l	0.03	0	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0	0	0	200	300
Dissolved Oxygen	Mg/l	15	16.65	13.51		
B.O.D	Mg/l	10.58	11.64	9.45		
Bacterial Count	Cfu/l	7	7	7	0	0

Table 4.7 Physical Chemical and Biological Analysis of Hand Dug Well for Sample 3

Parameters	UNIT	Sample 3 (CAC IBUDO)			W.H.O	NSDWQ
		Raw sample	**Moringa**	**Coagulant**		
Temperature	^0C	26.3	26.3	26.3	Ambient	Ambient
Appearance	U	Slightly Cloudy	Clear	Clear	Clear	Clear
Odour	U	Unpleasant	Odourless	Odourless	Odourless	Odourless
Total Solid	Mg/l	5	1.2	1.3	500	500
Turbidity	NTU	9	1	1.7	6	0 – 5
E. Conductivity	µS/cm	2100	1800	3000	1000	1200
pH Value		6.1	6.5	4.2	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0.45	0	0	30	30
Total Alkalinity	Mg/l	140.4	85.4	161	250	250
Chloride Cl^{-2}	Mg/l	581.26	560.11	573.1	250	250
Magnesium Hardness Mg^{2+}	Mg/l	42	23	64.5	50	50
Calcium Hardness(Ca^{2+})	Mg/l	156	135	155	50	50
Iron (Fe^{2+})	Mg/l	0.06	0.03	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0.22	0	0	200	300
Dissolved Oxygen	Mg/l	11.15	12.37	10.04		
B.O.D	Mg/l	8.05	8.86	7.02		
Bacterial Count	Cfu/l	15	15	15	0	0

Table 4.8 Physical Chemical and Biological Analysis of Hand Dug Well for Sample 4

Parameters	UNIT	Sample 4 (OLAMIDE'S HOSTEL)			W.H.O	NSDWQ
		Raw sample	Moringa	Coagulant		
Temperature	^{O}C	27.1	27.1	27.1	Ambient	Ambient
Appearance	U	Slightly Cloudy	Clear	Clear	Clear	Clear
Odour	U	Unpleasant	Odourless	Odourless	Odourless	Odourless
Total Solid	Mg/l	15	3.6	4.5	500	500
Turbidity	NTU	11	1.5	3	6	0 – 5
E. Conductivity	µS/cm	1500	1400	2000	1000	1200
pH Value		6.4	6.7	4.4	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0.33	0.15	0	30	30
Total Alkalinity	Mg/l	97.6	85.5	112	250	250
Chloride Cl^{-2}	Mg/l	446.7	337	475	250	250
Magnesium Hardness Mg^{2+}	Mg/l	92	34.2	75	50	50
Calcium Hardness(Ca^{2+})	Mg/l	75	45	136	50	50
Iron (Fe^{2+})	Mg/l	0	0	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0.65	0.21	0	200	300
Dissolved Oxygen	Mg/l	8.5	9.43	7.65		
B.O.D	Mg/l	5.95	6.59	5.35		
Bacterial Count	Cfu/l	12	12	12	0	0

4.0.3 Physical chemical and biological analysis of hand pump and borehole

Table 4.9, 4.10, 4.11, and 4.12 shows the physical, chemical and biological analysis of the hand pump and borehole water samples gotten from Iya-Ibo house, Alayerogun street, Ayeni villa and Coded villa respectively.

Table 4.9 Physical Chemical and Biological Analysis of Hand Pump Borehole for Sample 1

	UNIT	Sample 1 (IYA-IBO HOUSE)			W.H.O	NSDWQ
Parameters		**Raw sample**	**Moringa**	**Coagulant**		
Temperature	^{0}C	24.2	24.2	24.2	Ambient	Ambient
Appearance	U	Clear	Clear	Clear	Clear	Clear
Odour	U	Odourless	Odourless	Odourless	Odourless	Odourless
Total Solid	Mg/l	2.5	0.6	0.8	500	500
Turbidity	NTU	0	0	0	6	0 – 5
E. Conductivity	µS/cm	1000	1200	9500	1000	1200
pH Value		6.5	6.7	4	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0.3	0	0	30	30
Total Alkalinity	Mg/l	97.6	61	108.8	250	250
Chloride Cl^{-2}	Mg/l	354.5	255.2	645	250	250
Magnesium Hardness Mg^{2+}	Mg/l	42	25	64	50	50
Calcium Hardness(Ca^{2+})	Mg/l	61	32.1	77	50	50
Iron (Fe^{2+})	Mg/l	0	0.05	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0.36	0.05	0.3	200	300
Dissolved Oxygen	Mg/l	9.2	10.21	8.29		
B.O.D	Mg/l	6.43	7.14	5.8		
Bacterial Count	Cfu/l	0	0	0	0	0

Table 4.10 Physical Chemical and Biological Analysis of Hand Pump Borehole for Sample 2

	UNIT	Sample 2 ALAYE ROGUN STREET			W.H.O	NSDWQ
Parameters		**Raw sample**	**Moringa**	**Coagulant**		
Temperature	^0C	25.1	25.1	25.1	Ambient	Ambient
Appearance	U	Clear	Clear	Clear	Clear	Clear
Odour	U	Odourless	Odourless	Odourless	Odourless	Odourless
Total Solid	Mg/l	5	1.2	1.2	500	500
Turbidity	NTU	1	0	0	6	0 – 5
E. Conductivity	μS/cm	820	830	2800	1000	1200
pH Value		6.8	6.7	3.8	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0	0	0	30	30
Total Alkalinity	Mg/l	97.6	48.8	48.8	250	250
Chloride Cl^-_2	Mg/l	860.5	520	924.22	250	250
Magnesium Hardness Mg^{2+}	Mg/l	84	52	32.2	50	50
Calcium Hardness(Ca^{2+})	Mg/l	32	15	96	50	50
Iron (Fe^{2+})	Mg/l	0.03	0.05	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0	0	0	200	300
Dissolved Oxygen	Mg/l	15	16.65	13.62		
B.O.D	Mg/l	10.58	11.83	9.15		
Bacterial Count	Cfu/l	0	0	0	0	0

Table 4.11 Physical Chemical and Biological Analysis of Hand Pump Borehole for Sample 3

Parameters	UNIT	AYENI VILLA			W.H.O	NSDWQ
		Raw sample	**Moringa**	**Coagulant**		
Temperature	^{O}C	24.5	24.5	24.5	Ambient	Ambient
Appearance	U	Clear	Clear	Clear	Clear	Clear
Odour	U	Odourless	Odourless	Odourless	Odourless	Odourless
Total Solid	Mg/l	6	1.7	2	500	500
Turbidity	NTU	9	1.6	3	6	0 – 5
E. Conductivity	µS/cm	1400	1500	2100	1000	1200
pH Value		6.4	6.8	4.1	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0.11	0	0	30	30
Total Alkalinity	Mg/l	48.8	36.6	61	250	250
Chloride Cl^{-2}	Mg/l	194	190.5	220	250	250
Magnesium Hardness Mg^{2+}	Mg/l	60	35.5	68.5	50	50
Calcium Hardness(Ca^{2+})	Mg/l	56	42	86.2	50	50
Iron (Fe^{2+})	Mg/l	0	0	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0	0	0	200	300
Dissolved Oxygen	Mg/l	16.2	17.82	14.78		
B.O.D	Mg/l	11.63	12.56	10.35		
Bacterial Count	Cfu/l	0	0	0	0	0

Table 4.12 Physical Chemical and Biological Analysis of Hand Pump Borehole for Sample 4

Parameters	UNIT	CODED VILLA			W.H.O	NSDWQ
		Raw sample	Moringa	Coagulant		
Temperature	^{O}C	26.2	26.2	26.2	Ambient	Ambient
Appearance	U	Clear	Clear	Clear	Clear	Clear
Odour	U	Odourless	Odourless	Odourless	Odourless	Odourless
Total Solid	Mg/l	3	0.5	0.6	500	500
Turbidity	NTU	4.5	0.7	1	6	0 – 5
E. Conductivity	µS/cm	460	480	1600	1000	1200
pH Value		6.8	7	5.4	6.5	6.5 – 8.5
Nitrate (NO_4)	Mg/l	0	0	0	30	30
Total Alkalinity	Mg/l	85.5	85.5	102	250	250
Chloride Cl^{-2}	Mg/l	194	165	225	250	250
Magnesium Hardness Mg^{2+}	Mg/l	52	36	62	50	50
Calcium Hardness(Ca^{2+})	Mg/l	52	36	67	50	50
Iron (Fe^{2+})	Mg/l	0	0	0	0.3	0.3
Sulphate (SO_4)	Mg/l	0	0	0	200	300
Dissolved Oxygen	Mg/l	10.2	11.45	9.22		
B.O.D	Mg/l	7.45	8.22	6.42		
Bacterial Count	Cfu/l	0	0	0	0	0

4.1 Analysis of result and discussion

Temperature

The temperature of the rain water samples taken are the range of 22.7-25.4°C. While for the Hand dug well samples, the temperature of the samples taken, are in the range of 25.7-27.1°C. Also, for the hand pump and borehole samples, the temperature of the samples are in the range of 24.2-26.2°C. The temperature of the samples taken are dependent on the environmental condition at the time of collection. It was observed that the rain water samples collected has the lowest temperature.

Appearance

It was observed that the four samples gotten from the rain water, hand pump and borehole sources, have a clear appearance and they meet up with WHO and NSDWQ standard. The water still remained clear upon addition of Moringa seed powder and alum. It was also observed that all the four samples gotten from the hand dug well source are slightly cloudy in appearance. After treatment with Moringa and alum, the initial colour of water was completely removed and then the samples were clear in appearance. The Moringa Oleifera seeds show absorbent properties

Odour

Odour can originate from natural inorganic and organic chemical contaminants and biological sources or processes (e.g. aquatic microorganisms), from contamination by synthetic chemicals, from corrosion or as a result of problems with water treatment (e.g. chlorination). Odour may also develop during storage and distribution as a result of microbial activity.

Odour in drinking-water may be indicative of some form of pollution or of a malfunction during water treatment or distribution. It may therefore be an indication of the presence of potentially harmful substances. The cause should be investigated and the appropriate health authorities should be consulted, particularly if there is a sudden or substantial change.

It can be observed that all the samples from the rain water, hand pump and borehole sources are odourless and they conform with the WHO and NSDWQ standards. The samples remained odourless upon treatment with alum and Moringa seed powder. For the samples taken from the hand dug well, samples 1,3,4 has an unpleasant smell. But upon treatment with alum and Moringa, the unpleasant smell was changed to odourless.

Total solids

The total solids for the rain water samples ranged between 3.2-14.2 mg/l for the four samples. The values are 4.5mg/l, 3.2mg/l, 14.2mg/l, and 3.2mg/l for sample 1 sample 2 sample 3 and sample 4 respectively.Although the four samples fall within the WHO and NSDWQ permissible limits. The samples were first treated with alum which reduced the total solids to 1.32mg/l, 0.98mg/l, 4.13mg/l and 1.04mg/l for samples 1,2,3,4 respectively. Addition of Moringa seed powder to the raw water samples further reduced the Total solids to 1.1mg/l, 0.8mg/l 3.6mg/l and 0.7mg/l for samples 1,2,3,4 respectively.

For the hand dug well samples, the total solids for the raw water are 8mg/l, 6mg/l, 5mg/l and 15mg/l for samples 1,2,3,4 respectively. The samples also fall within the WHO and NSDWQ standard. The samples were then treated with Alum and Moringa which reduced the total Solids. Also, for the hand pump and borehole samples, the total solids of the water samples were reduced upon addition of alum and Moringa. Moringa seed powder proved to be more efficient in reducing the total solids of water than alum. Moringa Oleifera is known to be a natural cationic polyelectrolyte and flocculant with a chemical composition of basic polypeptide with molecular weights ranging from 6000 to 16000 dalton's, containing up to six amino acids of mainly glutamic acid, methionine and arginine.

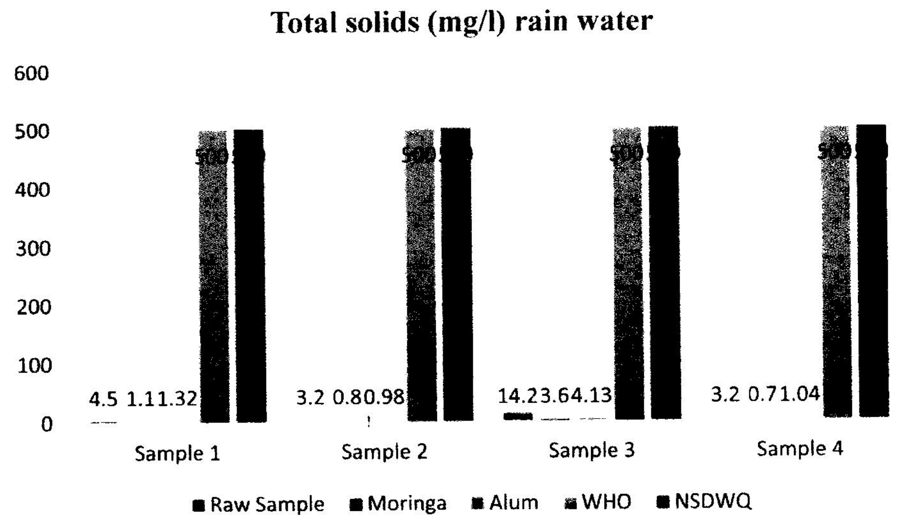

Figure 4.1 Total solids (mg/l) rain water

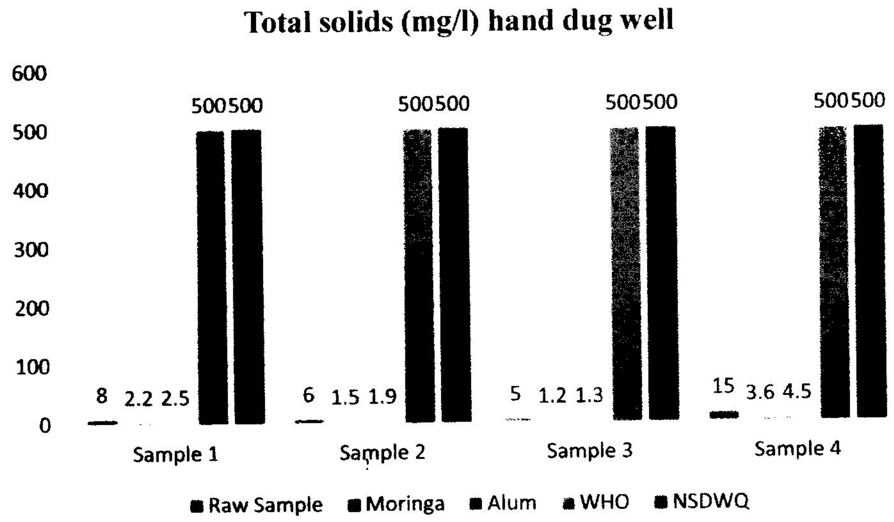

Figure 4.2 Total solids (mg/l) hand dug well

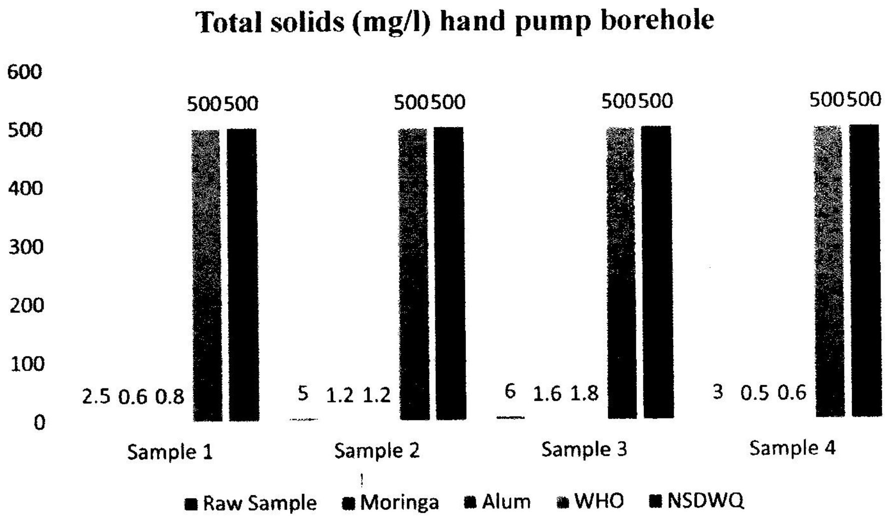

Figure 4.3 Total solids (mg/l) hand pump borehole

Turbidity

Turbidity is a term that refers to the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through water. It is caused by suspended and colloidal matter such as clay, silt, finely divided organic matter, plankton and microscopic organism. The four rain water samples are not turbid. Samples 1, 3, 4 have 0 NTU while sample 2 have 1 NTU. The four samples fall within accepted limits. When alum and Moringa was added to all the samples, samples 1,3,4 remained 0 NTU while sample 2 was reduced to 0 NTU.

The four samples gotten from the hand dug well were all turbid. They do not fall within WHO standard which is 6 NTU and NSDWQ standard which is 5 NTU. The turbidity for the hand dug well fell between the range of 8 to 11 NTU. When the samples were treated with alum, the values were reduced to the range of 0.93 to 3 NTU which fall within the permissible limits. Also when Moringa was added to the raw water samples, the values were further reduced to the range of 0.8 to 1.5 NTU which also fall within the WHO and NSDWQ limit.

For the Hand pump and borehole, all the samples gotten are not turbid except for sample 3 which have a value of 9 NTU. The samples when treated with alum and Moringa reduced the turbidity of sample 3 to 3 NTU and 1.6 NTU respectively. Treatment using Moringa tend to be more effective than that of alum.

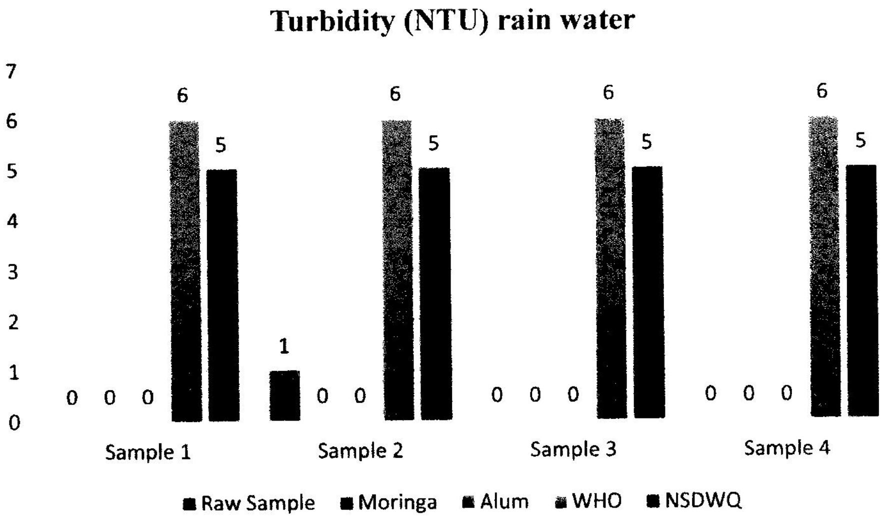

Figure 4.4 Turbidity (NTU) rain water

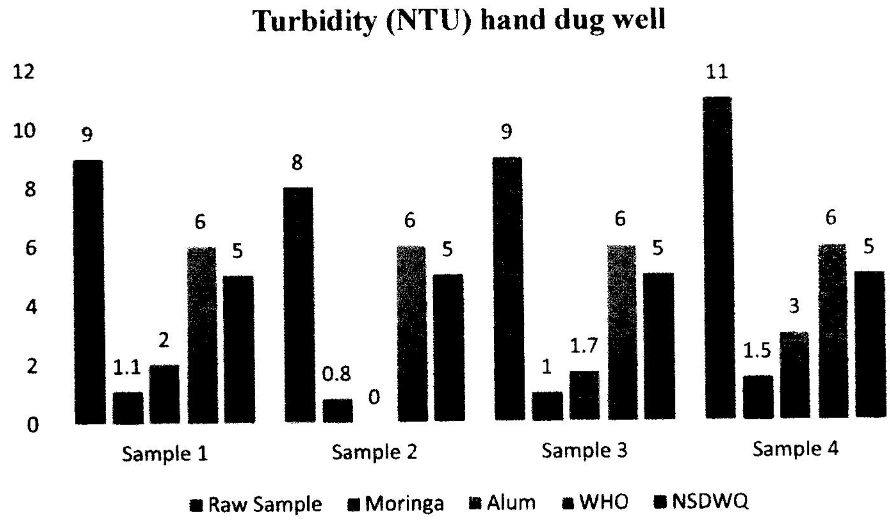

Figure 4.5 Turbidity (NTU) hand dug well

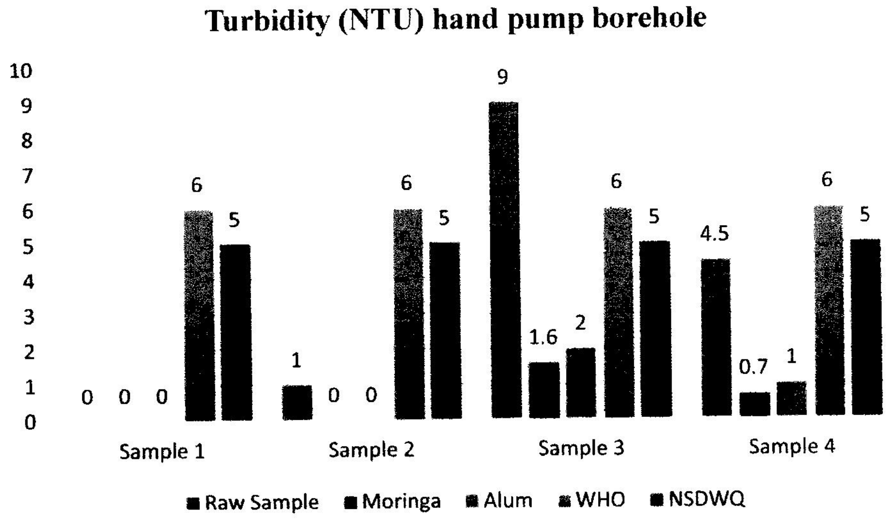

Figure 4.6 Turbidity (NTU) hand pump borehole

E. conductivity

Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. Compounds that dissolve into ions are also known as electrolytes. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is.

The electrical conductivity values for the rain water samples are 400, 500, 400, and 700µs/cm for samples 1,2,3,4 respectively. The four rainwater samples meet up with the WHO and NSDWQ standard which is 1000 and 1200µS/cm respectively. Addition of alum further increased the electrical conductivity to 1100, 2000, 1500, 1100µS/cm for samples 1,2,3,4 respectively. But upon addition of Moringa seed powder the electrical conductivity of the raw water samples was reduced to 300, 400, 300, and 300µS/cm for samples 1,2,3,4 respectively.

The results gotten from the hand dug well samples indicated that all the samples do not meet up with the WHO and NSDWQ permissible limit. As witnessed earlier, addition of alum into the water samples further increased the conductivity value, while addition of Moringa reduced the conductivity value of the water. Although after addition of Moringa seed powder, only samples 1 and 2 were able to meet up with the NSDWQ standard which is 1200µS/cm.

In the samples gotten from hand pump and borehole, the electrical conductivity of the raw water are 1000, 820, 1400 and 400μS/cm for samples 1,2,3 and 4 respectively. Addition of Alum sharply increased the values to 9500, 2800 , 2100, and 1600μS/cm for samples 1,2,3,4. A new twist occurred when Moringa seed powder was added in which the electrical conductivity of the water increased slightly to 1200, 830, 1500 and 480vS/cm for samples 1,2,3,4 respectively. It can be observed from this result that addition of Moringa seed powder tend to reduce the number of ions present in the water, which resulted in the reduction of the conductivity value of the raw water.

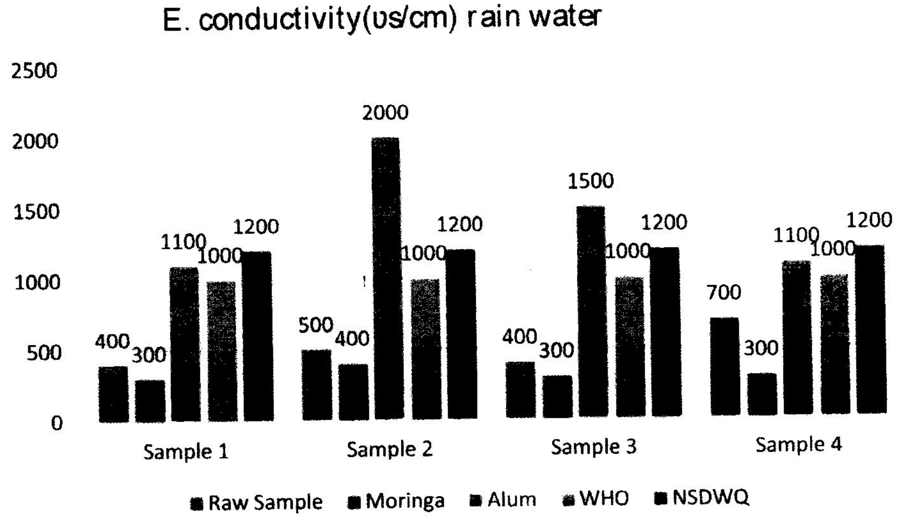

Figure 4.7 E. conductivity(υs/cm) rain water

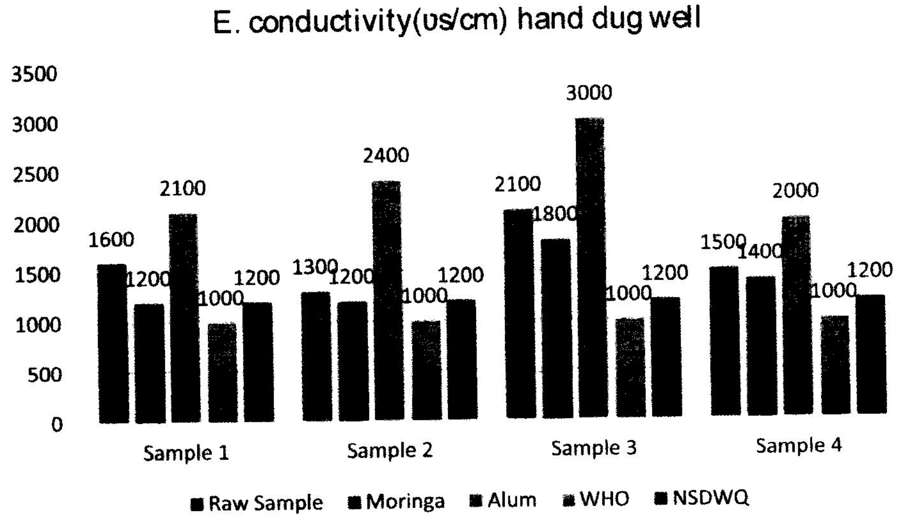

Figure 4.8 E. conductivity(υs/cm) hand dug well

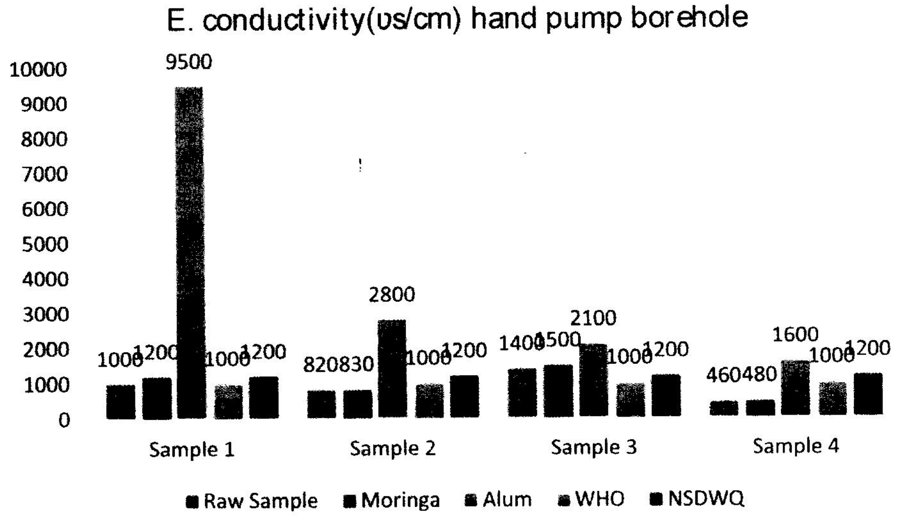

Figure 4.9 E. conductivity (uS/cm) hand pump borehole

pH value

All the rain water samples collected do not meet up with the WHO and NSDWQ standard. The pH for samples 1,2,3,4 are 5.8, 5.9, 5.7, 5.6 respectively. The pH further decreases when the samples were treated with alum. The WHO standard for pH value is 6.5 while the NSDWQ standard for ph ranges between 6.5 to 8.5. The raw water was then treated with Moringa seed powder. Addition of the seed powder resulted in the increase in pH. Although only sample 2 was able to meet up with the WHO standard which is 6.5. Samples 1,3, and 4 increased in pH value for did not meet up with WHO and NSDWQ permissible limit.

Also, all the samples gotten from the hand dug well do not meet up with the WHO and NSDWQ standard except for sample 2 which have a pH of 6.8. The samples became more acidic when alum was added. Sample 2 which had a pH value of 6.8 further reduced to 4 when alum was added. But upon addition of Moringa the pH value increased in value. For sample 1 the pH increased from 6 to 6.7, for sample 2, the pH increased from 6.8 to 7.2, for sample 3, the pH increased from 6.1 to 6.5 and for sample 4 the pH increased from 6.4 to 6.7. All the samples met up with the WHO and NSDWQ permissible limit when Moringa was added.

For the hand pump and borehole samples, all the samples collected are within permissible limit except for sample 3 which have a pH of 6.4. As witnessed earlier, the pH decreased when alum was added and also the pH increased when Moringa powder was added. The pH increased when Moringa powder was added. This is because it represents that water soluble actions are present in the seed in the form of protein. It was reported that the action of Moringa Oleifera as a coagulant lies in the presence of water soluble cationic proteins in the seeds. This suggests that in water, the basic amino acids present in the protein of Moringa would accept a proton from water resulting in the release of a hydroxyl group making the solution basic.

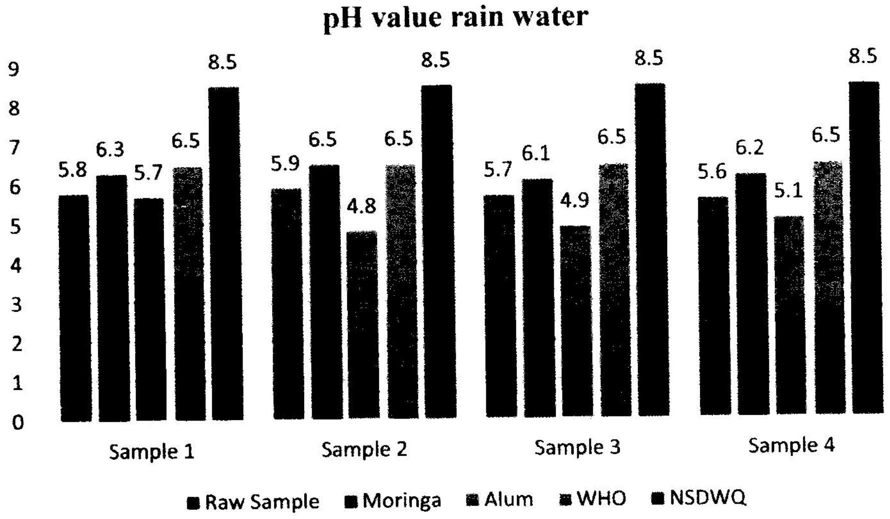

Figure 4.10 pH value rain water

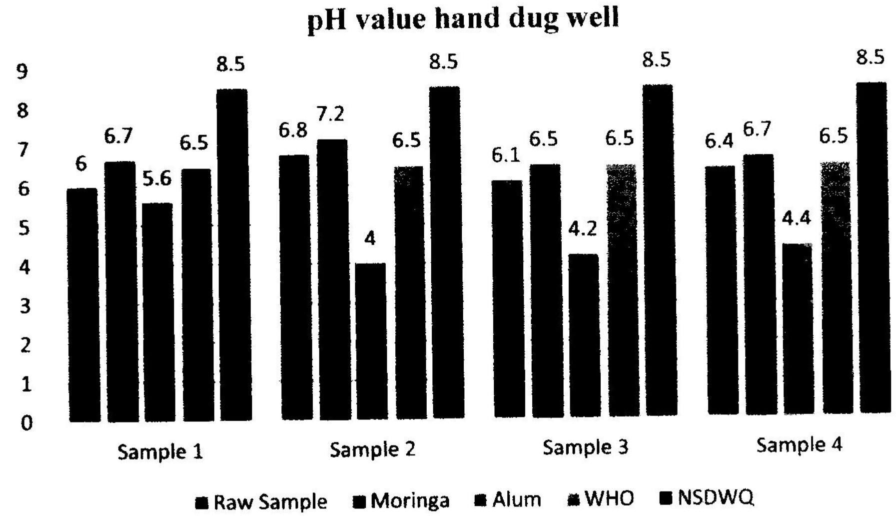

Figure 4.11 pH value hand dug well

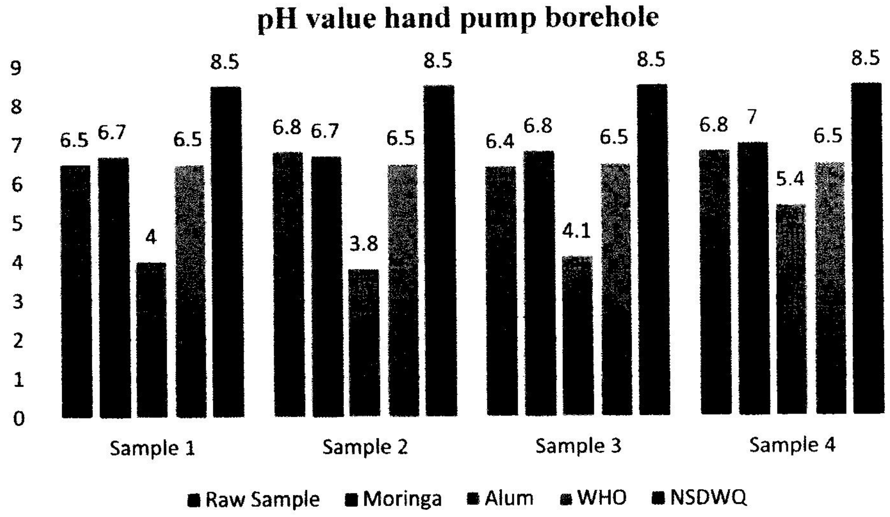

Figure 4.12 pH value hand pump borehole

Nitrate (NO4)

Nitrate is one of the most common groundwater contaminants in rural areas. It is regulated in drinking water primarily because excess levels can cause methemoglobinemia, or "blue baby" disease. Although nitrate levels that affect infants do not pose a direct threat to older children and adults, they do indicate the possible presence of other more serious residential or agricultural contaminants, such as bacteria or pesticides.

Nitrate in groundwater originates primarily from fertilizers, septic systems, and manure storage or spreading operations. Fertilizer nitrogen that is not taken up by plants, volatilized, or carried away by surface runoff leaches to the groundwater in the form of nitrate. This not only makes the nitrogen unavailable to crops, but also can elevate the concentration in groundwater above the levels acceptable for drinking water quality. All the rain water samples collected have no nitrate contamination. For the hand dug well samples, the nitrate level for sample 1,2,3 and 4 are 4.25, 6.3, 0.45, and 0.33 mg/l respectively. When alum and Moringa was added, the nitrate level decreased.

Also, the nitrate level for the hand pump and borehole are low compared with the WHO and NSDWQ standard which is 30mg/l. The nitrate level was reduced to 0 mg/l when Moringa and alum was added for all the samples.

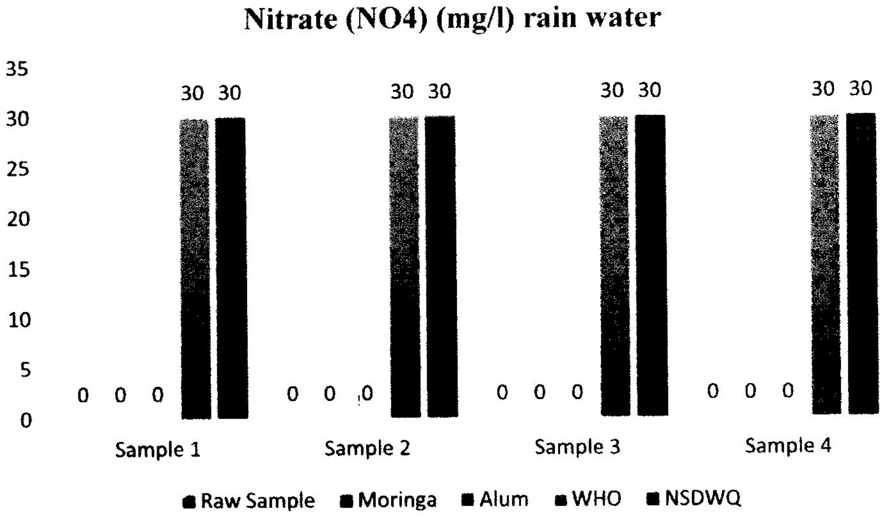

Figure 4.13 Nitrate (NO4) (mg/l) rain water

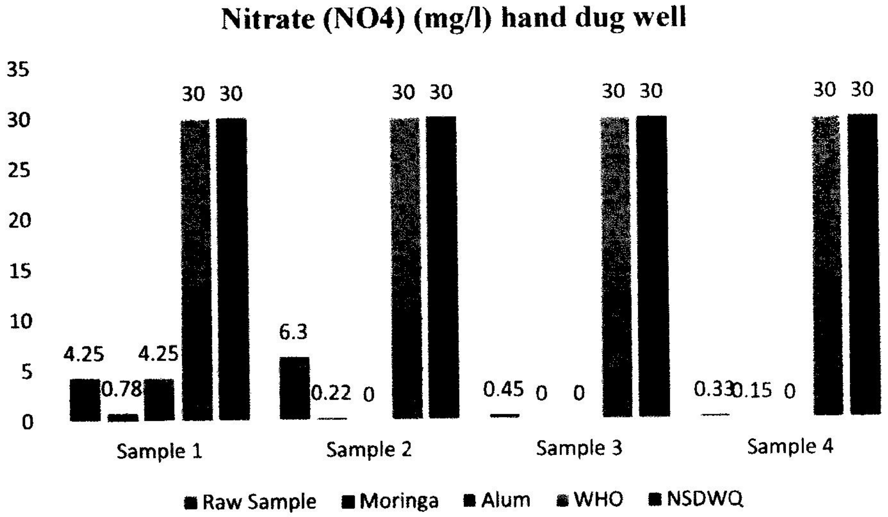

Figure 4.14 Nitrate (NO4) (mg/l) hand dug well

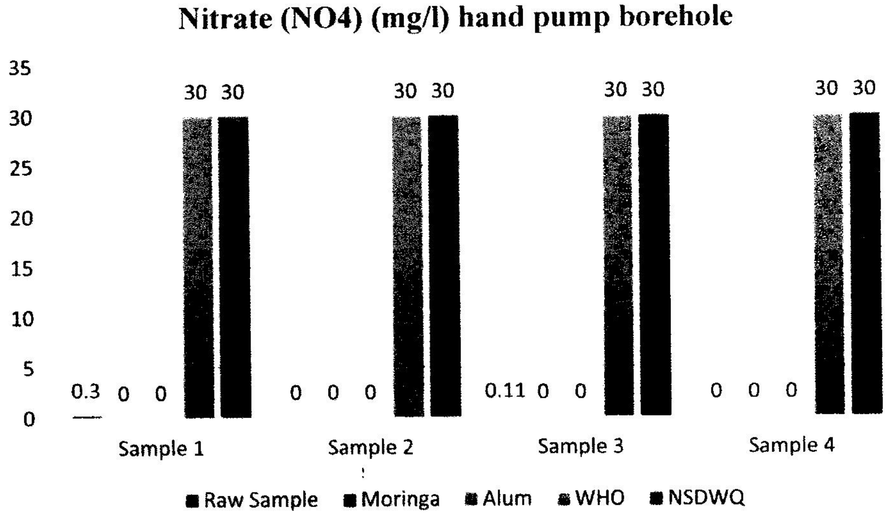

Figure 4.15 Nitrate (NO4) (mg/l) hand pump borehole

Total alkalinity

Alkalinity during the research work was observed to be in the range of 48.8-73.2mg/l for the rain water. Upon treatment with Moringa seed powder, it was observed that the alkalinity was reduced. The alkalinity was present in the range of 22.4-48.8mg/l which was within the limits of WHO and NSDWQ standards. When the raw water was treated with alum, the alkalinity was observed to be in the range of 48.8-75.2mg/l. For the hand dug well, the alkalinity was observed to be in the range of 61-140.4mg/l.

The alkalinity range decreased in value when Moringa was added while, the value got increased when alum was added. And also for the Hand pump and borehole samples, the value increased when alum was added and it was reduced when Moringa was added. The slight decrease in alkalinity of the water samples may be due to precipitation of insoluble products of the reaction between the Moringa Oleifera and the hardness causing ions similar to precipitation softening. The Moringa Oleifera seed extract appears to have natural buffering capacity.

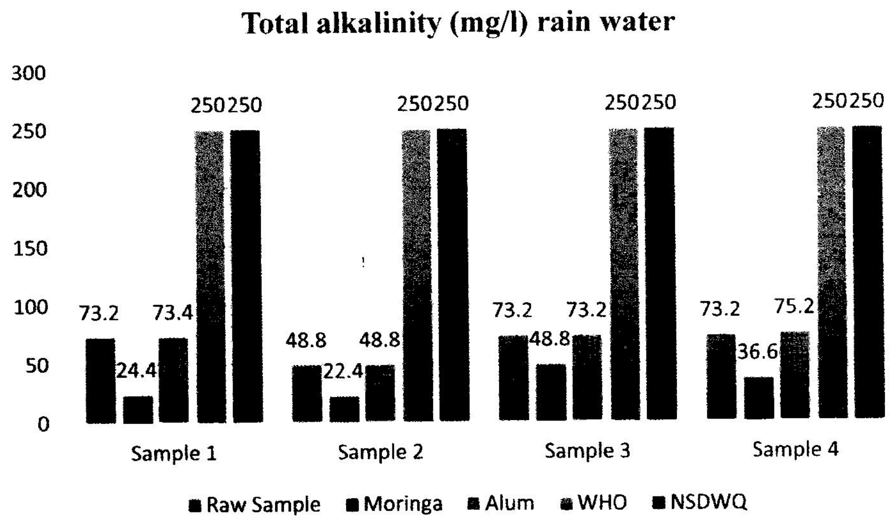

Figure 4.16 Total alkalinity (mg/l) rain water

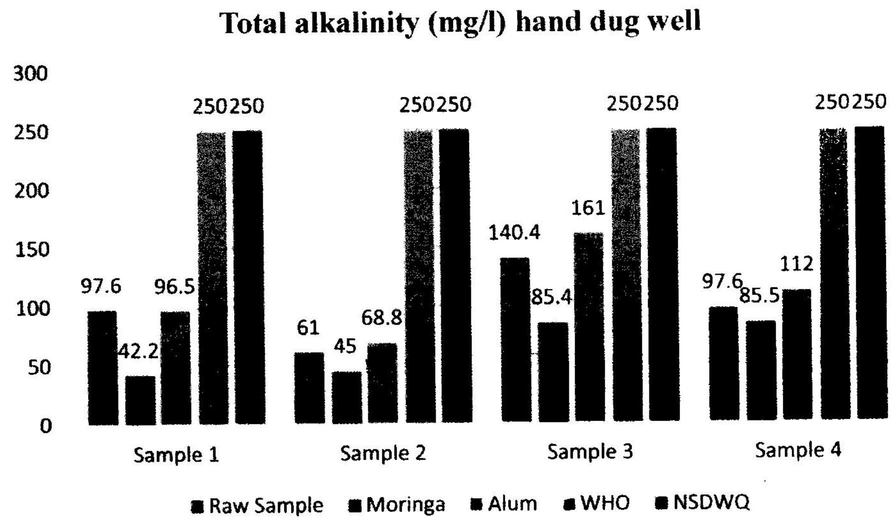

Figure 4.17 Total alkalinity (mg/l) hand dug well

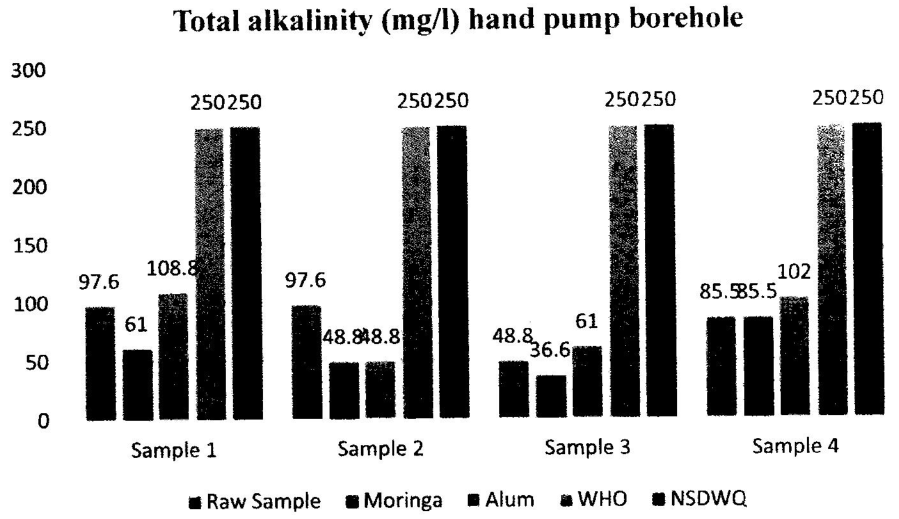

Figure 4.18 Total alkalinity (mg/l) hand pump borehole

Chloride

Chloride is considered to be an essential nutrient for human health and the main source of chloride is from foods, with drinking water making up only a small portion of normal dietary intake. Chloride in drinking water is not harmful, and most concerns are related to the frequent association of high chloride levels with elevated sodium levels. There is no health based drinking water guideline for chloride however the Guidelines for Nigerian Standard for Drinking Water Quality and World Health Organisation recommend and aesthetic objective for chloride levels of 250 mg/L, based on the potential for undesirable tastes at concentrations above this level, and the increased risk of corrosion of pipes.

The chlorides were present in the range of 142-709 mg/l in the rain water samples. It was observed that Moringa seed treatment with chloride ions reduced the chloride level, because cations from the seed attract negatively charged chloride ions present in raw water and neutralise the chloride and therefore chloride ions was reduced to the range of 115-397 mg/l. Upon treatment with alum, the chloride ions increased to the range of 404.13-1966.5 mg/l. This is well above the WHO and NSDWQ permissible limit. Also, the Hand dug well samples have chloride ions in the range of 446.7-652.28 mg/l.

The four samples taken from the Hand dug well source did not meet up with the acceptable limits. The chloride ions was decreased when Moringa seed powder was added, and also the chloride ions was increased when alum was added. Similar trend occurred in the hand pump and borehole samples in which the chloride ions decreased upon addition of Moringa seed powder while also the chloride ions increased when alum was added.

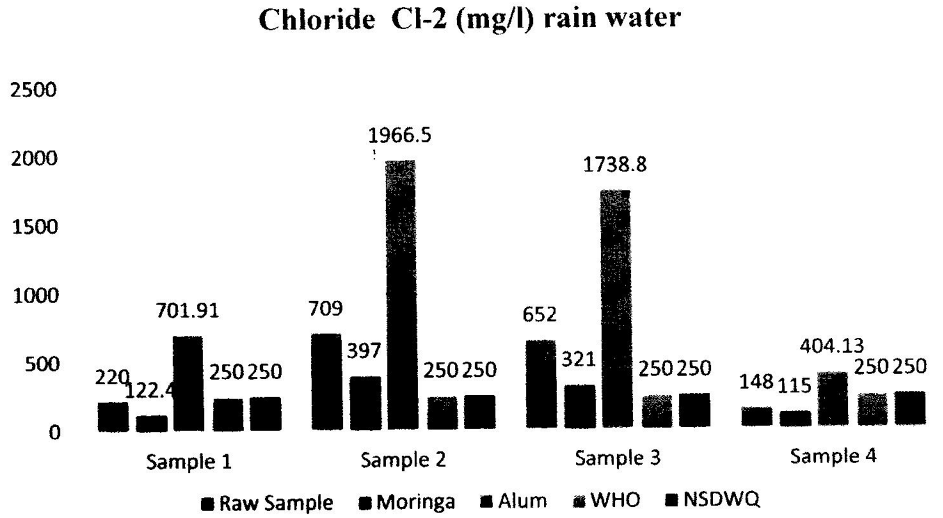

Figure 4.19 Chloride Cl-2 (mg/l) rain water

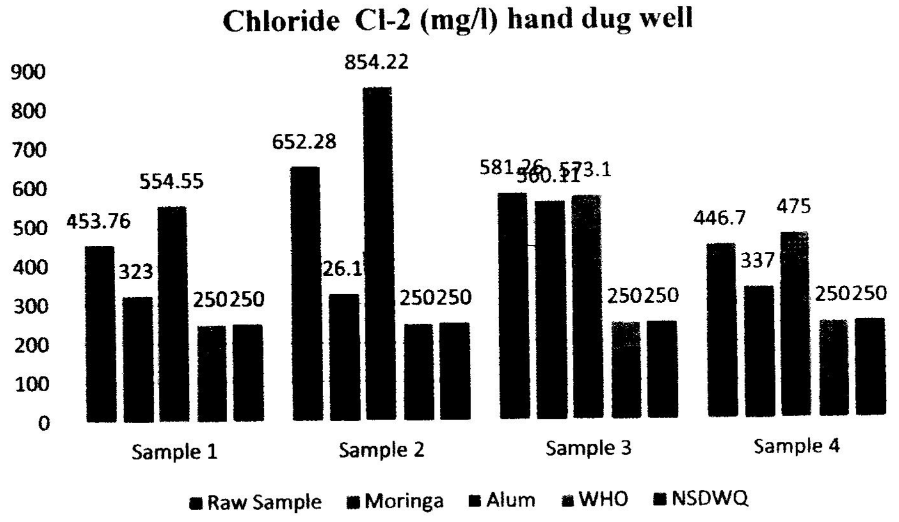

Figure 4.20 Chloride Cl-2 (Mg/l) hand dug well

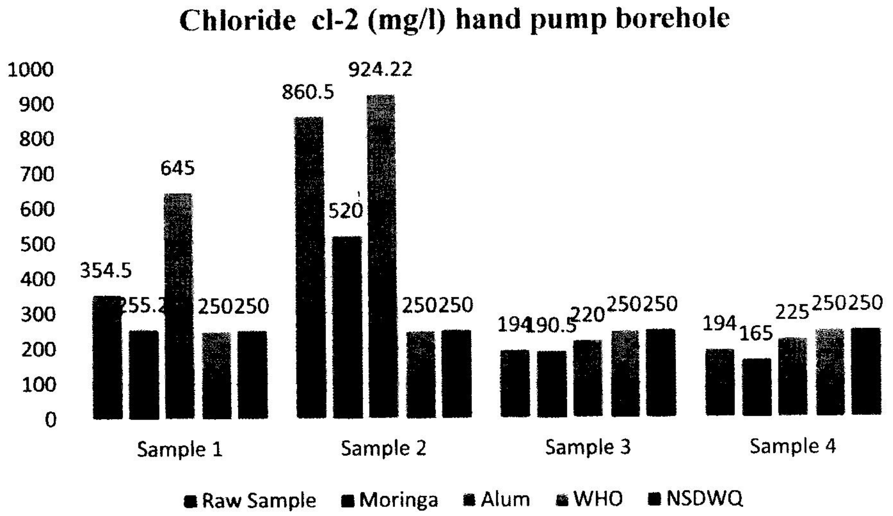

Figure 4.21 Chloride Cl-2 (mg/l) hand pump borehole

Magnesium calcium hardness

Water described as "hard" is high in dissolved minerals, specifically calcium and magnesium. Hard water is not a health risk, but a nuisance because of mineral buildup on fixtures and poor soap and/or detergent performance.

When water is combined with carbon dioxide to form very weak carbonic acid, an even better solvent results. As water moves through soil and rock, it dissolves very small amounts of minerals and holds them in solution. Calcium and magnesium dissolved in water are the two most common minerals that make water "hard." The degree of hardness becomes greater as the calcium and magnesium content increases and is related to the concentration of multivalent cations dissolved in the water.

Hard water is not a health hazard, but dealing with hard water in the home can be a nuisance. The hardness (calcium and magnesium concentration) of water can be measured more accurately with a laboratory water test.

The magnesium and calcium ions present in the rain water samples are within the WHO and NSDWQ permissible limit except for the magnesium ion in sample 1 which is 52 mg/l. This value was reduced to 18 and 40 mg/l when treated with Moringa and alum respectively. Most of the samples from the hand dug well source contain calcium and magnesium ions above the WHO and NSDWQ standards which is 50 mg/l. The magnesium and calcium ions was further increased when alum was added to the raw water. For instance the calcium ions in sample 2 of hand dug well source got increased from 136 mg/l to 204 mg/l when alum was added. Upon addition of Moringa seed powder, the calcium and magnesium ions was reduced. For instance the magnesium ions in sample 2 of the hand dug well sample reduced from 84 mg/l to 30 mg/l.

Similar trend as witnessed in the hand dug well samples occurred in the hand pump and borehole samples. The magnesium and calcium ions increased when alum was added. Example is sample 4 of the hand pump and borehole sample in which the magnesium ion increased from 52 mg/l to 60 mg/l. Also, when the magnesium and calcium ions reduced when Moringa seed powder was added. For instance the calcium ions in sample 1 decreased from 61 mg/l to 32.1 mg/l.

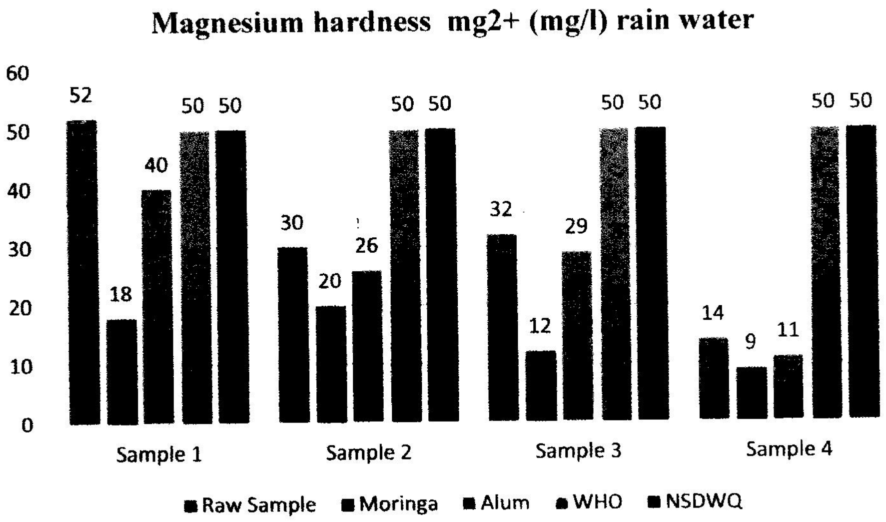

Figure 4.22 Magnesium hardness Mg2+ (mg/l) rain water

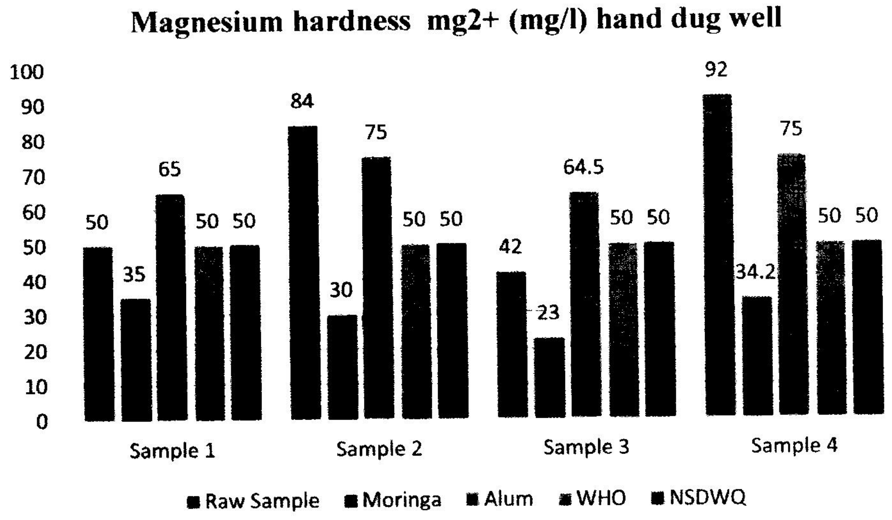

Figure 4.23 Magnesium hardness Mg2+ (mg/l) hand dug well

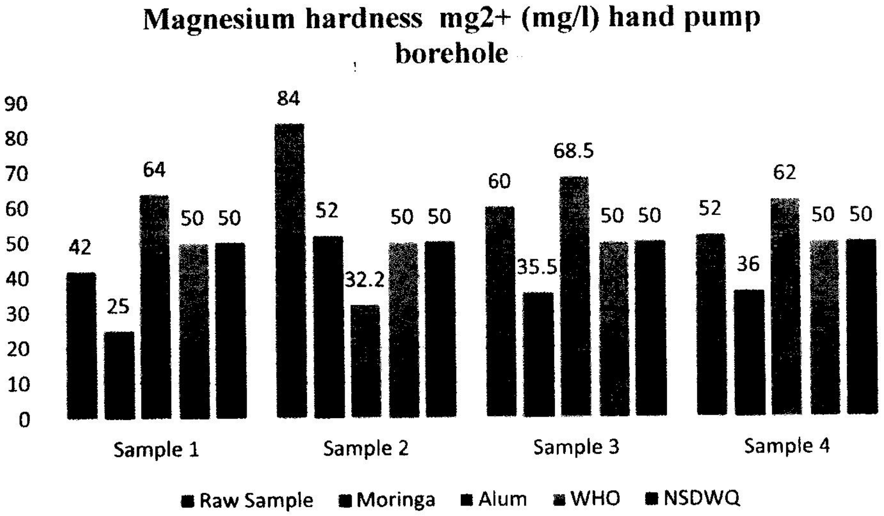

Figure 4.24 Magnesium hardness Mg2+ (mg/l) hand pump borehole

Calcium hardness

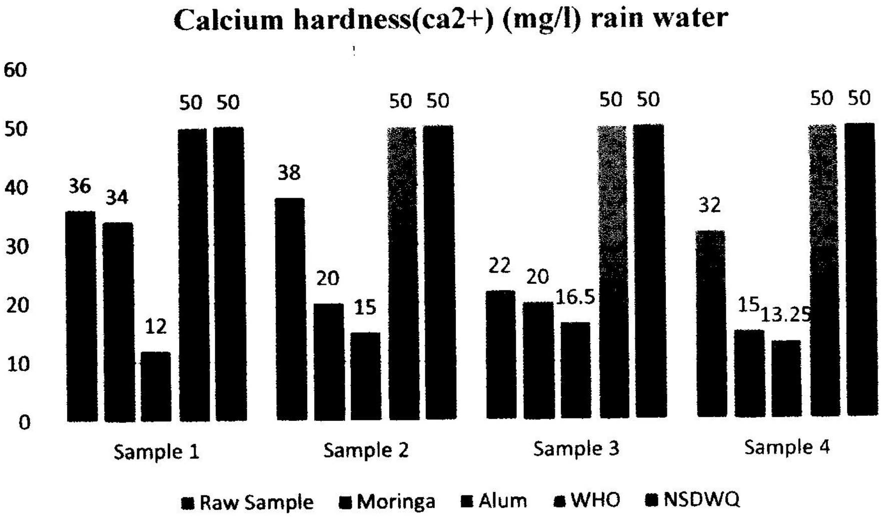

Figure 4.25 Calcium hardness (Ca2+) (mg/l) rain water

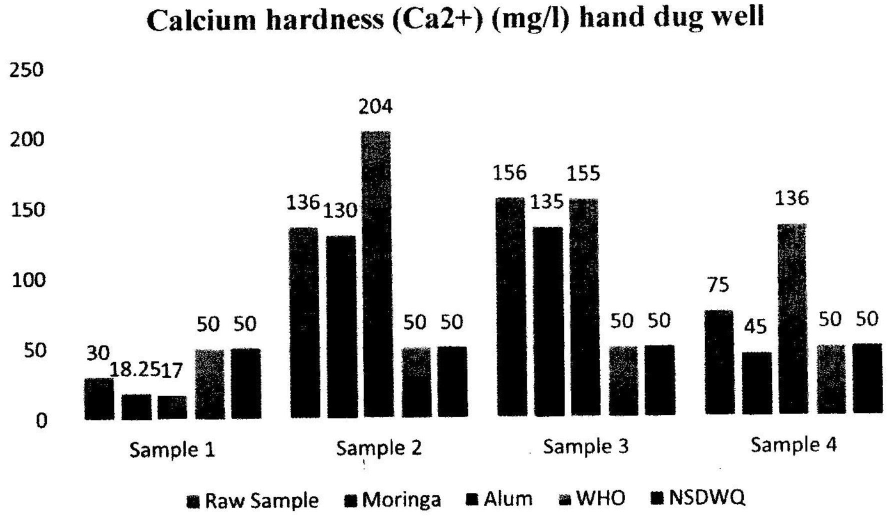

Figure 4.26 Calcium hardness (Ca2+) (mg/l) hand dug well

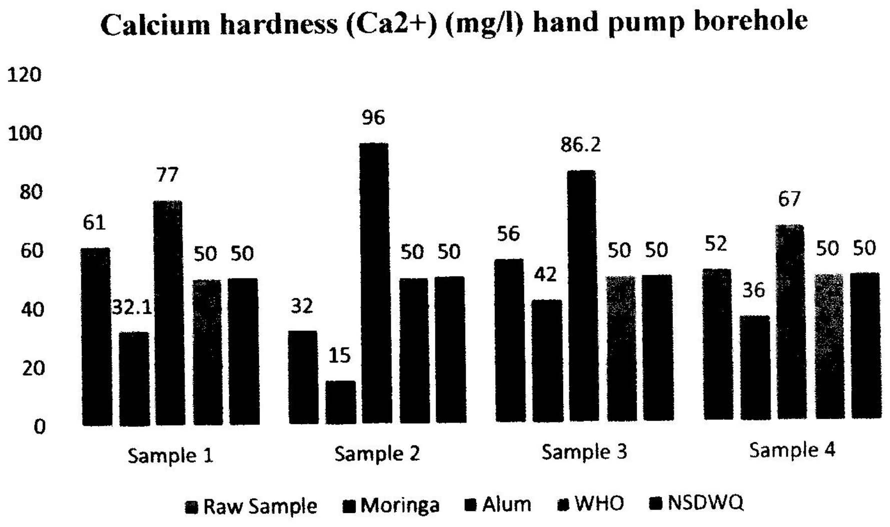

Figure 4.27 Calcium hardness (Ca2+) (mg/l) hand pump borehole

Iron

Iron can be a troublesome chemical if present in water. Making up at least 5 percent of the earth's crust, iron is one of the earth's most plentiful resources. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron, causing it to seep into aquifers that serve as sources of groundwater for wells. Although present in drinking water, iron is seldom found at concentrations greater than 10 milligrams per liter (mg/L) or 10 parts per million. However, as little as 0.3 mg/l can cause water to turn a reddish brown color. Although iron is not hazardous to health, but it is considered a secondary or aesthetic contaminant. Essential for good health, iron helps transport oxygen in the blood.

All the samples gotten from the rain water source are within the WHO and NSDWQ permissible limit which is 0.3 mg/l. The iron ions are in the range of 0.01-0.04 mg/l. It was observed that addition of alum and Moringa seed powder further reduced the iron ions present in the rain water samples. Also, all the samples gotten from the hand dug well source are within the WHO and NSDWQ permissible limit. They have iron ions ranging from 0-0.06 mg/l. Similarly, the ions was reduced upon addition of alum and Moringa seed powder.

It was also observed that samples 1,2,3 and 4 of the hand pump and borehole samples have 0 mg/l, 0.03 mg/l, 0 mg/l, and 0 mg/l number of iron ions respectively, and they are within permissible limit. The ions was also reduced upon addition of alum and Moringa seed powder.

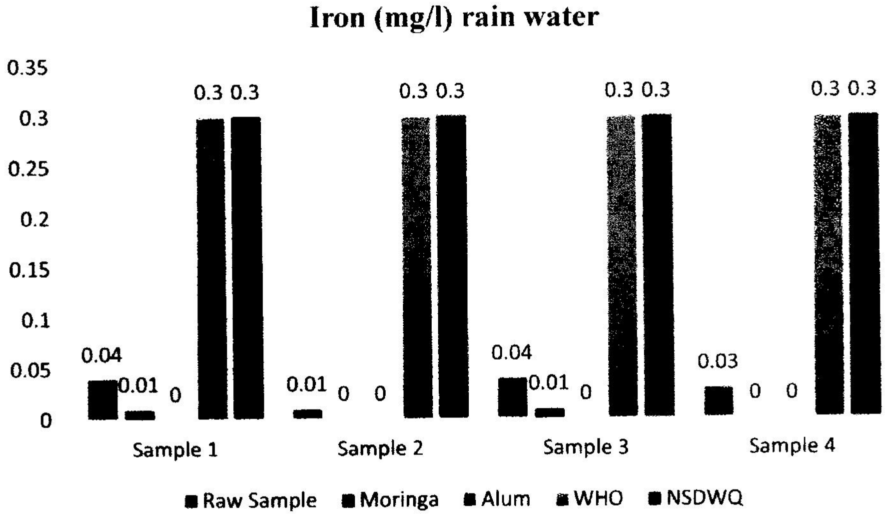

Figure 4.28 Iron (mg/l) rain water

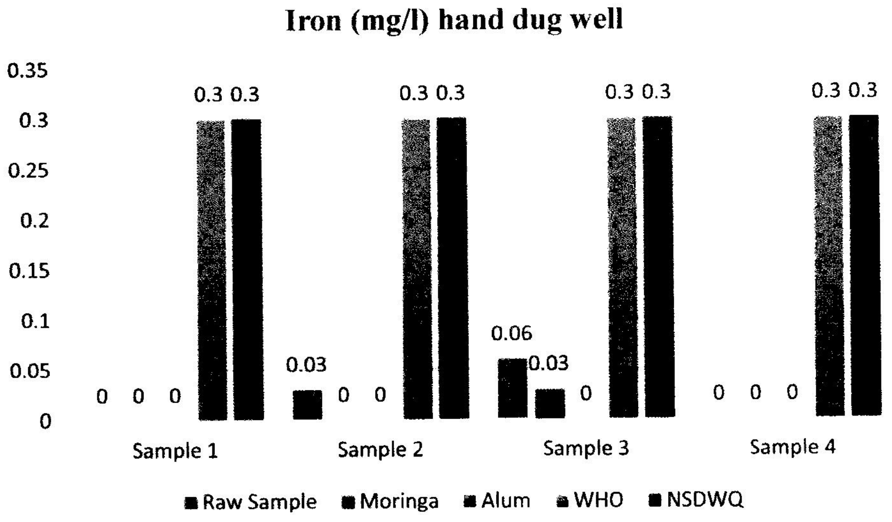

Figure 4.29 Iron (mg/l) hand dug well

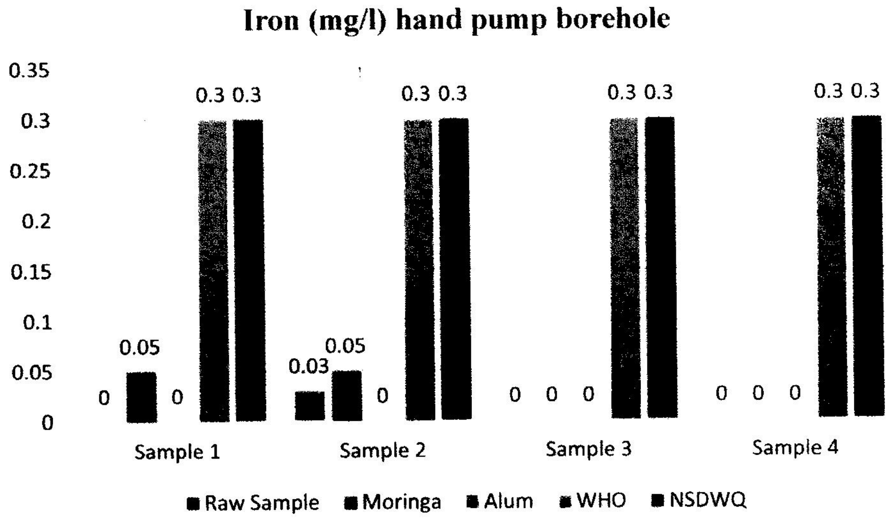

Figure 4.30 Iron (mg/l) hand pump borehole

Sulphate

Sulphate (SO4) can be found in almost all natural water. The origin of most sulphate compounds is the oxidation of sulphite ores, the presence of shales, or the industrial wastes. High concentrations of sulphate in the water we drink can have a laxative effect when combined with calcium and magnesium, the two most common constituents of hardness. Bacteria, which attack and reduce sulphates, form hydrogen sulphide gas.

The maximum level of sulphate suggested by the World Health Organization (WHO) in the Guidelines for Drinking-water Quality is 200. Also the permissible limit set by Nigerian Standard for Drinking Water Quality is 300. It can be observed that all the rain water samples collected have zero presence of sulphate. It can also be observed that upon addition of Moringa seed powder and alum, the sulphate level remained zero.

As for the hand dug well samples, the level of sulphate present are in the range of 0-0.65 mg/l. This is well below the WHO and NSDWQ standards. When alum and Moringa seed powder was added, it was observed that the sulphate level was reduced. Also, for the hand pump and borehole samples, the sulphate level are well below the WHO and NSDWQ permissible limit. Their sulphate level are in the range of 0-0.36 mg/l. Similarly, upon addition of alum and Moringa seed powder, their sulphate level was reduced.

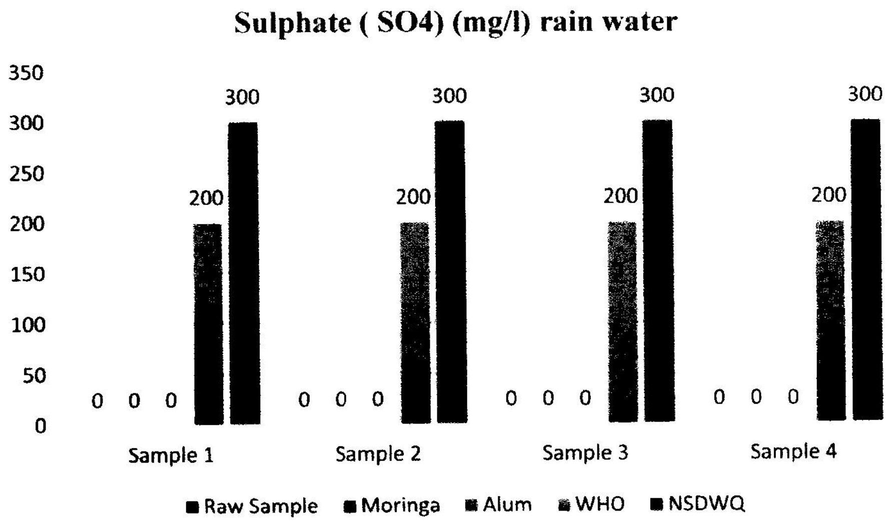

Figure 4.31 Sulphate (SO4) (mg/l) rain water

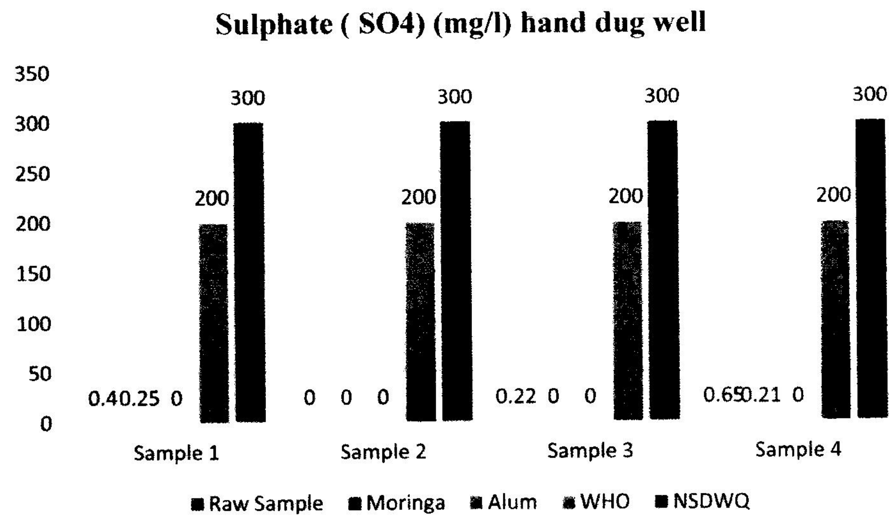

Figure 4.32 Sulphate (SO4) (mg/l) hand dug well

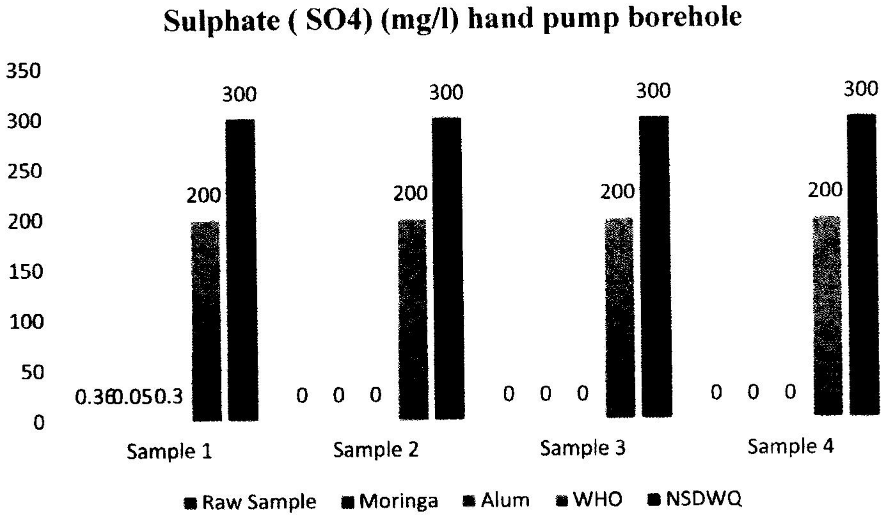

Figure 4.33 Sulphate (SO4) (mg/l) hand pump borehole

Dissolved oxygen

The amount of oxygen dissolved in water depends on the rate of aeration from the atmosphere, temperature, air pressure and salinity. While the actual amount of oxygen that can be dissolved in water depends on the relative rates of respiration by all organisms and of photosynthesis by plants, oxygen levels are actually low where organic matter accumulates because aerobic decomposers require and consume oxygen. The initial dissolved oxygen level of the rain water samples are in the range of 13.1-18.2 mg/l. It was observed that addition of Moringa seed powder further increased the dissolved oxygen to the range of 14.54-20.2 mg/l, while addition of alum reduced the dissolved oxygen to the range of 11.8-16.3 mg/l.

Also, for the hand dug well samples, the dissolved oxygen was in the range of 7.5-15 mg/l. Similarly, when Moringa seed powder was added, the dissolved oxygen level increased to a range of 8.32-16.65 mg/l. Also, addition of alum reduced the level of dissolved oxygen to a range of 6.75-13.51 mg/l. Lastly, the dissolved oxygen level of the hand pump and borehole samples are in the range of 9.2-16.2 mg/l. It was also observed that addition of Moringa seed powder increased the dissolved oxygen to the range of 10.21-17.82 mg/l, while addition of alum reduced the dissolved oxygen level to a range of 8.29-14.78 mg/l. There is no limiting values given for dissolved oxygen in drinking water by WHO and NSDWQ.

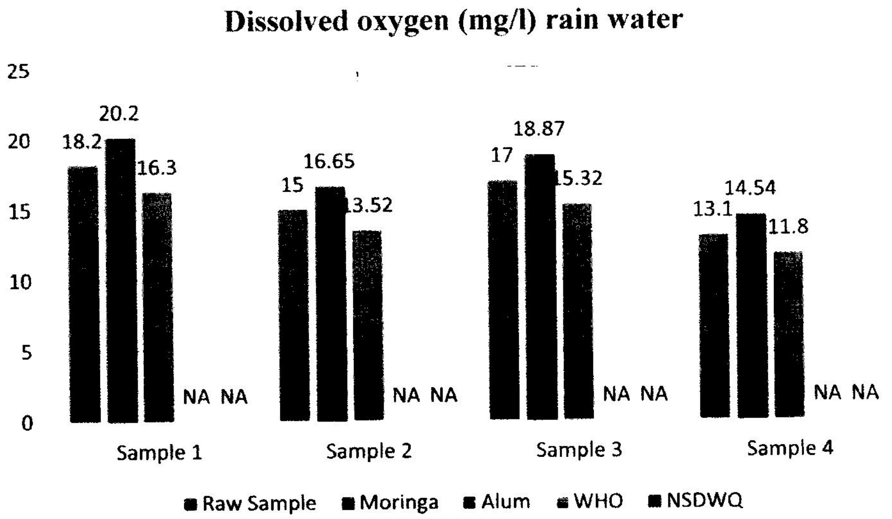

Figure 4.34 Dissolved oxygen (mg/l) rain water

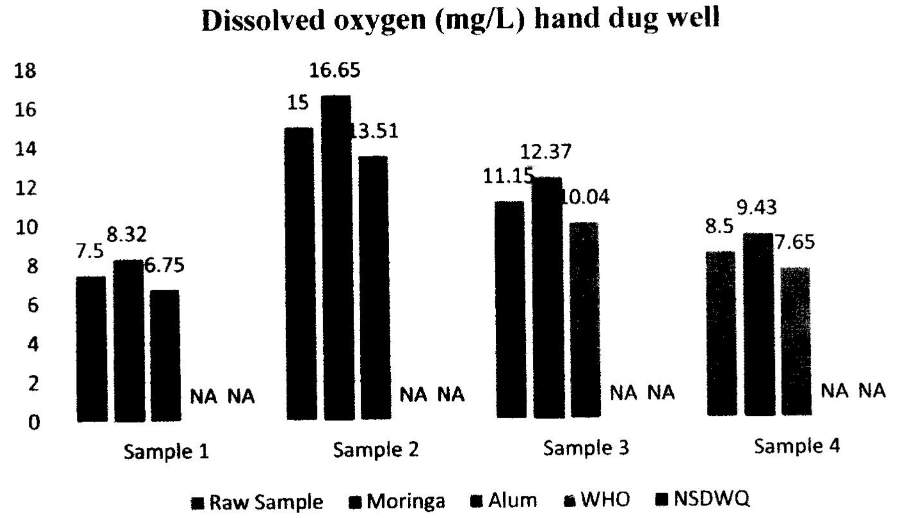

Figure 4.35 Dissolved oxygen (mg/l) hand dug well

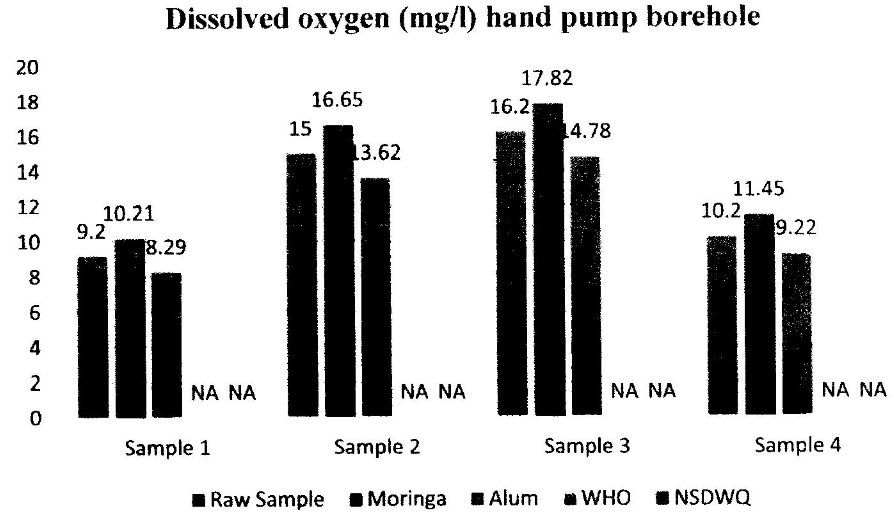

Figure 4.36 Dissolved oxygen (mg/l) hand pump borehole

B.O.D

Biochemical Oxygen Demand (BOD) is used as an index for determining the amount of decomposing organic materials as well as the rate of biological activities in water. This is because oxygen is required for respiration by microorganisms involved in the decomposition of organic materials. Thus high concentration of BOD indicates the presence of organic effluent and oxygen requiring microorganisms.

The initial BOD for the rain water samples was in the range of 9.17- 12.17 mg/l. When the samples were treated with Moringa seed powder, the BOD was increased to the range of 10.17-14.2 mg/l. And also, treatment with alum reduced the BOD level to the range of 8.26-11.44 mg/l.

The raw water BOD for the hand dug well samples are in the range of 5.7-10.58 mg/l. The BOD level was increased when treated with Moringa, and also the BOD was reduced when treated with alum.

Also, for the hand pump and borehole samples, the BOD level was in the range of 6.43- 11.63. It was observed that upon treatment with Moringa, the BOD level was increased to the range of 7.14-12.56 mg/l. Also, when alum was added, the BOD was reduced to the range of 5.8- 10.35 mg/l.

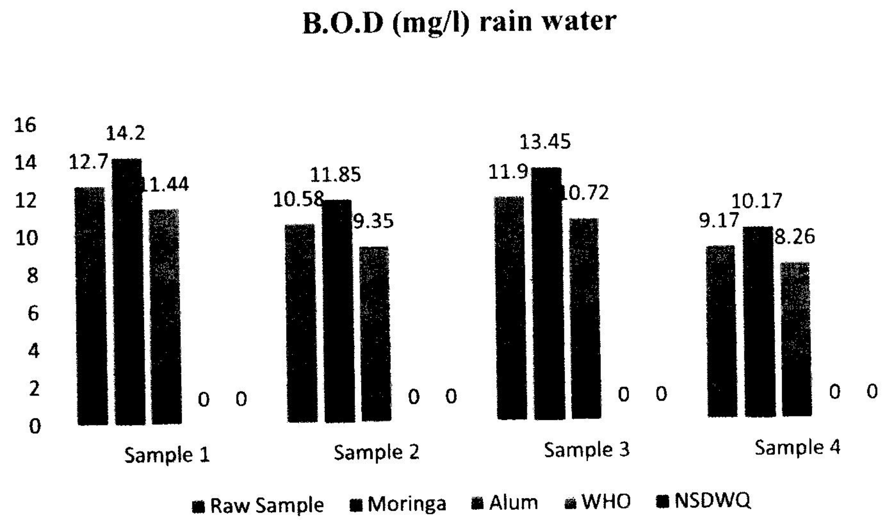

Figure 4.37 B.O.D (mg/l) rain water

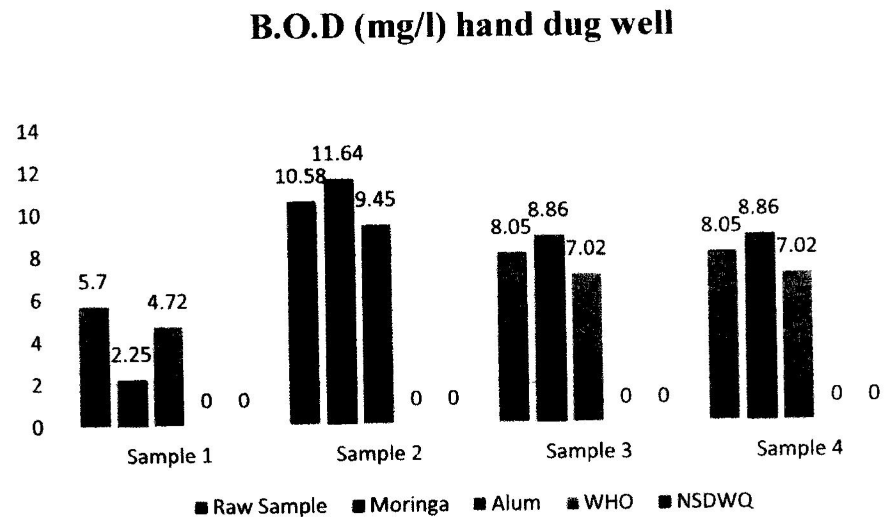

Figure 4.38 B.O.D (mg/l) hand dug well

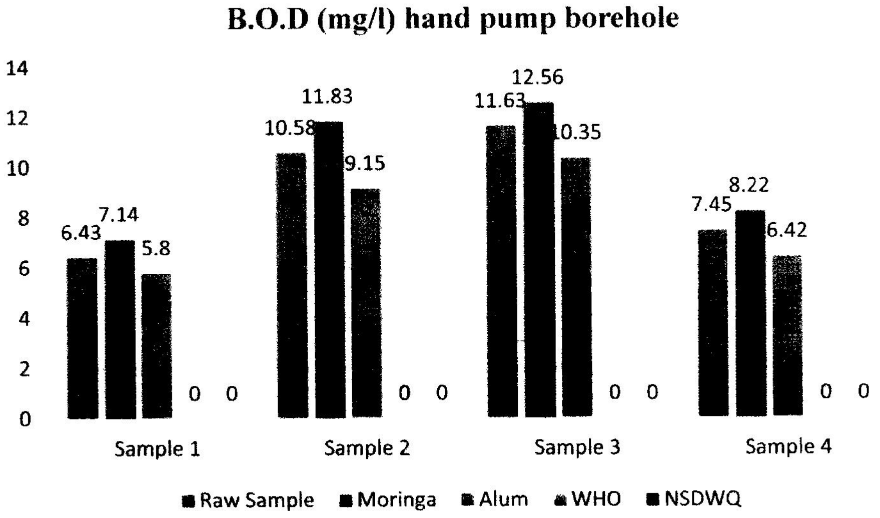

Figure 4.39 B.O.D (mg/l) hand pump borehole

Bacterial count

The presence of bacteria and pathogenic (disease-causing) organisms is a concern when considering the safety of drinking water. Pathogenic organisms can cause intestinal infections, dysentery, hepatitis, typhoid fever, cholera, and other illnesses. Human and animal wastes are a primary source of bacteria in water. These sources of bacterial contamination include runoff from feedlots, pastures, dog runs, and other land areas where animal wastes are deposited. Additional sources include seepage or discharge from septic tanks, sewage treatment facilities, and natural soil/plant bacteria. Bacteria from these sources can enter wells that are either open at the land surface or do not have water-tight casings or caps.

For the rain water, hand pump and borehole samples, the bacteria count is 0 cfu/l. Addition of alum and Moringa seed powder had no effect on the bacteria count. The samples meet up with the WHO and NSDWQ permissible limit which is 0cfu/l. But all the samples in the hand dug well source, do not meet up with the WHO and NSDWQ standards which is 0cfu/l. They have bacteria count ranging from 7-15 cfu/l. It was observed that addition of alum and Moringa seed powder had no effect on the bacteria count.

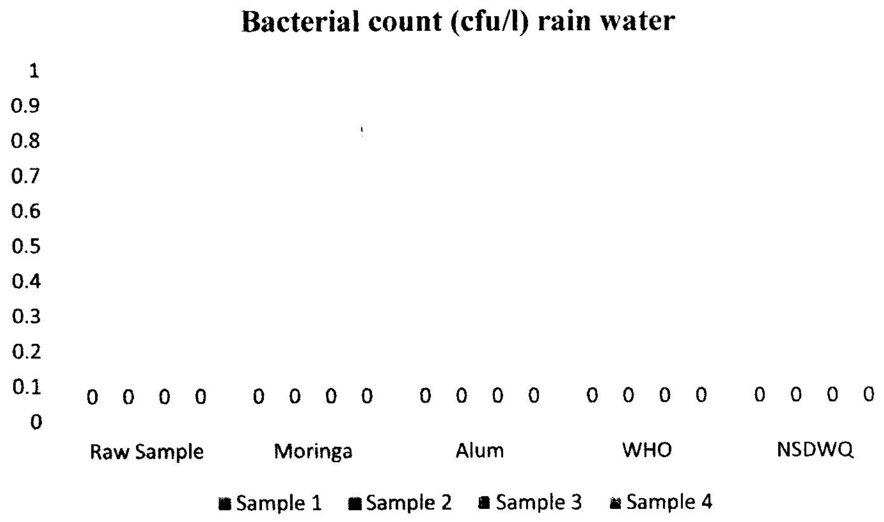

Figure 4.40 Bacterial count (cfu/l) rain water

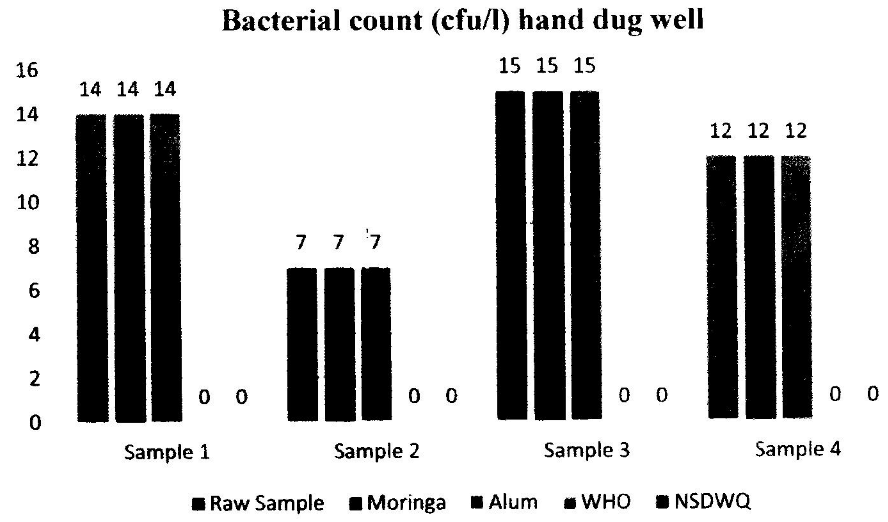

Figure 4.41 Bacterial count (cfu/l) hand dug well

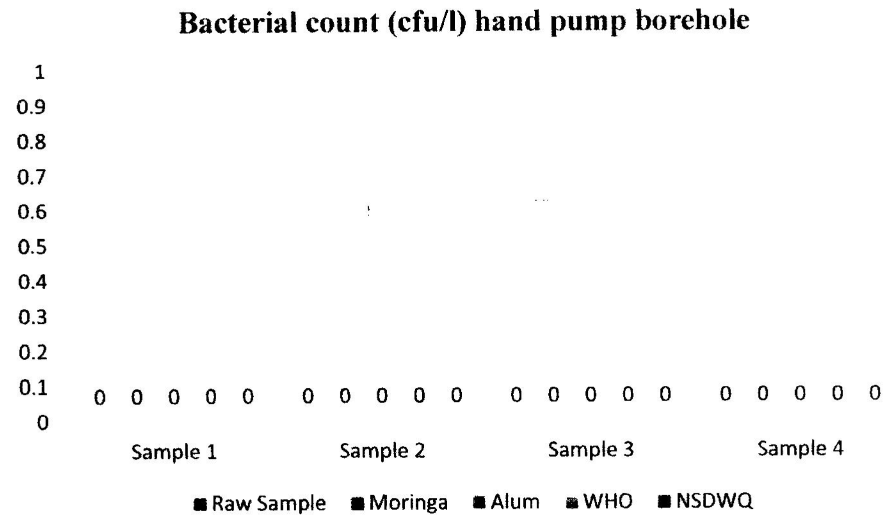

Figure 4.42 Bacterial count (cfu/l) hand pump borehole

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The following conclusions can be drawn from this study:

1. Moringa oleifera is an effective natural coagulant which can be used in improving the physicochemical characteristics of water in terms of appearance, odour, total solids, turbidity, conductivity, pH, nitrate, total alkalinity, chloride, hardness, iron, sulphate, dissolved oxygen, and BOD.
2. In water treatment, Moringa seeds hardly affect pH of water as compared to alum which requires pH adjustment after treatment. This is likely to reduce the high cost of the current water treatment systems.
3. Moringa oleifera is not suitable when used as disinfectant. This is because the bacteria count remained unchanged after the addition of Moringa seed powder.
4. Moringa oleifera seed extract can be used as an alternative to alum in treating domestic water for rural inhabitants since it is environmental friendly and cheaper.

5.2 Recommendation

1. Moringa oleifera is biodegradable, eco-friendly and has non-toxic substances hence, it is highly recommended in rural areas where no facilities are available for drinking water treatment. For its optimum utilization, "boil before use" approach should be applied immediately after treatment.
2. Moringa oleifera stands to be a suitable substitute for commercial alum in the nearest future of water treatment technology. It is recommended that studies must be carried out determine the optimum detention time for water treated with the coagulants so as to obtain higher removal efficiency.
3. There is need for the government to sensitise rural dwellers on the use of Moringa in water treatment through workshop and seminar and also through the use of media in all states and local councils in Nigeria.
4. Government should encourage farmers and private investors to invest in the cultivation of Moringa since it has the potential of reducing cost of water treatment and can help improve water quality for rural inhabitants.

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