COMPARATIVE STUDIES ON THE EFFECTS OF *MORINGA OLEIFERA* IN IMPROVING WATER QUALITY FOR SOME COMMUNITIES IN SEKYERE SOUTH DISTRICT

By

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DECLARATION

I hereby declare that this submission is my own work towards the award of MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

This thesis is dedicated to all members of the Addo family for their love, generous support and prayers.

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ABSTRACT

The high cost of treating drinking water makes most poor people in the rural communities resort to readily available sources which are mostly polluted, thus, exposing them to waterborne diseases. 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 in four communities in the Sekyere South District. Water samples from two streams and two hand dug wells from four communities were treated with *Moringa oleifera* seed extract as coagulant using jar test. The quality of treated water was analyzed and compared with alum treated water. Five millilitres (5ml), 10ml, 15ml and 20ml concentrations of seed extract were used and their results compared to that of 0.2ml, 0.4ml, 0.6ml and 0.8ml concentrations of alum. A control (water without alum and *Moringa* treatments) was also included**.** The pH, turbidity, total dissolved solids, conductivity and microbial counts were measured at three different time intervals (0, 12 and 24 hours). Efficient turbidity reduction was observed at 20 ml and 10 ml concentrations of *Moringa* for stream and well water from an initial value of 24.59 NTU to 5.09 NTU and 13.17NTU to 5.48NTU respectively after 24 hour settling time. Alum concentration of 0.4ml reduced turbidity to 3.32 NTU for stream water and 3.0 NTU for well water. Total dissolved solids and conductivity gradually increased for both alum and *Moringa* with increasing concentrations but fell within the recommended drinking water standard. *Moringa* concentrations did not influence pH of water. pH values were observed to range between 7.29 to 6.27 for stream water and 7.05 to 6.06 for well water, however, alum concentrations reduced pH to acidic levels. Bacterial removal range of 61% and 68% was observed for 20ml *Moringa* concentration for streams whereas alum concentration of 0.8ml recorded 75% and 80% bacterial removal. Well water recorded percentage bacterial removal range of 57% and 54% for 15ml *Moringa* concentration as compared to the removal range of 69% and 74% recorded by alum at the 12 hour treatment period. Findings from this study indicate that *Moringa oleifera*, a natural coagulant, can be a potentially viable substitute to alum in treatment of water.

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CHAPTER ONE

1.0 INTRODUCTION

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 (Bartram *et al*., 2005). 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).

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" (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 (WHO, 2008). 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. Nevertheless, 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 (WHO, 2008).

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 (Rondinelli, 1991). Due to this distressed situation people in rural areas are forced to use traditional sources that are polluted (WHO and UNICEF, 2000). 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 (WHO, 2003).

The 2003 Ghana Demographic and Health Survey (DHS) reported that 46.4% of rural households lack access to improved drinking water. Thus diarrhoeal prevalence in the two weeks preceding the DHS was lowest in households that have access to indoor piped water (Ghana Statistical Service *et al*., 2004).

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.

1.2.1 HEALTH

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 (Billig *et al*., 1999). Studies have reported that diarrhoea, dysentery and malaria are the causes of high rate of mortality in these countries (Verheyen, 1986). 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. (Billig *et al*., 1999).

1.2.2 EDUCATION

Water-related diseases cost 443 million school days each year, equivalent to an entire school year for all seven-year-old children in Ethiopia (UNDP, 2006). 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. Children with infections are twice as likely to be absent from school as those without and they perform poorly even when in school (UNDP, 2006).

1.2.3 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).

1.3 CAUSES OF WATER SCARCITY

1.3.1 POPULATION INCREASE

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 (Acquah, 1997).

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. The rapid increase in population and urbanization, particularly the conversion of watersheds into residential facilities and farmlands is leading to depletion of water resources (Goundern, 1997).

1.3.2 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. Farming close to river banks and uncontrolled discharge of waste into freshwaters pose significant threat to water quality in rural and urban areas (Acquah, 1997).

1.3.3 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. Another factor accelerating and intensifying water shortage is drought caused by the green house effects and global warming (Nsiah-Gyabaah, 2001).

1.4 NEED FOR WATER TREATMENT

As the case in most parts of sub-Saharan Africa, water demand far outstrips supply in Ghana. Rural water supply and sanitation projects that are now implemented in several rural districts in the country by the Community Water and Sanitation Agency (CWSA) are facing certain drawbacks, of which poor management and financial constraints are prominent. The outcome of this is that the few installed water facilities for these communities are unable to suffice the needs of the population.

Rural communities most often rely greatly on ground water provided that it is available in sufficient quantities, and also on surface water which may be contaminated in most cases. Most of the diseases causing death in the country are related to poor water and sanitation with malaria, diarrhoea and cholera being the most causes of mortality. Two major epidemics were recorded in 1991 and in 1999 with fatality ranging from 2.2 to 3.4% (UNICEF, 2004).

Water collection and storage practices especially the choice of water collection and storage containers are fundamental in determining household water quality (Sobsey, 2002). A CWSA/CIDA survey reported that about 43% of rural households in the northern region of Ghana store water in open containers (CIDA, 2001).

Treatment of water therefore becomes necessary to improve the quality to meet standards and avert disease outbreaks. The objective of water treatment is the removal of turbidity and other contaminants including natural organic materials and organisms. Murcott (2006), identified three broad areas of water quality: physical, chemical and microbiological that can be improved by household water treatment. Physical removal technologies include ceramic and biosand filters, cloth filters and coagulation and flocculation technologies. Boiling, solar disinfection (SODIS) and chlorination are examples of technologies that improve microbial quality of water.

1.5 MAIN OBJECTIVE

The main objective of the study was to determine the suitability of *Moringa oliefera* as an alternative and cheap local coagulating material in the improvement of water quality in terms of turbidity, pH, colour and microorganism removal for rural Ghana.

1.5.1 SPECIFIC OBJECTIVES

The specific objectives were to:

1. compare the efficiency of different traditional water purification methods used by the inhabitants.
2. evaluate and compare the performance and effectiveness of *Moringa* seed powder as a replacement to alum in water treatment systems.
3. determine the amount of seeds required for efficient treatment of the various pollution levels encountered in the study area.

4. determine the antimicrobial effects of various concentrations of alum and *Moringa oleifera* seeds on removal of pathogenic bacteria isolated from water sources.

CHAPTER TWO

2.0 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 (Suarez *et al*., 2003). In conventional water treatment a series of processes including coagulation, flocculation, sedimentation, filtration and disinfection are often used (AWWA, 1990). 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 (Kalibbala, 2007).

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. 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 (Ghebremichael *et al*., 2005).

2.1 COAGULATION

Coagulation describes the consolidation of smaller metal precipitate particles into larger metal precipitate particles (flocs). 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. As flocs density increases, inter

particle contact increases due to Brownian motion, promoting agglomeration of colloidal particles into larger flocs for enhanced settling (Qasim *et al*., 2000).

Treatment of water to remove turbidity is essential for large and small-scale production of drinking water. 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 (Raghuwanshi *et al*., 2002). 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. Aluminium and iron coagulants react with bicarbonate alkalinity (HCO_3^-) in acid drainage, creating aluminium, ferric or ferrous hydroxide flocs which attract metals in solution through co-precipitation (Faust and Aly, 1999)

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. 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 (Amirtharajah and O´Melia, 1990; Gregory and Duan, 2001).

2.2 FLOCCULATION

Flocculation involves the combination of small particles by bridging the space between particles with chemicals (Skousen *et al*., 1996). Essentially, coagulants aid in the formation of metal precipitate flocs, and flocculants enhance the floc by making it heavier and more stable. For this reason, flocculants are sometimes referred to as coagulant aids at water treatment operations (Tillman, 1996; Faust and Aly, 1999).

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. Activated silica has been used as a flocculant since the 1930's to strengthen flocs and reduce the potential of deterioration (Skousen *et al*., 1996). 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 nonionic 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.

2.3 CHEMICAL COAGULANTS

2.3.1 IRON SALTS

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 (Tillman, 1996). 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. It is effective over a much greater pH range than aluminium sulphate, ferric sulphate, and ferrous sulphate (Skousen *et al*., 1996).

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 $A1_2O_3$. Liquid alum is about 49 % solution, or approximately 8.3 % by weight aluminium as $A1_2O_3$. 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 and 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. It reacts with phosphorous and bicarbonate compounds in water to adjust pH causing precipitation of calcium carbonate and magnesium hydroxides (Cosidine, 1974).

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. They have been used with or without alum to achieve clarification in lime water-softening plants (Cosidine, 1974).

2.3.5 POLYELECTROLYTES

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. They can be either natural or synthetic and can be used as both primary coagulants and coagulant aids (Hashimoto *et al*., 1991). 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 (Gregory and Duan, 2001).

Although 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 (Özacar and Şengil, 2003).

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 ($Al_2 (SO_4)_2.14H_2O$) 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 Al_2O_3 (AWWA, 1990).

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

- Removal of turbidity , inorganic or organic
- Removal f harmful bacteria and other pathogens
- 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 (Rossi and Ward, 1993; Kalibbala, 2007).

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 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 (Gregory and Duan, 2001).

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. To achieve effective coagulation, proper mixing is also necessary to allow active coagulant species to be transferred onto turbid water particles (Gregory *et al*., 1997).

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. Thus, 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 (Gregory and Duan, 2001).

2.7 HEALTH RISKS ASSOCIATED WITH CHEMICAL COAGULATION AND FLOCCULATION

Although 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 (Driscoll and. Letterman, 1995). 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 (AWWA, 1990). Moreover, monomers of some synthetic organic polymers such as acrylamide have neurotoxicity and strong carcinogenic properties (Hashimoto *et al*., 1991).

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. These 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 (Tokmak *et al*., 2004).

Alternative disinfectants such as chlorine dioxide, chloramines and ozone are also associated with the formation of disinfection by- products (DBPs) that are toxic compounds and impart objectionable taste and odour (Sadiq and Rodriguez, 2004). Irradiation with ultraviolet (UV) light is a promising alternative method of disinfection but it is expensive and leaves no residue and hence another disinfectant is required to disable bacteria and viruses. In addition, UV light can react with nitrate in water to produce nitrite, the precursor for methaemoglobinaemia in infants (Mole *et al*., 1999).

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).

2.8 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 and Narasiah, 1998).

There has been a resurgence of interest in using naturally occurring alternatives to currently used coagulants for water treatment in developing countries (Jahn, 1988), mainly due to cost implications that are associated with inorganic chemicals, synthetic organic polymers and disinfectants (Ndabigengesere and Narasiah, 1998). There is also an interest in reusing some of the by-products from natural coagulants in other enterprises (Kawamura, 1991).

Traditionally, treatment of turbid surface water sources is carried out at household level using local materials of plant or animal origin. For example, 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 (Jahn, 2001).

In India, crushed seeds of the nirmali tree (*Strychnos potatorum*) have been used for centuries to clarify muddy water (Tripathi *et al*., 1976). Traditional water treatment using crushed or chopped *Maerua pseudopetalosa* (kordala) roots is practised in some parts of Sudan. In Northern Chad and villages around Maiduguri in Northern Nigeria, people use wood ash as a natural water coagulant. Knowledge on natural coagulants is widespread in many parts of the developing world and therefore there is good potential for such knowledge to be used efficiently provided concerted efforts can be devoted to maximising their performance through research (Jahn and Dirar, 1979). Studies have acknowledged that the most important plant families from which several genera are used traditionally for domestic water coagulation are Acanthaceae, Capparidaceae and Papilionaceae (Samia, 1988).

2.8 TYPES OF NATURAL COAGULANTS

2.8.1 Materials of Soil Origin

It has being observed that mineral substances are used as flocculation aid in modern water treatment. A dose of 10 mg/l of bentonite, for instance, together with 10 mg/l of aluminium sulphate yield significantly better results than a higher dose of aluminium sulphate alone. In rural households in developing countries, however, various naturally occurring materials are traditionally used as coagulants. Examples are fluvial clays from rivers and clarifying rock material from desert regions (Jahn, 1984).

2.8.2 COAGULANTS OF PLANT ORIGIN

***Vicia faba* (*Faba vulgaris*) - horse bean**

This belongs to the family Papilionaceae and largely cultivated in Sudan. Seeds have been used successfully to purify water in arid regions of Sudan. It is known locally as Ful masri (Jahn, 1986).

Trigonella foenum graecum

This is known in Sudan as "helba" belonging to the family of Papilionaceae. It also largely cultivated in Sudan.

***Moringa oleifera* (Horse radish or Drumstick tree)**

It is believed to have originated from India but now largely cultivated in Sudan and many other countries. It was identified in Ghana in the Volta region where it is referred to as "Babati". In the Northern and Upper West Regions, it is referred to as "Wobnyukuo" (Donkor, 1996).

Moringa stenopetala and Moringa longituba

These are indigenous shrubs in Northern Kenya and Southern Ethiopia. Dried stalks and fruits of these plants have been reported to be efficient in water clarification. They are known locally as "Lorensienjo" and "Mawa" respectively (Jahn, 1986).

2.9 ORIGIN AND HISTORY OF MORINGA

This tree species originally came from India and was introduced to Kenya at the turn of the 20th century by Indian workers who came to Africa to build the Mombasa-Kampala railway line (Mundia, 2003). *Moringa oleifera* Lam. is the most widely cultivated species of the monogeneric family Moringaceae (order Brassicales), that includes 13 species of trees and shrubs distributed in sub-Himalayan ranges of India, Sri Lanka, North Eastern and South Western Africa, Madagascar and Arabia. Today it has become naturalized in many locations in the tropics and is widely cultivated in Africa, Sri Lanka, Thailand, Burma, Singapore, West Indies, Sri Lanka, India, Mexico, Malabar, Malaysia and the Philippines (Fahey, 2005).

2.10 SOCIO-ECONOMIC IMPORTANCE OF *Moringa oleifera*

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 (Scoones *et al*., 1992).

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. Introduction of this plant into a farm which has a biodiverse environment can be beneficial for both the owner of the farm and the

surrounding eco-system (Foidl *et al*., 2001). In India, economic analysis has illustrated that cultivation of *Moringa oleifera* can be very profitable for farmers with access to urban markets (Sherkar, 1993).

2.11 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. While it grows best in dry sandy soil, it is adaptable to various soil conditions from pH 4.5 to 8 (Rashid *et al*., 2008). 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 (Odee, 1998)

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 (Duke, 1983).

2.12 COMMON USES OF MORINGA

2.12.1 NUTRITIONAL

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 (Rams, 1994). 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).

2.12.2 MEDICINAL USES

M. 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. 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 (Donkor, 1996).

2.12.3 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).

The characteristics of *M. oleifera* seed oil are especially desirable, because of the current trends of replacing polyunsaturated vegetable oils with monounsaturated fatty acids (Abdulkarim *et al*., 2005). Moreover, the oil has the capacity to absorb and retain volatile substances and is therefore valuable in the perfume industry (Foidl *et al*., 2001).

2.12.4 Water purification

Attracting attention in recent decades is the use of the dried, crushed seeds as a coagulant (Jahn, 1984). 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. The cleaned water can then be poured off and boiled (Gupta and 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 algae are removed by sedimentation, dried and pulverized, and then used as protein supplement for livestock (Akhtar *et al*., 2006).

2.13 WATER BORNE DISEASES AND INDICATOR ORGANISMS

2.13.1 Waterborne Pathogens

Waterborne diseases occur in part because of the impurities found in water. The nature of impurities regarding infectious diseases is biological and do not relate to the chemical nature of water.

The numerous illnesses caused by waterborne pathogens indicate that the transmission of microbes in water remains a significant cause of outbreaks. Even in developed countries where the regulations are stricter in terms of water pathogen concentration, drinking water might still carry pathogenic microorganisms after treatment. These pathogens cause occasional illness within the community supplied with this drinking water (e.g., diarrhoea). Diseases associated with water are typically placed in four classes: waterborne, water-washed, water-based, and water-related insect vectors (Gleick, 2002).

Waterborne diseases are caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogenic bacteria or viruses. These include cholera, typhoid and bacillary dysentery and other diarrhoeal diseases. Water-washed diseases are caused by poor personal hygiene and skin or eye contact with contaminated water. These include scabies, trachoma and flea, lice and tick-borne diseases (Gleick, 2002). Parasites found in intermediate organisms living in contaminated water are the causes of water-based diseases such as dracunculiasis, schistosomiasis, and other helminths (Cairncross and Valdmanis, 2004).

Four classes of microbial organisms contribute to the spread of diseases with drinking water. These pathogens can infect humans via ingestion, inhalation or contact with skin, wounds, eyes, or mucous membrane. These are bacteria, viruses, protozoa, and helminths (WHO, 2004).

Usually, unhygienic practices during the handling of food, utensils and clothing play a major role in the transmission of the disease. These pathogens are introduced into water by human or animal waste and cannot proliferate in water. The microbial organisms following this route are called enteric because their first niche is the intestines, or enteron, of their host. The most problematic microbial contaminants for waterborne diseases are the ones that possess a high resistance to decay (WHO, 2004).

2.13.2 BACTERIA

Bacteria are unicellular prokaryotes whose length varies between 0.3 and 100µm. Among bacteria families, the Enterobacteriaceae are particularly pathogenic to humans. The organisms belonging to that family are gram-negative enteric bacilli. Species falling into this category, which are notorious waterborne pathogens include *Salmonella typhi, Shigella spp., E. coli*, and *Yersinia enterocolitca* (Mattelet, 2005).

S. typhi is typically present in all kinds of foods grown in faecally polluted environments. This bacterium is responsible for typhoid fever which can be a fatal disease. *Shigella* spp. causes dysentery in humans and is usually transmitted through direct contact with infected individuals or consumption of contaminated food and water. *E coli* is ubiquitous in nature and is part of the intestinal fauna of humans and other animals. Usually, it is harmless in the intestines at normal concentrations. Certain virulent strains of the species can cause serious illness, such as urinary tract infections and meningitides (Mattelet, 2005). Some strains can lead to mild to highly bloody diarrhoea. *E coli* like *Shigella* spp. spreads from contact with infected individual or contaminated

food and water. *Yersinia enterocolitca* infections can lead to gastroenteritis, abdominal pain, fever, enlarged lymph nodes and diarrhoea. The main ecological niche for this bacterium is contaminated water and sewage, although some harmless strains can be found in nature. Transmission of the bacterium can occur via consumption of contaminated food predominantly but also to a smaller extent, with polluted water or contact with infected individual (WHO, 2004).

2.13.2 VIRUSES

Viruses are considered non-cellular because they need a host to reproduce. The pathogenic pathway begins with the attachment of the virus particle (called virion) to a host cell. Subsequently, the virion penetrates the cell and replicates within it, changing the host cell metabolism with its nucleic acid synthesis. Usually, viruses are much less easily degraded than bacteria with disinfection and treatment processes because of their resistant capsid protecting their genetic information. The main transmission route of these pathogens is through contact with contaminated individual or with contaminated food or water (Madigan *et al*., 2003).

Most of the waterborne viruses are enteric viruses which reproduce in the intestinal tract of human and animals causing infection and subsequently are excreted in faeces. One of the most notorious viruses is Hepatitis A virus. This virus causes diarrhoea and jaundice resulting in liver damages. Other important classes of viruses include adenoviruses (e.g., causing pneumonia, acute respiratory diseases, gastroenteritis and cervicitis), rotaviruses (e.g., causing gastroenteritis primarily in children), enteroviruses (e.g., source of gastroenteritis), polioviruses (e.g., causing polio) and Hepatitis E viruses (WHO, 2004).

2.13.3 PROTOZOA

Protozoa are unicellular organism possessing nucleus (eukaryotes). Compared to bacteria and viruses, protozoa are larger with a size ranging from a few microns to several mm. They usually get their food by phagocytosis and are responsible for infections in humans and animals. The most common diseases caused by protozoans are diarrhoea and dysentery.

Giardia lamblia is one of the most common protozoa found in water. It causes an acute form of gastroenteritis and infects individuals by faecal-oral transmission. Other protozoans such as *Cryptosporodium sp.* is also a source of diarrhoea and is waterborne related. Infected hosts shed oocysts, the environmentally resistant transmission stage of the parasite with their faeces (Fayer *et al*., 1997).

2.13.4 HELMINTHS

Helminths are eukaryotic multi-cellular worms occupying the intestinal tract of vertebrates. They do not multiply in the human host. Rather, they live in the soil and have the potential to infect humans by penetrating their skin. The life cycle of helminths can be direct or indirect. In the direct cycle, helminths have one definitive host and they develop the infective stage during the free living period. In the indirect life cycle, helminths have intermediate hosts and a free-living stage before infecting the final host organism. Helminths include two major waterborne pathogens; *Dracunculus medinensis* and *Fasciola sp.* (Mattelet, 2005).

2.14 Microbial Indicators of Waterborne Pathogens in Water

The idea to estimate water quality is to use non-pathogenic and easy detectable microorganisms as indicators of contamination in drinking water. From their presence or absence, it can be

inferred whether or not there is a risk for health. There are two main approaches to water quality monitoring for pathogen detection (Mattelet, 2005).

The first one is to measure directly the concentration of the pathogen agent in water. This method is accurate when specific disease-causing waterborne agents are detected directly for the determination of water quality. It is practically impossible to take into account the broad range of pathogen organisms present in contaminated water. In addition, this type of method is relatively expensive and therefore difficult to implement in developing countries. The manipulation of such organisms often requires intensive training and is time-consuming. The second approach based on "microbial indicators" has several advantages compared to the first method and is most commonly used for the microbial monitoring of water.

The role of the microbial indicators in drinking water is to use them as an index of faecal pollution and therefore the results are used for the assessment of the health risk. According to WHO guidelines for drinking water quality (GDWQs), a suitable indicator should fulfil the following criteria:

• Safe water does not have to contain the indicator but contaminated water should always carry these organisms.

• The indicator should neither be pathogenic nor multiply in the environment.

• The number of indicators should exceed the number of pathogens.

• The identification, enumeration and isolation of the indicators should be easy.

• The indicators and pathogens should share the same characteristic relative to their common environment and water treatment processes.

• In order to increase the sampling number, the test should be inexpensive (Dufuor *et al*., 2003)

The indicator method is also largely applied because faecal contamination varies with time, usually presenting higher health risk at higher peaks. *Escherichia coli* seem to be the best indicator to indicate faecal contamination because it meets all the qualities cited above. Thermotolerant coliforms indicators are often used as an alternative to *E coli* (Solo-Gabriele *et al.*, 2000).

2.14.1 The Coliform Group

The coliform group is composed of 2 subgroups of microorganisms that are used to identify pathogens more or less related to faecal pollution. The first subgroup, the Total coliform, includes bacteria that multiply at 37°C. The second subgroup, the thermotolerant, is composed of bacteria that are able to grow at 44.2°C, among them, *Escherichia coli*, which is the typical indicator of faecal contamination. In case of water contamination by any coliform, whether thermotolerant or not, subsequent water treatment is required to discover the source of the pollution (Dufuor *et al*., 2003).

2.14.1.1 Total Coliform (TC)

The basic definition for their characterization is: gram-negative aerobic to facultative anaerobic, non-spore forming, rod shaped bacteria which ferment lactose at 35-37°C in 24-48 hours. A genotypic definition has recently been raised in complementation; it is based on the presence of β- galactosidase activity that bacteria fermenting lactose possess. By using this principle, total coliform is defined as members of species within the Enterobacteriaceae able to grow at 37°C and possessing β-galactosidase (Dufuor *et al*., 2003).

Total coliform is not an index of faecal contamination or health risk because they are not necessarily indicative of the presence of pathogens. Instead, the microorganisms belonging to the group give information on water quality. In U.S., the use of coliform organisms as microbial

indicator of drinking water quality has been agreed by the EPA Safe Drinking Water Act since 1989 (USEPA, 2001). The main reason is that these bacteria are easy to enumerate and detect. The ability of enteric coliforms to survive for a long period out of the intestinal tract suggests that the use of these is not recommended (Carrillo *et al*., 1985).

Included in this group are the genera *Escherichia, Enterobacter, Citrobacter and Klebsiella.* The group also includes many lactose fermenting bacteria such as *Citrobacter freundii* and *Enterobacter cloacae*. Members of genera such as *Budvicia* and *Rahnella* fall also in this group (Rivera *et al*., 1988). These bacteria are considered to be non-pathogenic under normal conditions and all except *Escherichia sp.* are able to exist as free living saprophytes as well as in the intestinal tract. If these bacteria are detected in water treatment, remediation should be directly undertaken (Gerba *et al*., 2000).

2.14.1.2 Thermotolerant (Faecal) Coliform

The term “faecal coliform organisms” refers to the thermo-tolerant forms of the total coliform group which ferment lactose at 44.5 ± 0.2°C in 24 hours. Within this group *Escherichia coli* and *Klebsiella sp.* are the organisms of interest since, when present, they indicate that recent faecal contamination has occurred with the possibility of accompanying enteric pathogens. Among these organisms, only *E. coli* is considered to come specifically from faecal origins, as it is found in human, other mammals and bird faeces in much larger proportion than it is in water or soil in temperate climates not previously contaminated (Bermudez and Hazen, 1988).

E. coli belongs to the Enterobacteriaceae family and is characterized by the possession of the enzymes β-galactosidase and β-glucoronidase. This organism grows on complex media at an incubation temperature of 44-45°C. It ferments lactose and mannitol with the production of acid

and gas, and it produces indole from tryptophan. Nevertheless, some strains do not have the same characteristics; some *E coli* are able to grow at 37°C but not at 44-45°C, others do not produce gas (Pérez-Rosas and Hazen, 1989).

E. coli is present in human and animal faeces in which it may reach a concentration of 109 per gram. It is isolated from soil, natural waters, sewage, and treated effluent that have undergone a recent faecal contamination from human, animal or agricultural activities. *E. coli* is the preferred index of faecal contamination, and is also used as an indicator of treatment effectiveness although it is more sensitive to disinfection than many pathogens. The presence of *E coli* indicates the presence of faecal contamination but its absence does not always imply that pathogens have been eradicated (Dufuor *et al*., 2003).

2.14.1.3 Hydrogen Sulphide-Producing Bacteria

The H_2S-producing bacteria include *Citrobacter freundii*, *Salmonella typhimurium*, *Proteus vulgaris,* strains of *Klebsiella,* genera *Edwardsiella* and *Arizona*. *Desulfovibrio* is also commonly found in aquatic habitats providing sufficient organic material and levels of sulphate. The presence or absence of these bacteria can be indicated by the hydrogen sulphide test (Manja *et al*., 1982).

2.15 WATER QUALITY AND QUANTITY STANDARDS

2.15.1 WHO Guidelines for Drinking Water Quality

The WHO GDWQs provide the background and foundation for the microbiological analysis of this thesis. WHO states that drinking water should contain no indicator organisms such as total coliform or *E. coli*. Nevertheless, the3rd of WHO Guidelines states that “neither the minimum safe practices nor the numeric guidelines are mandatory limits”. Rather than that, the guidelines limits for the drinking water of the local or national environmental, social, economic and cultural

conditions should be taken into account (WHO, 2004). WHO also supports that 7.5L is the minimum necessary volume of water required per person per day for both consumption and food preparation (Howard and Bartram, 2004).

2.15.2 Drinking Water Guidelines in Ghana

Ghana currently follows the 2nd edition of the GDWQ (WHO, 1996). However, Ghana is trying to develop its own drinking water standards legislation appropriate to the Ghanaian economy, society and culture. Such legislation should be consistent with achievement of the United Nations MDGs and should take into account of levels of acceptable access outlined in General Comment 15 on the Right to Water of the UN Committee on Economic, Social, and Cultural Rights1 and associated documents (WHO, 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The villages studied were Baasare, Apaah, Abrakaso and Pongyaw with a population of 242,728, 328 and 314 respectively are located in the Sekyere South District, formerly Afigya Sekyere District located in the North Central part of Ashanti Region. It shares boundaries with five districts: namely Ejura-Sekyeredumase to the North, Sekyere West to the East, Sekyere East and Kwabre to the South and Offinso to the West. Specifically the district lies between Latitudes 6º 50´N. and 7º 10´N. and Longitudes 1º 40´W. and 1º 25´W. Currently, the District spans a total area of 780 square kilometers forming about 3.27% of the total land area of the region (Ghanadistricts.com).

The climate of the district is equatorial having a double rainfall maxima regime. The major rainy season occurs between March and July whereas minor rainfall occurs between September and November. The average number of rainy days for the year is between 110 and 120 days with mean annual rainfall ranging between 855mm and 1500mm. temperatures are generally high throughout the year with mean monthly temperature of about 27^{o}C (Ghanadistricts.com).

Lying within the rain forest belt, the vegetation can best be described as moist semi deciduous forest. The forest abounds in different species of tropical woods of high economic value. These include Wawa, Odum, Mahogany, Sapele, etc.

The 2000 population and housing census put the district's population at 119,093. By projection using a growth rate of 3.14%, the district's population stands at 139,736 as at 2006. Urban population constitutes 64.4% with being 35.6% rural. Sekyere South district relies heavily on agriculture. The major food crops cultivated include cassava, plantain and maize with Cocoa

being the major cash crop. 21% of the population farm on subsistence level, 6% farm on commercial and about 73% cultivate on both levels (Ghanadistrict.com).

The main sources of potable water supply in the district are boreholes and the non-portable sources are traditional wells and streams.

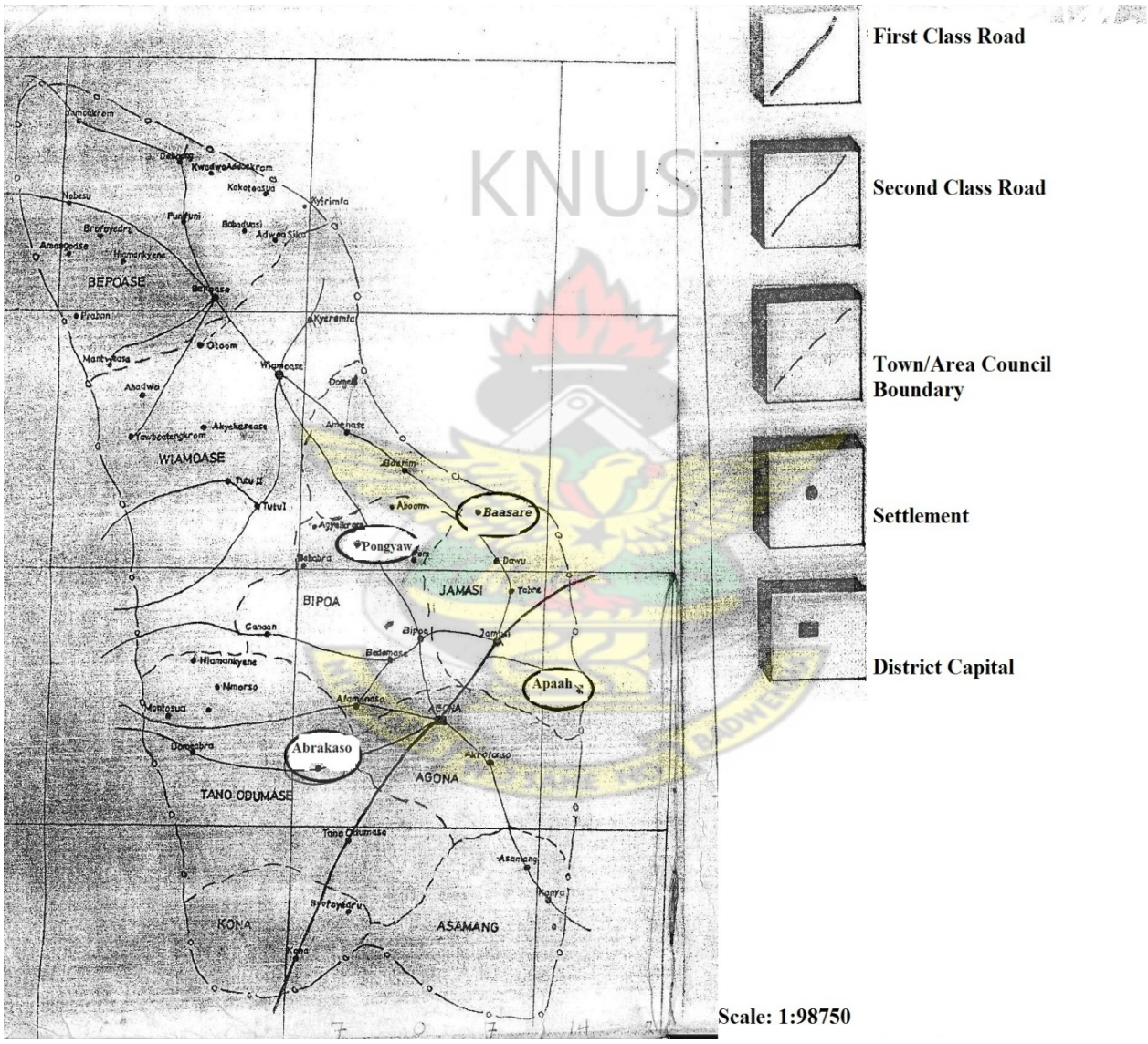

Figure 1: map of Study area

3.2 Methodology

Specific studies on water supply problems were conducted in four selected villages within the study area. Literature studies, field observations and discussions with stakeholders were used to gather information about the water supply situation in the study area. Structured questionnaire interviews were employed to assess the water supply situation and existing traditional water coagulation methods employed by inhabitants (Appendix E). Random sampling method was used to select houses for the interview.

3.3 Sterilization

Petri dishes, reagent bottles and beakers were sterilized at 160^{o}C for an hour in a hot oven box. Glass wares like marcarthny bottles, test tubes and conical flasks were sterilized in the autoclave at 121^{o}C for 15 minutes. Inoculating loops were sterilized by heating to red hot in a gas flame and cooled before use. Work benches were sprayed with 70% ethyl alcohol and dried before use. All culture media were sterilized at recommended temperatures by autoclaving before use.

3.4 Preliminary Study

3.4.1 Sampling

Sampling was done from three different sample sites (upstream, mid stream and downstream) in each of the community to establish the level of pollution and its origin. Isolation of *E. coli* to ascertain faecal pollution was done. Water was hauled from the wells with buckets tied to the end of ropes as normally practiced by the villagers and sample collected was transferred aseptically to fill a 500ml sterilized bottle. In the case of fresh water from streams the sterile bottle was completely immersed slanted careful to avoid collection of surface water. The collected samples were transported to the laboratory for bacteriological examination. Triplicate samples were collected at each sampling site for three months. A total of 27 samples were taken from each community for the baseline study.

3.5 MEDIA PREPARATION

3.5.1 Liquid isolation media

40 g of MacConkey Broth (OXOID® Basingstoke, Hampshire, England) was dissolved in 1 litre distilled water and 5 millilitres of the broth medium were distributed into test tubes containing inverted Durham tubes. Test tubes containing media were sterilized by autoclaving at 121^{o}C for 15 minutes and allowed to cool before use. 20g of buffered peptone water (Park Scientific Lab) and 16g of Tryptone broth (Scharlau C02-418, Barcelona Spain) were also dissolved in 1 L distilled water, 5ml each distributed into test tubes and autoclaved at 121^{o}C for 15 minutes.

3.5.2 SOLID ISOLATION MEDIA

52 g of MacConkey agar (Biotec ltd) and 28g of Nutrient agar (Biotec Ltd) were also dissolved in 1L distilled water, swirled and sterilised by autoclaving for 15 minutes at 121^{o}C. The prepared media was allowed to cool to about 45^{o}C and 20 ml volumes of the liquid medium was poured aseptically into sterilized petri dishes and allowed to cool before inoculation.

20.5g of Plate Count Agar (Biotec Lab ltd, UK.) was also dissolved in 1L distilled water and sterilized by autoclaving for 15 minutes at 121^{o}C and cooled to 45^{o}C. 20 ml volumes of the liquefied agar was poured aseptically into sterilized 90mm petri dishes and allowed to solidify.

3.6 BACTERIOLOGICAL EXAMINATION

This was done to ascertain whether the water samples under investigation were polluted with pathogenic microorganisms or not and whether it was wholesome for drinking and domestic use. Most Probable Number (MPN) method commonly used for determining the presence and number of coliform and faecal coliform organisms was used. The method entails three phases which are the presumptive, confirmatory and complete (Martins *et al*., 1997).

3.6.1 Presumptive Test

The decimal dilution with three tubes inoculated at each dilution was used. 1ml of the diluted sample was inoculated into three tubes containing MacConkey broth for growth. Inverted Durham tubes were placed in the test tubes to detect the presence of gas. One setup was incubated at 37^{o}C for 24 hrs and the other incubated at 44^{o}C for 24 hrs for faecal coliform counts. Tubes that showed change in colour and gas formation were considered presumptive positive for coliform bacteria. From the number and distribution of positive and negative reactions, counts of the most probable number (MPN) of indicator organisms in the sample were estimated by reference to MPN statistical tables (APHA-AWWA-WEF, 1998).

3.6.2 Confirmatory Test

Confirmation of samples from all presumptive positive tubes was done by establishing growth of target bacteria on Endo and MacConkey agar. Inoculum from positive tubes were cultured on Endo agar by streaking to fill the petri dish and incubated at 37^{o}C for 48 hrs. Also MacConkey plates were inoculated at 37^{o}C for 48 hrs and morphological characteristics of colonies were noted.

3.6.3 Complete Test

This involved the use of the indole, methyl red, Voges Proskauer and citrate (IMViC) test to differentiate *E. coli* from *Enterobacter*. Three test tubes were filled with 5ml tryptone broth (indole test), methyl red - Voges Proskauer broth (MR-VP broth), and citrate.

Indole Test

Selected colonies from cultured plates of Endo and MacConkey agar were inoculated into test tubes containing 5ml tryptone broth and incubated at 37^{o}C for 48 hours. 0.5ml of Kovac's reagent (p-dimethylaminobenzaldehyde) was added gently along the side of the tube after the

addition of xylene to accumulate the gas. The presence of indole was detected by formation of a deep red colouration almost immediately at the surface or upper layer indicating a positive result.

Methyl Red and Voges-Proskauer Tests

Tubes of glucose phosphate broth were inoculated with organisms from selected colonies and incubated 37^{o}C for 48 hrs. The media was split into two after 48 hrs of incubation. Two drops of methyl red indicator was added to one to determine acid production level. Two drops of 1% creatine powder in 0.1M hydrochloric acid and 1ml 40% potassium hydroxide were added to the other tube, mixed and observed after 4 hours.

3.6.4 Gram Staining

This was used to distinguish two groups of bacteria namely gram negative and gram positive. A loop full of the culture under study was transferred onto the surface of clean glass slides and heat fixed. The slides were flooded with crystal violet solution for up to one minute and wash gently in tap water and drain against a paper towel. After draining the smeared slides were again flooded with Gram iodine solution, and allowed to act as a mordant for one minute. This was also washed under running tap water and drained. Stained slides were flooded with 95% alcohol for 10 seconds and washed off with water. The slides was drained afterwards, flooded again with safranin solution and allowed to counterstain for 20 – 30 seconds. The safranin-flooded slides were washed with tap water, drained and blotted with filter paper. The slides were then examined under the microscope using the oil immersion lens to characterise the isolated organisms.

3.7 Sub Culturing

Colonies from plates showing presence of pure isolates of *E. coli* were cultured on MacConkey agar and re-tested with the above biochemical test to confirm their purity. Pure isolates were sub

cultured on prepared nutrient agar and MacConkey agar slants in Mccarthny bottles at 37^{o}C overnight and refrigerated for further use.

3.8 Standard Plate Count

3.8.1 Pour Plate Procedure

Serial dilution tubes containing distilled water were prepared for samples collected. 1ml of each dilution was introduced into labelled sterile petri dishes and 15ml of molten plate count agar poured into each plate. The plates were rotated gently six times clockwise and anticlockwise, allowed to set and incubated at 37^{o}C for 24 hrs in an inverted position

3.8.2 Counting

After 24 hours of incubation, bacterial colonies for each dilution were counted using automatic colony counter. Counts were recorded as colony forming units (CFU/ml) and bacterial loads were determined by multiplying average counts by dilution factor.

3.9 PHASE II

This part of the study was done for a period of three months at the Civil Engineering Laboratory KNUST, Kumasi. The following analyses were undertaken in this laboratory:

1. Measurement of physicochemical parameters of raw water samples before and after jar test.
2. Jar test to estimate effective dose of coagulant.
3. Standard plate count of sample water before and after jar test to observe load changes.

3.9.1 Sample Collection

Sampling was done at sites with low bacteria counts in the four communities namely Baasare Pongyaw, Apaah and Abrakaso (Table 4). Triplicate samples were collected using sterilized 1.5 litre bottles into clean Jerry cans. Samples were immediately transported to the laboratory for analysis.

3.9.2 Measurement of Physicochemical Parameters

Hydrogen Ion Concentration

Mettler Toledo MP220 pH meter was used for the measurements of hydrogen ion concentration. The pH meter was calibrated with two buffer solutions of pH 4.01 and 7.00. The water sample was placed in a beaker and the electrode rinsed with distilled water and placed in the sample. The readings were recorded.

Colour

This was taken using the Lovibone Nesslerizer Model 2150. A test tube was rinsed three times with the sample to be analyzed and fitted into the test kit alongside another test tube filled with distilled water. The arrow buttons were rotated until the exact values displayed and recorded.

Turbidity

Turbidity values were taken using Cybercan IR TB 100 Turbidimeter. The turbidimeter was calibrated using the 1000 NTU, 100 NTU, 10 NTU and 0.02 NTU calibration standards. The cuvette was rinsed three times with the sample to be analysed and pushed firmly into the optical well and index to the lowest reading. The NTU values were measured by pressing and releasing the arrow button and value recorded after the display has stopped flashing.

Total Dissolved Solutes (TDS)

This was measured using the Hanna instrument HI 9032 microcomputer conductivity meter. The electrode was placed in the sample in a beaker and the TDS key selected. The value displayed on the screen was recorded in mg/L.

Conductivity

The conductivity of the samples was measured using Hanna instruments HI 9032 microcomputer conductivity meter. This was calibrated by immersing the electrode in a reference buffer of 12.88µs/cm. the water sample was put in a beaker and the electrode rinsed in distilled water and lowered into the sample. The conductivity, in µs/cm of the sample was recorded.

3.9.3 Jar Test

This was used to estimate the optimal dose of *Moringa oleifera* seed extract and alum as coagulants for raw water from the communities.

Preparation of 10% Alum

Ten grammes of granular aluminium sulphate was weighed, dissolved in 20 ml distilled water and topped up to 100ml.

Preparation of 5% Seed Extract

Seeds were dried, shelled and blended. Five grammes of seed powder was weighed. 10ml distilled water was added, mixed and filtered. The filtrate was topped up to 100ml

3.9.4 Jar Test Procedure

One litre of raw water was poured into 5 beakers and placed under a multiple stirrer. 0.1ml of prepared pure inoculum was added to each beaker before adding coagulant. The prepared seed extract was added at concentrations of 5, 10, 15 and 20ml. This procedure was repeated for alum in five other beakers at concentrations of 0.2, 0.4, 0.6 and 0.8 ml. The coagulant concentrations were added simultaneously. The fifth beaker was used as a control set up with no coagulant. The set up was mixed thoroughly at a speed of 200 rpm for 5 minutes to enable total dispersal of coagulant and 30 rpm for 15 minutes to aid in effective flocculation of colloidal particles. After thorough mixing, the beakers were removed and placed on a work bench for an hour to settle

flocs for both coagulants. Supernatants were decanted and the colour, hydrogen ion concentration, total dissolved solutes and conductivity were measured and recorded at three different times (0, 12 and 24 hours). Serial dilution of supernatant at the three time intervals was done, pour plated and incubated at 37^{o}C for 24 hours for colonies to be counted.

3.9.5 Statistical Analysis

All statistical analysis was carried out using both Microsoft Excel 2006 Edition and Statistical Package for Social Science (SPSS) 16.0. Analysis of Variance (ANOVA) was used to determine differences in the means of values obtained.

CHAPTER FOUR

4.0 RESULTS

4.1 Household demographic Studies

Most of the household heads were males (73.8%) with only 26.2% being females. The average number of people per household was 5. Farming which is entirely dependent on rainfall is the most important occupation of the inhabitants in the study area (Table 1). The main products of their labour are cassava, cocoyam, plantain and cocoa as well as livestock. Cash and food crops are sold to earn the people some money for other family needs. The results showed that 45.0% of the inhabitants (both males and females) in the four villages are into agriculture while 7.5% have formal employment in education. 36.2% are traders whilst 11.3% are engaged in other activities such as driving (Table 1).

Table 1: Occupation of households heads in the study communities

Occupation	Frequency	Percentage
Farming	36	45.0
Trading	29	36.2
Dressmaking	2	3.3
Teaching	6	7.5
Others	7	8
Total	80	100

The main sources of potable water supply in the study area are pipe borne and borehole and the non-potable sources are streams and hand dug wells. It was evident from the respondents and hospital data that water borne diseases are among the most prevalent health problems in the study area. It was also observed during the survey that 62.5% of the households in the study area

do not have any kind of toilet and waste disposal facilities. This condition most possibly aggravates the problem of water borne diseases due to the pollution of water sources and unhygienic practices of the villagers. Fig. 1 shows the distribution of preferred water sources for domestic and other uses in the study area. 11.5% of the respondents have access to pipe borne water, 3.8% from boreholes, 27.5% from hand dug wells and 57.5% fetch water from water ponds and streams. The results also showed that women and children are the main domestic water carriers and have preference for multiple water sources which is influenced by the availability of water from the various sources during different times of the year.

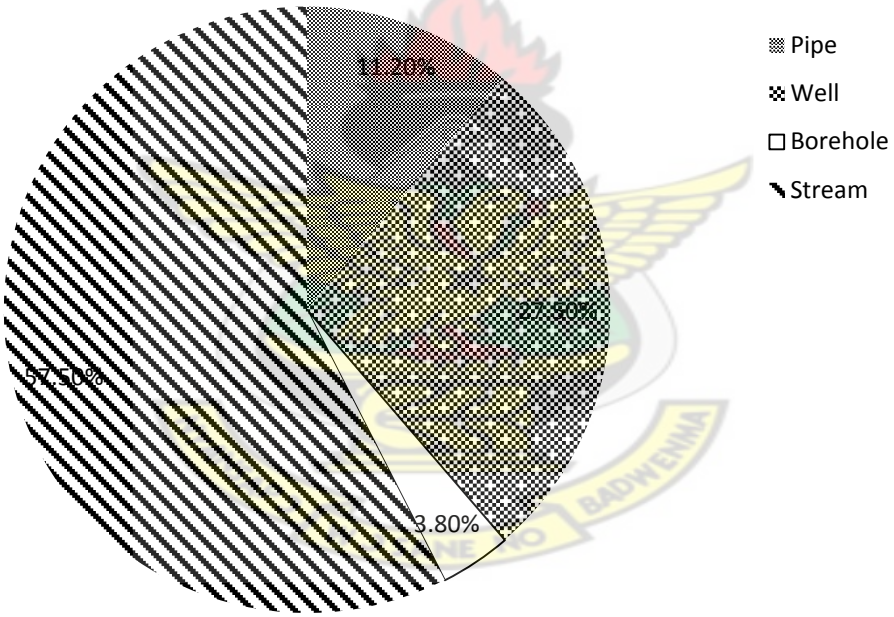

Figure 2: Sources of water in study communities

The results also showed that 87.5% of respondents do not treat the water obtained, whilst 12.5% employ boiling and filtering as traditional purification methods.

4.2 Preliminary Studies

4.2.1 Physical and Bacteriological Quality of Water from Streams and wells

Based on field survey and investigations of water sources, it was evident that water from streams and hand dug wells onsite were the most reliable and readily available sources for most of the inhabitants in the study villages.

4.2.2 Multiple tube technique

Total and faecal coliform counts at temperatures 37^{o}C and 44.5^{o}C after 48 hours of incubation showed positive reaction with a milky colour change indicating gas and acid production. Most of the inoculated tubes, after the 24 hour incubation period for both temperatures gave positive results of gas and acid production. The 48 hrs incubation also showed positive test for almost all the tubes. However control set-up showed no colour change for both incubation periods.

Table 2: Mean Most Probable Number values after incubation.

Source	Communities	Log_{10} MPN/100ml Total coliform	Log_{10} MPN/100ml Faecal coliform
Stream	Baasare	9.54	3.48
	Pongyaw	11.56	2.73
Well	Apaah	6.54	2.91
	Abrakaso	9.64	3.15

Comparing the MPN values obtained to bacteriological standards of drinking water, the streams and wells could be classified as grossly polluted having values greater than 1000/100ml for all the sampling sites (Table 2).

4.2.3 Confirmatory Test

Table 3: Test results obtained from positive tubes cultured on Endo and MacConkey agar

Period of incubation	Media	Observation	comments
24 hrs	Endo agar	Colonies with metallic sheen appearance and lack colouration at bottom.	Presence of *E. coli* suspected
48hrs	Endo agar	Pure black colouration at bottom of plate	*E. coli* suspected
24 hrs	MacConkey agar	Big and tiny pinkish colonies	Coliform suspected
48 hrs	MacConkey agar	Cream and pink colonies observed	Coliform suspected

4.2.4 Complete Test
IMVIC REACTIONS

Colonies suspected to be *E. coli* from the confirmed test reacted positively with Kovach's reagent for indole gas production. Formation of a deep red colouration almost immediately at the surface was observed. The suspected colonies also showed positive results for methyl red test by giving a red colouration upon the addition of methyl red indicator. However Vorges Proskauer test gave a negative reaction since no colour change was observed. Citrate test also showed negative reactions.

The IMVIC analysis showed positive results for indole and Methyl red, whilst Vorges Proskauer and citrate analysis showed negative results (++--) for the streams and well water samples. This confirms that indicator organisms isolated was *E. coli*.

4.2.4 GRAM STAINING REACTION

The staining reaction revealed short Gram negative non-spore forming rods known to be typical of *E.coli* and pinkish Gram positive cocci.

4.2.5 STANDARD PLATE COUNT

4.2.5.1 Pour Plate Method

Results obtained from plate count of water samples are shown in Table 4 below. This shows the number of heterotrophic bacteria cells present in the water sample. It was observed that sites III and II for Baasare and Pongyaw respectively had the lowest count of microbial load per 100 ml. However Apaah and Abrakaso showed site II having the lowest count.

Table 4: Mean Plate Count Values of Raw Water Samples from Streams and Wells in CFU/100ml

Bacterial count (CFU/100ml)										
	Baasare(Stream)						Pongyaw(Stream)			
Sample	Dilution	Control	Sites			Mean	Sites			Mean
			I	II	III		I	II	III	
1	10^{-3}	0	220	143	125	$1.49x10^{5}$	250	136	201	$1.96x10^{5}$
2	10^{-3}	0	242	127	100	$1.56x10^{5}$	265	112	150	$1.76x10^{5}$
3	10^{-3}	0	307	163	104	$1.91x10^{5}$	290	125	133	$1.83x10^{5}$
			Apaah (Well)				Abrakaso (Well)			
1	10^{-3}	0	106	75	128	$1.03x10^{5}$	280	104	132	$1.72x10^{5}$
2	10^{-3}	0	94	68	77	$7.96x10^{4}$	136	80	60	$9.2x10^{4}$
3	10^{-3}	0	135	110	149	$1.31x10^{5}$	112	96	88	$9.86x10^{4}$

PHASE II

This phase shows results obtained from measurements of physicochemical parameters and coagulation effects of moringa and alum and the standard plate count of water samples before and 0, 12 and 24 hours after treatment.

4.3 PHYSICOCHEMICAL MEASUREMENTS

The mean values of physicochemical parameters for raw water samples before treatment are shown in Table 5 below:

Table 5: Mean values of physicochemical parameters of raw water from streams and wells

COMMUNITIES	Colour (HU)	pH	Turb (NTU)	TDS (mg/L)	Cond (µs/cm)
BAASARE	66.11	7.29	24.59	69.11	140.98
PONGYAW	71.67	7.17	23.77	46.13	77.41
APAAH	14.44	6.92	13.17	97.89	192.66
ABRAKASO	13.33	7.06	11.83	64.58	137.80

Legend:
Turb: Turbidity, TDS: Total Dissolved Solids, Cond: Conductivity

Results for measurements showing mean values of pH, turbidity, total dissolved solutes, and conductivity for various concentrations of coagulants at 0 hrs, 12 hrs and 24 hrs after treatment are shown in Tables' 6-9(Appendix A)

4.3.1 Hydrogen ion concentration (Streams)

Mean pH values of raw water from the two streams (Baasare and Pongyaw) were 7.29 and 7.12 respectively. Agyemasum stream at Baasare recorded mean pH values ranging from 7.29 to 7.0 at 0 hours of treatment with various *Moringa* concentrations. After 12 hours of *Moringa* treatment the pH values were observed to be within the range 7.16-6.94. pH values ranged from 7.04-6.80 after 24 hours of treatment with *Moringa* (Table 6). The differences in the mean values among the treatment groups were not significant (P= 0.06) at 0 hour treatment. However significant differences were observed at 12 hours and 24 hours treatment periods (P= 0.001 and P= $4.48x10^{-5)}$ respectively.

Similar trend of pH decline was observed with increasing alum concentration. The 0 hr pH values ranged from 6.72 to 6.16, 6.33 to 5.74 after 12 hrs of treatment and 6.29 to 5.65 after 24 hrs (Table 6a). pH values for the control were within the range of 7.16 to 7.04 from 0 hr to 24 hrs. The pH values recorded were within the WHO recommended standard of pH 8.5 to 6.5 for chemically treated water (*WHO, 2004*). The differences in the mean values among the treatment groups were significant (P = $4.75x10^{-8}$, P = 0.0004 and P = $4.89x10^{-5)}$ respectively for the three treatment periods. Figure 2 shows effect of *M. oleifera* and alum concentrations on Agyemasum stream at Baasare.

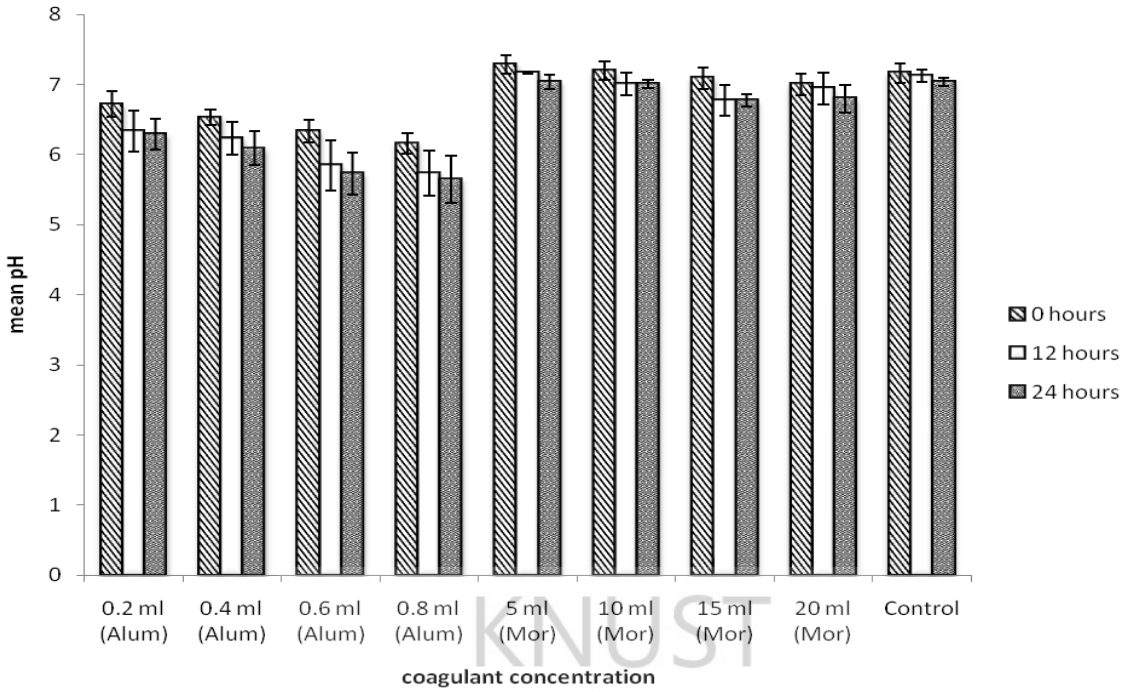

Figure 2: Influence of different concentrations of indicated coagulants on pH of stream water from Baasare after 0-24 h treatment time

Before treatment with *Moringa* extracts, the Bodedan stream at Pongyaw recorded pH values within the range of 7.14 to 7.09. After 12 and 24h of treatment pH of 6.98 to 6.69 and 6.47 to 6.27 was recorded respectively (Fig. 3). There were no significant difference between the mean values (P= 0.90, 0.18 and 0.23) for the three treatment periods. Similar trend of pH decline was observed with increasing alum concentration. Initially the pH values ranged from 6.64 to 6.01. After 12 and 24h the pH declined from 6.34 to 5.25 (Table 7) with no significant difference (P=0.07) at 0 hour treatment period. Significant differences were observed among the mean values at 12 hour (P= 0.0005) and 24 hour (P= 5.72×10^{-6}) treatment periods. pH values for the control were within the range of 7.04 to 6.50 from 0 hrs to 24 hrs.

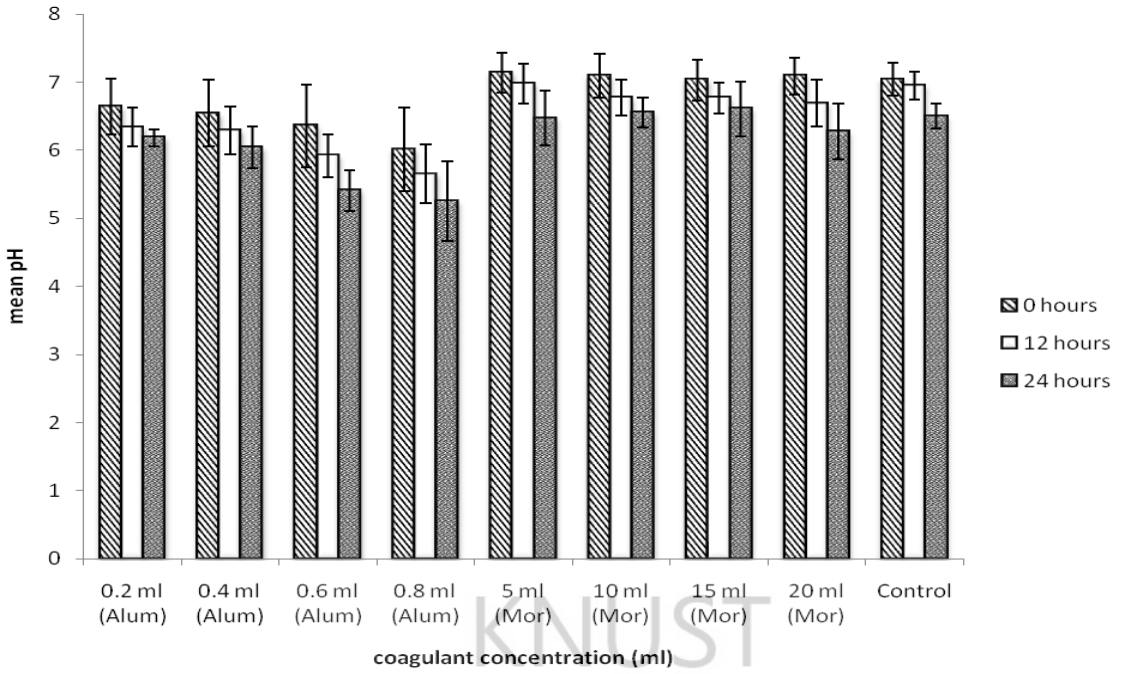

Figure 3: Influence of different concentrations of indicated coagulants on pH of stream water from Pongyaw after 0-24 h treatment time

4.3.2 Turbidity (Stream)

Turbidity values decreased for Agyemasum and Bodedan streams at Baasare and Pongyaw respectively. Mean turbidity values of Agyemasum stream were initially within the ranges of 22.26NTU to15.69NTU. After 12h of treatment it changed to 18.37 NTU to 12.99 NTU and 14.82 NTU to 5.09NTU after 24h of treatment with the different *Moringa* concentrations. Significant differences were observed between the treatment groups (P=0.02, 0.04 and $5.93x10^{-10)}$ respectively for the three treatment periods. A similar trend was observed with increasing concentrations of alum (Fig. 4). Mean values showed significant differences ($P=4.27x10^{-7}$, 0.0002 and 0.0006) for the treatment periods respectively. Control set-up recorded values between 21.56 NTU to 12.79 NTU from 0 hrs to 24 hrs.

At 0,12 and 24 hrs treatment time, Bodedan stream at Pongyaw recorded values within the ranges of 20.83 NTU to 19.18 NTU, 10.73 NTU to 9.43 NTU and 8.32 NTU to 8.49 NTU respectively for the different *Moringa* concentrations with no significant difference among mean values (P=0.13, 0.57 and 0.30). The different concentrations of alum on the other hand recorded mean values of 14.61 NTU to 6.82 NTU, 10.97 NTU to 3.44 and 7.57 NTU to 2.31

NTU for 0, 12 and 24 hours respectively(Fig.5). No significant difference was observed among mean values at 0 hour treatment period (P=0.13). However 12 hours and 24 hours treatment periods showed significant differences ($P=1.15x10^{-9}$ and $1.01x10^{-9}$) respectively.

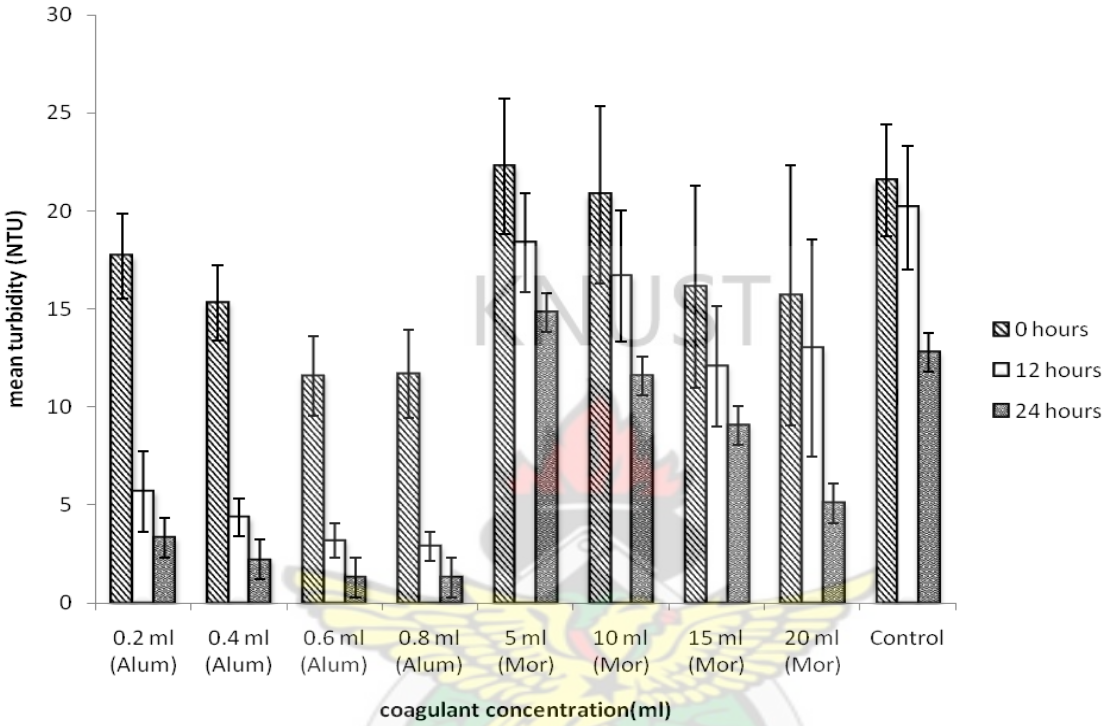

Figure 4: Influence of different concentrations of indicated coagulants on turbidity of stream water from Baasare after 0-24 h treatment time

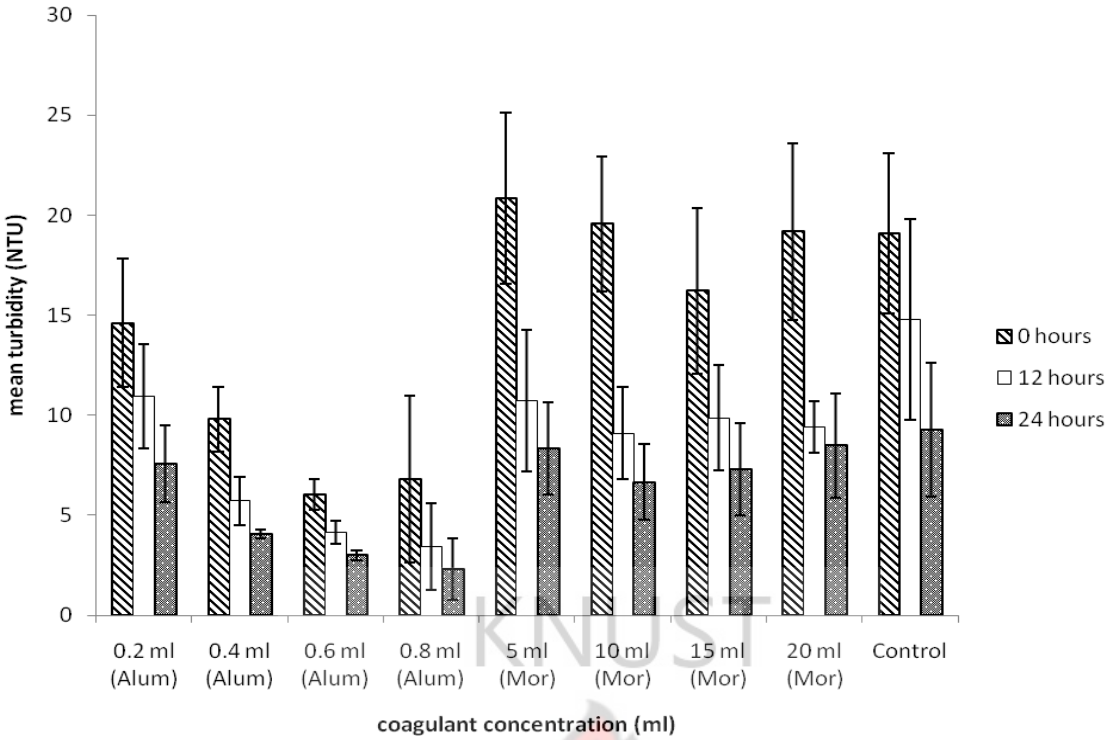

Figure 5: Influence of different concentrations of indicated coagulants on turbidity of stream water from Pongyaw after 0-24 h treatment time

4.3.3 Total Dissolved Solids (TDS) and Conductivity

At the three treatment hours, TDS values for Agyemasum stream at Baasare ranged from 74.57 to 78.38 for the different moringa concentrations with no significant differences among mean values (P=0.34, 0.62). Consequently conductivity values ranged from 154.91 to 168.80 for the various moringa concentrations with no significant differences among mean values (P=0.77, 0.53 and 0.55) for the three treatment periods respectively (Appendix B1).

Mean TDS values for the various concentrations of alum were between 74.96 to 82.61 with 0 hour treatment period showing no significant difference (P=0.10). On the other hand, 12 and 24 hours treatment periods showed significant differences among mean values ($P=2.5x10^{-16}$ and $7.33x10^{-19}$). Conductivity values for the various concentrations of alum ranged from 144.71 to 163.92 with no significant differences (P=0.47, 0.38 and 0.26) respectively at the three treatment periods. Control also recorded TDS values of 71.04 to 73.31 and corresponding conductivity values of 144.94 to 155.47 at the three treatment period.

Bodedan stream at Pongyaw recorded similar increasing trend of TDS of 48.93 to 62.54 with no significant differences (p=0.36, 0.08 and 0.06) for the different moringa concentrations at the three treatment period (appendix A1). Corresponding mean conductivity values ranged from 87.20 to 112.26. However, there were significant differences among mean values (P=0.02, 0.01 and 0.01) at the three treatment periods respectively (Appendix B1). TDS and conductivity values for the various concentrations of alum were between 51.22 to 62.86 and 94.96 to 127.72 respectively at the three treatment hours. No significant differences were observed among mean TDS values (P=0.38, 0.06 and 0.12) respectively at the treatment periods. Mean conductivity values however, showed significant differences ($P=1.36x10^{-7}$, $7.38x10^{-5}$ and 0.02) respectively at the three periods. Control set up recorded TDS values of 48.90, 51.74 and 59.08 at 0, 12 and 24 hours respectively.

4.3.4 Hydrogen ion concentration (Well water)

The pH of water from Apaah and Abrakaso ranged from 6.81 to 6.44 and 7.05 to 6.84 respectively for the different moringa concentrations at 0 hrs of treatment. pH values for alum concentrations also ranged from 6.70 to 6.04 and 6.38 to 5.92 respectively for the well water of the two communities at the same treatment period.

At 12 and 24 hrs of treatment with *Moringa oleifera*, pH values ranged from 6.60 to 6.24 and 6.30 to 6.06 for well samples from Apaah (fig. 6). Abrakaso well water also recorded mean pH values between 6.90 and 6.29 and 6.53 and 6.13 at 12 and 24 hrs of treatment (fig. 7). The differences in the mean values among the treatment groups for water from Apaah were not significant (P= 0.25, 0.28 and 0.41) respectively at the treatment periods. Well water from Abrakaso on the other hand, showed significant differences among treatment groups (P= 0.03, $3.02x10^{-7}$ and $8.02x10^{-7}$) at the treatment periods respectively.

The various alum concentrations recorded pH values 0f 6.51 to 5.68 at 12 hrs of treatment and 6.13 to 5.27 at 24 hrs of treatment for Apaah well samples with significant differences among mean values ($P = 5.34x10^{-6}$ and $2.77x10^{-6}$) respectively. Mean pH values for Abrakaso well were 6.01 to 5.66 and 5.81 to 5.36 at 12 and 24 hrs of treatment for the various alum concentrations with no significant difference ($P = 0.14$) at 0 hour treatment period. However 24 hours treatment period showed significant difference ($P = 0.009$).

Control samples on the other hand had mean pH values of 6.94 to 6.28 and 7.04 to 6.61 for Apaah and Abrakaso respectively from 0 to 24 hrs.

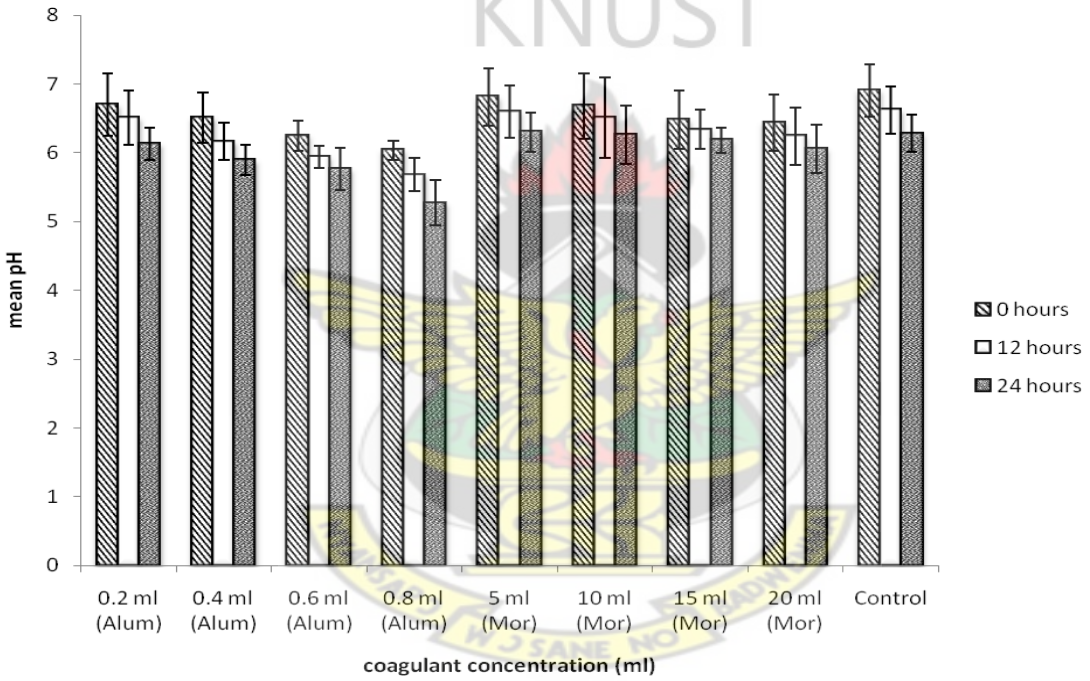

Figure 6: Influence of different concentrations of indicated coagulants on pH of well water from Apaah after 0-24 h treatment time

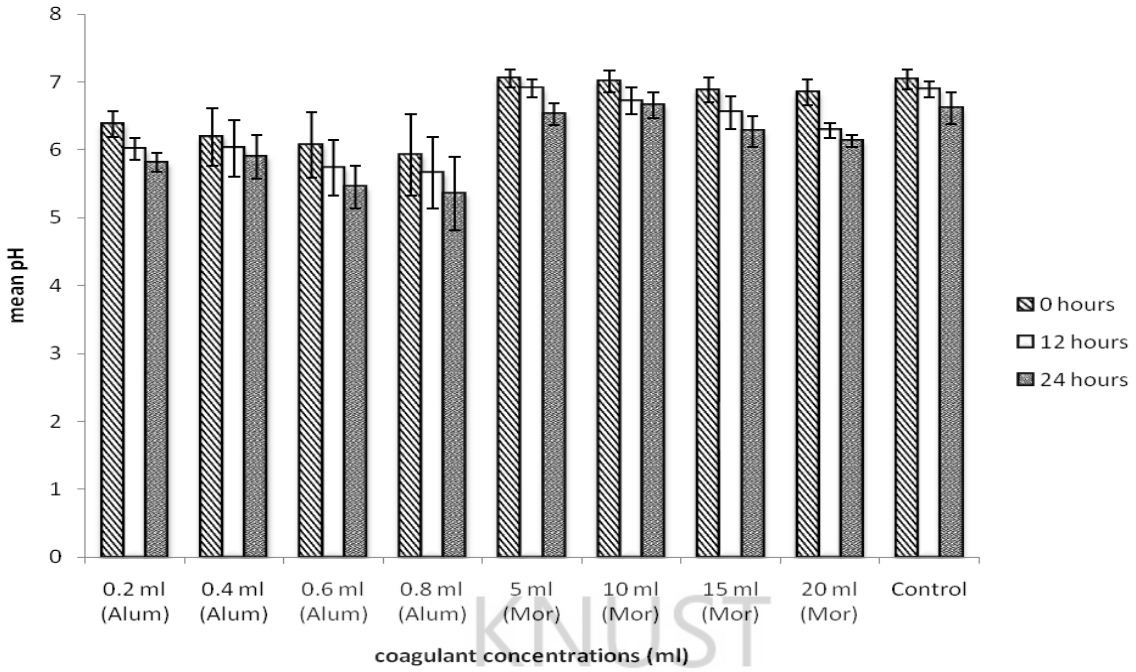

Figure 7: Influence of different concentrations of indicated coagulants on pH of well water from Abrakaso after 0-24 h treatment time

4.3.5 Turbidity (Well water)

The mean turbidity values of well water at Apaah were within the ranges of 11.86 NTU to 7.74 NTU, 8.69 NTU to 8.26 NTU and 6.80 NTU to 8.49 NTU for 0 hrs, 12 hrs and 24 hrs treatment times with the different moringa concentrations as well as a significant difference ($P=7.3x10^{-25}$, 0.002 and $9.13x10^{-5}$) respectively. The same decrease was observed for increasing concentrations of alum where 9.14 NTU to 7.66 NTU, 6.90 NTU to 4.22 NTU and 4.09 NTU to 1.83 NTU turbidity values were observed for 0 hrs, 12 hrs and 24 hrs respectively (Fig. 8). Significant differences were observed among the mean values ($P=3.04x10^{-5}$, 0.002 and 0.0001) respectively for the three treatment periods. The control recorded values between 12.27 NTU- 6.53 NTU for the three periods.

For the treatment times stated above, Abrakaso well water recorded turbidity values within the ranges of 10.34 NTU to 7.52 NTU, 6.79 NTU to 4.56 NTU and 6.84 NTU to 4.19 NTU respectively for the different moringa concentrations with significant differences (P = 0.03,

$3.02x10^{-7}$ and $8.02x10^{-7}$). The different concentrations of alum on the other hand recorded turbidity values of 6.69 NTU to 2.70 NTU, 4.25 NTU to 1.66 and 3.0 NTU to 1.10 NTU for 0, 12 and 24 hours respectively (Fig.9). There were significant difference among mean values ($P = 4.53x10^{-10}$, $4.48x10^{-5}$ and $1.39x10^{-5}$) for the treatment periods respectively. Correlation values were significant for turbidity of alum and moringa treated water.

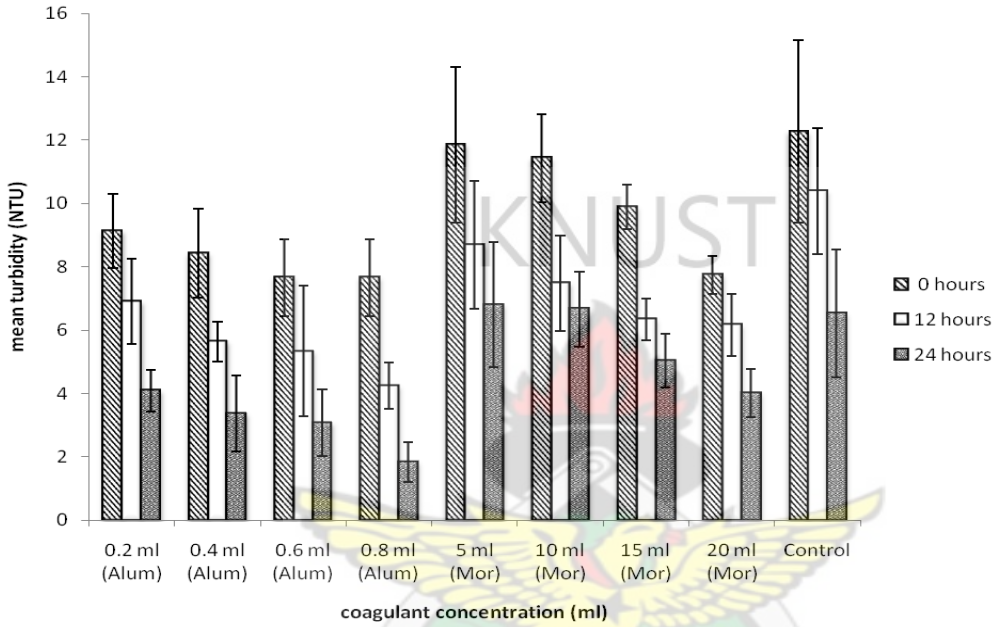

Figure 8: Influence of different of concentrations of indicated coagulants on well water from Apaah after 0-24 h treatment time

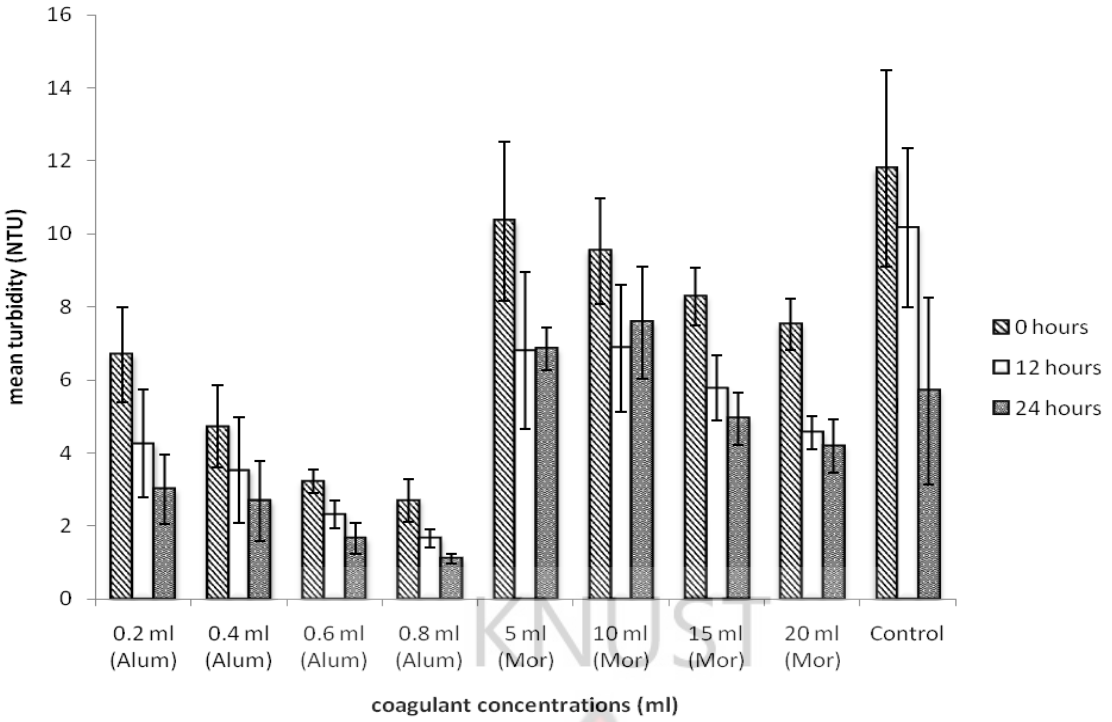

Figure 9: Influence of different concentrations of indicated coagulants on turbidity of well water from Abrakaso after 0-24 h treatment time

4.3.6 Total Dissolved Solids (TDS) and Conductivity

TDS values for well at Apaah ranged from 105.0 to 126.39 for the different moringa concentrations at the three treatment hours with no significant differences (P = 0.98, 0.34 and 0.45). Consequently conductivity values ranged from 199.18 to 232.83 for the various moringa concentrations with no significant differences (P= 0.45, 0.20 and 0.05) respectively at the three treatment times (appendix B2). TDS and conductivity values for the various concentrations of alum were 102.13 to 216.19 with no significant differences (P=0.77, 0.73 and 0.13) and 225.22-240.44 (p= 0.20, 0.93 and 0.96) respectively at the three treatment hours. Control set up also recorded TDS values of 100.16 to 118.88 and corresponding conductivity values of 193.90 to 211.84 at the three treatment hours.

Well water from Abrakaso recorded similar increasing trend of TDS of 68.28 to 93.69 and a corresponding conductivity values of 141.86 to 193.97 for the different moringa concentrations at the three treatment hours (Appendix B2 and C2). Mean TDS values showed significant differences among treatment groups (P= 0.05, 0.03 and 0.02) at the three periods

respectively. However, there were no significant differences in mean conductivity values (P= 0.06, 0.28 and 0.24). TDS values for the various concentrations of alum were 82.89 to 108.67 with no significant difference (P=0.31, 0.62 and 0.41) respectively at the three treatment hours. Corresponding conductivity values ranged from 187.33 to 219.39. Control treatment recorded TDS values of 65.84- 81.94 and conductivity values of 143.61-160.69 at 0, 12 and 24 hours respectively. There was no significant difference for mean conductivity values among alum treatment groups (P=0.99, 0.37 and 0.18).

4.4 Bacterial Decontamination

Fig. 10 and 11 below show graph of mean percentage bacterial removal recorded after treatment of water from Baasare and Pongyaw streams. It was observed that efficacies of bacterial decontamination were low for 5ml and 10ml of *Moringa* extract. Percentage removal of 21% and 24% and 9% and 17% respectively were recorded for the two streams. *Moringa* concentrations of 15ml and 20ml showed mean percentage removal values of 34% and 36% for Agyemasum stream and 26% and 33% for Bodedan stream at 0hrs. Significant differences were observed among treatment groups (P=0.0002 and $7.85x^{10-5}$) respectively for the two streams. Alum concentrations on the other hand showed recorded mean percentage removal values between the range of 30%-51% and 26%-46% for Agyemasum and Bodedan streams at the same treatment time with significant differences (P=0.004 and $7.4x^{10-7}$) respectively.

Percentage removal were observed to increase as the treatment time increased, with 15ml and 20 ml *Moringa* concentrations recording 54% and 61% for Agyemasum stream and 57% and 68% for Bodedan stream after 12hrs of treatment with significant differences (P= $2.12x10^{-10}$ and $3.7x10^{-10}$). Alum also recorded a similar trend with 0.6ml and 0.8ml showing values of 72% and 75% and 74% and 80% for the two streams respectively. The differences in the

mean values among the alum treatment groups were significant (P= $8.78x10^{-10}$ and $1.49x^{10-7}$) for the two streams respectively.

However at 24hrs of treatment decreasing bacterial removal was observed for both *Moringa* and alum concentrations for the two streams. Agyemasum stream recorded mean values as low as 11% for *Moringa* concentrations and 15% for alum concentrations. Bodedan stream also recorded values between the range of 10% to 14% and 15% to 17% for *Moringa* and alum concentrations respectively (Appendix D). There were no significant differences between mean values of alum and moringa treatment groups at 24 hour period.

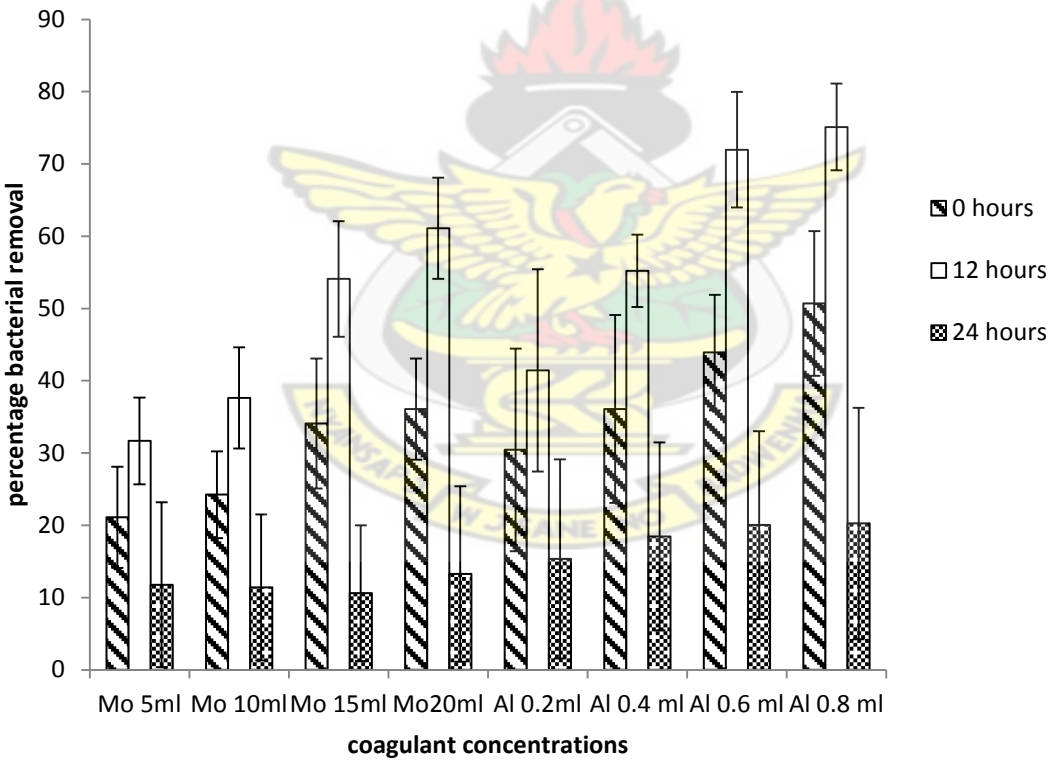

Figure 10: Effect of different concentrations of indicated coagulants on bacterial removal in stream water from Baasare after treatment for up to 24 h

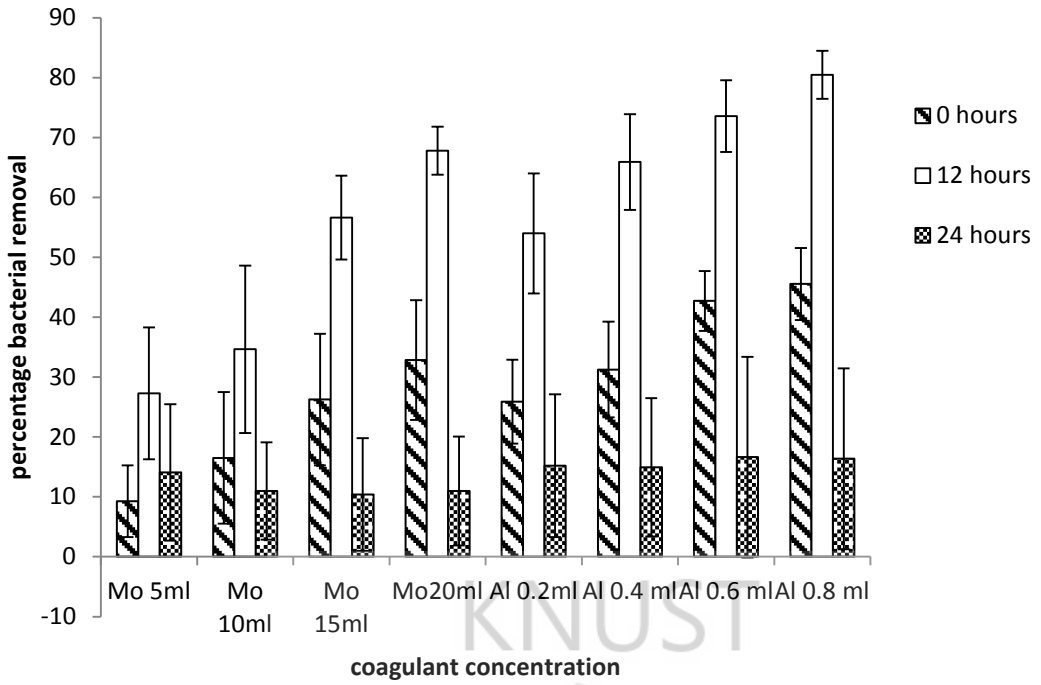

Figure 11: Effect of different concentrations of indicated coagulants on bacterial removal in stream water from Pongyaw after treatment for up to 24 h

Well water from Apaah and Abrakaso recorded lower percentage removal values at 0hrs of treatment with coagulant concentrations. It was observed that 5ml and 10 ml *Moringa* concentration recorded removal values of 16% and 21% and 17% and 27% for Apaah and Abrakaso respectively. Mean values of 27% and 31% and 33% and 37 % were recorded at 15ml and 20ml for Apaah and Abrakaso. Differences among mean values were observed to be significant (P= 0.007 and 0.001) respectively for Apaah and Abrakaso. Alum however recorded percentage removal of 22%-41% for Apaah and 24%-46% for Abrakaso with significant differences (p= 0.003) among mean values.

After 12 hrs of treatment it was observed that 15ml of *Moringa* extract recorded higher percentage removal of 57% as compared to 5ml, 10ml and 20ml for Apaah well (Fig. 12). Removal levels for alum at the same time also peaked at the 0.6ml and 0.8ml showing values of 62% and 69%. Well water from Abrakaso recorded percentage removal values of 54% at 15ml *Moringa* concentrations and 61% and 74% for that of 0.6ml and 0.8 ml alum

concentrations (Fig. 13). Significant differences were observed among mean values of both *Moringa* and alum treatment groups at the 12 hour period.

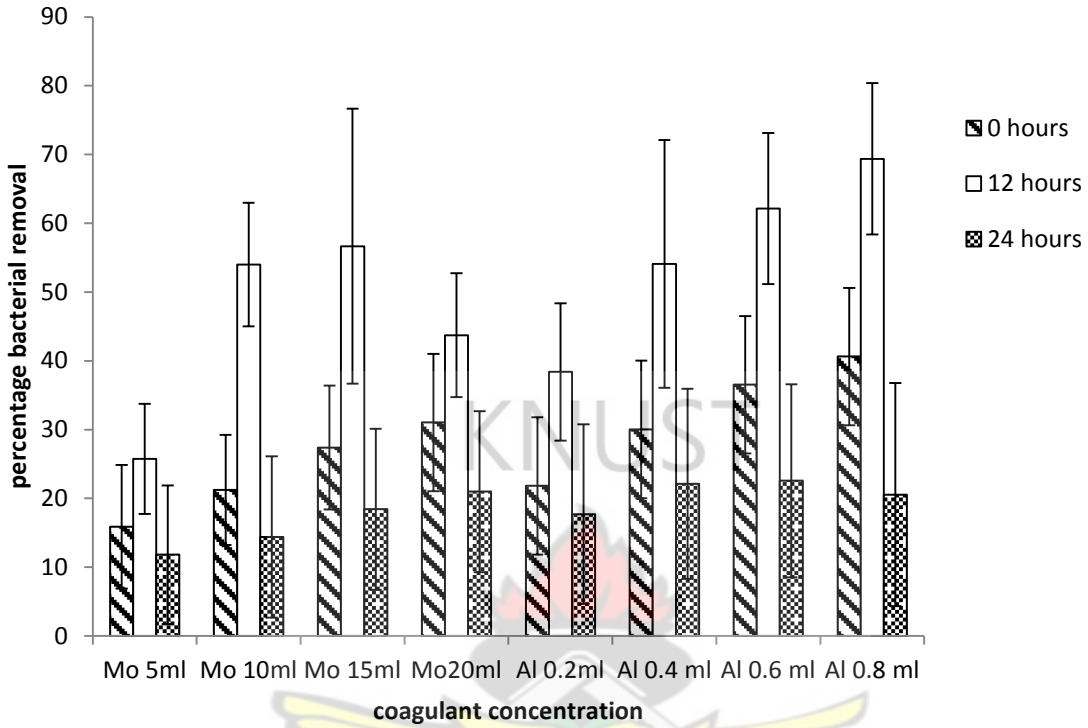

Figure 12: Effect of different concentrations of indicated coagulants on bacterial load in well water from Apaah after treatment for up to 24 h

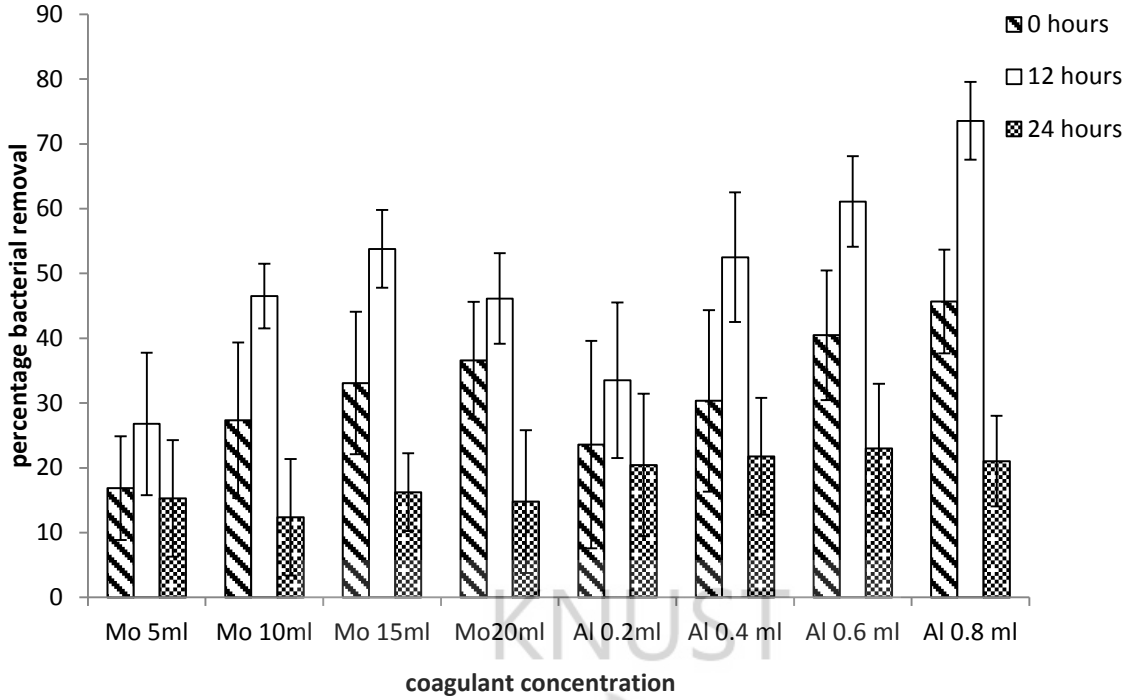

Figure 13: Effect of different concentrations of indicated coagulants on bacterial load in well water from Abrakaso after treatment for up to 24 h

Well water from Apaah after 24 hrs of treatment with *Moringa* recorded 12% to 21% bacterial regrowth. Abrakaso well also recorded values of 12% to 16%. Alum treated water showed bacterial regrowth recording values between 18% to 23% and 20% to 23% for wells of Apaah and Abrakaso respectively.

The observed differences in mean values among moringa treatment group were not significant (P= 0.96 and 0.83) for Apaah and Abrakaso well respectively. Alum treatment group also showed no significant differences (P= 0.89 and 0.95) in mean values.

In general it can be observed that efficient bacterial removal occurred at 12 hours of treatment for both coagulant dosages. Bacterial regrowths were higher in moringa than alum after the 24hr of treatment.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Household Demographic Studies

The large percentage of males as household heads in the communities studied was due to the belief that women are less powerful and have lower status. This underpins the findings of Ridgeway and Smith-Lovin (1999) who stated the reinforced dominant beliefs about status and competence which always favoured men. In these communities men are always expected to be responsible for protecting and sheltering women. However, other factors such as wars and migration to urban centres in search of better employment opportunity (Ngorima *et al*., 2008) which has been found to reduce male population in a community were non-existent in the study area.

The Ministry of Local Government and Rural Development Ghana, (1996) classify these communities as low income settlements. These low income levels are mostly associated with the household heads who are employed in the informal sector, due to their inability to pursue higher education. According to the International Labour Organization (2004), the informal sector employees seldom attract substantial income to cater for the needs of their families.

Lack of sufficient boreholes in these communities has increased reliance on streams and well water. The absence of pipe borne water in the communities was due to the inability of Ghana Water Company Limited to extend the supply network to these rural settlements. Cost (which is a major factor in the provision of this utility), might be hindering the supply network since most District Assemblies cannot afford this service. A large percentage of the people use water from streams and wells. The low patronage of borehole water in the communities is as a result of the “pay per use scheme” which residents consider to be expensive as compared to streams and ponds which is free (Howard, 2002).

Whilst some studies have found other methods of disinfecting drinking water which includes solar disinfection (Clasen *et al*., 2005), only 12.5 % of the households visited treat their water by boiling and filtration before drinking. This low percentage of water treatment is as a result of low income and ignorance. Traditional beliefs in rural settings that chemically treated water loses its natural taste might have also accounted for the low treatment of drinking water in the study communities.

5.2 Bacteriological Examination

Streams and wells which are the main drinking water sources in the studied communities were heavily polluted based on the bacteriological tests results. The most probable number (MPN) recorded showed values greater than 1000 cells/100 ml. The water sources can therefore be classified as grossly polluted thereby exceeding WHO Standards of less than 3 CFU/100ml (Cheesborough, 1994).

Sources of this bacterial pollution include anthropogenic activities such as indiscriminate open defecation and unplanned wastewater disposal management. This was confirmed by sanitation survey which revealed no proper form of waste disposal. Residents are at risk of consuming water from these sources which are presumed to be "clean". The American Water Works Association (AWWA) Standards (1990) prescribes that surface water must be treated before consumption. This was not the case in the study area.

Due to inadequate toilet facilities faeces and wastewaters are being discharged into open areas resulting in high levels of bacteria pollution accentuated by surface runoffs and leachate during rainfall. The practice of burying faecal matter in the immediate subsurface by some residents during their farming activities could presumably contribute to the high coliform levels through seepage and runoffs.

5.3 Effectiveness of *Moringa oleifera* and Alum on water quality

5.3.1 pH

The World Health Organization (WHO) classifies as standard drinking water any water with a pH between 6.5 and 8.5. Although pH usually has no direct impact on water consumers, it is one of the most important water-quality parameters.

There were significant differences ($p < 0.05$) between all the treatments at the different coagulant concentrations on pH. Treatments with varying concentrations of *Moringa* however did not influence pH of water. The pH ranged from 7.29 to 6.27 for the two streams and 7.05 to 6.06 for the well samples. These pH values fall within the WHO standards for drinking water. Alum however, reduced the pH of water to acidic levels (Table 6-9).

The effectiveness of *M. 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 (Ndabigengesere *et al.*1995). In a similar study, Muyibi (1993) observed that in a completely randomized factorial experiment with different concentrations of *Moringa oleifera*, pH did not have any significant effect on the quality of treated water.

Alum at different concentrations significantly influenced the pH of the water causing a decrease with increasing concentrations. The low pH resulting from the use of alum could be altered by addition of sodium hydroxide, thereby increasing treatment cost. The addition of alum in the treatment procedure produced sulphuric acid which lowered the pH levels. This tendency towards increase in acidity could be due to the trivalent cation aluminium that can accept lone pair of electrons (Miller *et al*., 1984). Sulphuric acid reacts with the alkaline present in the water to lower pH. High dosage of alum in water treatment even though a better coagulant, may lead to high acidity raising health concerns about alum related diseases as reported by Martyns *et al*., (1989).

In general, the pH of the two streams and well water samples treated with *Moringa* seed extract was within the recommended standards (WHO, 2006). According to Jahn (1986) *Moringa* seeds have high advantage over alum in water treatment for rural people since no pH adjustment is required. Thus *Moringa* extract maintains the water in its neutral state.

5.3.2 Turbidity

Prior to the treatment of water from the communities with *Moringa* and alum, turbidity values were observed to be above the recommended standards for drinking water. The turbidity recorded could be attributed to phytoplankton, re-suspended bottom sediments and organic detritus. Surface runoffs, characteristics of parent rock and anthropogenic activities such as farming in the immediate surroundings of water sources also contributes to turbidity increase (USEPA, 1997). Excessive turbidity in water causes problems with water purification process such as flocculation and filtration and is mostly associated with the possibility of microbial pollution (DWAF, 1989).

The two coagulants used for water treatments resulted in significant differences in turbidity. The optimal concentration of *Moringa* coagulant for treating stream water of Baasare and Pongyaw was 20 ml. This concentration reduced the turbidity of Agyemasum stream at Baasare Bodedan stream at Pongyaw from an initial of 24.59 NTU to 5.09 NTU and 23.77 NTU to 6.66 NTU respectively after 24 hrs settling time.

It was observed that 15ml of Moringa reduced the well water samples from Apaah and Abrakaso turbidity from an initial 13.17 NTU to 5.48 NTU and 11.83 to 4.93 NTU respectively after 12hrs settling time. These turbidity values obtained after seed coagulation were within the WHO acceptable turbidity value of 5NTU for safe drinking water (WHO, 2006).

In the case of alum, a concentration of 0.2ml reduced turbidity from 24.59 NTU to 3.32 NTU for stream water and from 13.17 NTU to 3.0 NTU for well water after 24 hrs settling time. It was observed that optimal concentrations of *Moringa* seed extract (15ml and 20ml) as coagulant gave similar reduction effect on turbidity as compared to 0.2ml concentration of alum.

Coagulation using *Moringa* is caused by the destabilization of negatively charged colloids by cationic polyelectrolytes (Folkard *et al.,* 1989). The most likely mechanisms involved in this coagulation activity are adsorption and neutralization of charges, or adsorption and bridging of destabilized particles (AWWA, 1990).

In the *Moringa* seed- treated waters, turbidity increased with increasing concentration beyond the optimal concentration. This was due to re-stabilization caused by reversal of colloidal charge due to adsorption This can be explained by the possible saturation of the polymer bridge sites in the *Moringa* protein which resulted in the restabilization of the destabilized particles due to insufficient number of particles to form more inter-particle bridges (Bratby, 1980). Bhuptawat *et al*. (2007) also observed restabilization phenomenon during coagulation of synthetic turbid water using crude extracts of *Moringa* seeds.

However, in the present study, turbidity removal was dependent on settling time and the degree of turbidity of raw water. For example, an initial turbidity of 24.59 NTU and 23.77 NTU of Agyemasum and Bodedan streams respectively required 24 hr settling time to achieve clarification within the acceptable drinking water standards of 5NTU. Similar results were reported by Mhaisalker *et al.* (1991) who found that the optimum turbidity reduction is dependent on the raw water turbidity and time, and that the optimal rapid mixing and settling times increase with increase in raw water turbidity.

5.3.3 TOTAL DISSOLVED SOLIDS (TDS)

Total dissolved solids is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular suspended form. These originate from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water.

The TDS concentrations gradually increased for both coagulants with increasing concentrations with all the three settling times. This was probably due to increased levels of inorganic substances such as calcium, magnesium, bicarbonates, chlorides and sulphates. TDS values were however higher in alum treated water than *Moringa* treated water due to higher levels of aluminium and sulphates components adding on to the inorganic level (Adomako, 2000).

An important aspect of TDS in respect to drinking water quality is its effect of taste. Water with TDS levels less than 600 mg/l is generally considered to be good and palatable (WHO, 1984). Since TDS values of both streams and wells treated with *Moringa* seed extract and alum were below 130mg/l the water could be classified as palatable since the recommended guideline value of TDS in drinking water is 1000 mg/l based on taste (WHO, 2006).

5.3.4 CONDUCTIVITY

Conductivity, which is a measure of total dissolved solids (TDS) in water varies considerable in different geographical regions owing to differences in the solubility of minerals; hence there is no standard value for it but high levels in drinking water maybe objectionable to consumers (WHO, 2006).

At 95.0% confidence level, there were significant differences ($p < 0.05$) in conductivity between all the treatments at all the various coagulant dose concentrations. However,

Treatments with *Moringa* and alum concentrations influenced conductivity of water greatly. Increasing concentrations of both coagulants was attended by increase in conductivity for both stream and well water samples at the three settling times. This may be attributed to the increase in cationic polyelectrolyte in *Moringa* seeds and sulphate ions in alum as the concentrations increased thereby producing high dissolved solids that increased the conductivity (Okuda *et al.*, 2000).

Results from this thesis contrast the work by Amagloh and Benang (2009) who reported that increasing concentrations of both alum and *Moringa* coagulants led to decrease in conductivity values. Ndabigengesere and Narasiah (1996) also showed that *Moringa* seed extract did not influence conductivity of water.

5.3.5 Bacterial Removal

Coagulation with alum resulted in high bacterial removal of 75% and 80% for Agyemasum and Bodedan streams respectively. Well water from Apaah and Abrakaso also recorded 69% and 74% bacterial removal respectively at 0.8ml alum concentrations after 12 hrs settling time. Correspondingly, optimal *Moringa* concentration of 15ml-20ml also gave high bacterial removal percentages of 54%-61% and 57%- 68 % for Agyemasum stream at Baasare and Bodedan stream at Pongyaw respectively at the same settling time. Concentrations of 10-15ml applied to water from Apaah and Abrakaso recorded bacterial removal percentages of 54%-57% and 47%-54% respectively.

Data obtained in this thesis show that the *Moringa* coagulant treatment had an added advantage of reducing microbial load. This supports the findings of Olayemi (1994) who stated that the process of flocculation removes about 55% - 65% of bacteria which are normally attached to the solid particles. Bacterial reduction may be due to antimicrobial agent in the seed extract as well as settling time (Jahn, 1986). Antimicrobial peptides in the seed

extract are thought to act by disrupting bacterial cell membranes or inhibiting essential enzymes (Suarez *et. al.,* 2003).

In the case of alum, the reduction could be attributed to the reduced pH making the water slightly acidic, as well as the length of time for treated water to settle. On the whole bacterial removal was higher in alum treated water than *Moringa* treated water. This could be due to the non-availability of carbon source in the case of alum as it turns to get rid of all organic matter in the water resulting in the starvation microorganisms to death (Donkor, 1996).

However, after 24 hr settling time, both *Moringa* and alum treated water decreased in bacterial count with emission of odour from the *Moringa* treated water. This could probably be attributed to bacterial regrowth on impurities with the organic matter present in *Moringa* seed providing additional nutrient support.. Secondary bacterial growth might also be due to the presence of some bacterial cells which were initially sub-lethally inactivated, but resuscitated after some period of contact with the sub-lethal concentration of the chemical. Other parameters such as treatment time, temperature and water constituent may also exert a profound influence on bacterial regrowth (Madsen *et al.,* 1987).

To date no adverse health effects have been recorded in humans using *Moringa*-treated water in India, Sudan, Malawi and even the northern part of Ghana. *Moringa* powder is therefore a potential anticoagulant antibacterial agent to be used as a supplement to alum in water clarification. It can be deduced from the study that although *Moringa* seeds used in treating did not render treated water completely bacteria free but considerably reduced the numbers to safe levels comparable with what was obtained with alum. Therefore, its use in water treatment must be combined with filtration or boiling in households before it could be passed as fit for human consumption (Bensimon, 1997).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The following conclusions can be drawn from this study:

- *Moringa oleifera* is an effective natural coagulant which can be used in improving the physicochemical characteristics of water in terms of pH, turbidity, TDS and conductivity. In coagulation, *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.
- The results obtained show that powder from seed of *M. oleifera* contains some coagulating properties with optimal doses of 20 ml and 15ml for stream and well water respectively. These concentrations have similar effect as the conventional coagulum, alum.
- Both coagulants possess almost the same time-dependent potency in antimicrobial properties. Bacterial regrowths were recorded after 24 hours settling time. There is therefore the need for filtration or boiling of the water if it is to be stored for a longer time.
- *Moringa oleifera* seeds present a viable alternative coagulant to alum in treating water for rural dwellers since it's environmentally friendly and cheaper.

6.2 Recommendation

1. There is the need for public education on uses of *Moringa* in water clarification through workshops and the media in all District Assemblies and regions of Ghana.
2. Secondary bacterial growth after 24 hours of settling time with both coagulants necessitates that water for drinking purposes should be boiled or filtered before use.
3. Government and private organizations should invest more in *Moringa* cultivation since it has the potential of reducing cost of water treatment and can help improve water quality for rural dwellers.
4. Future research is suggested on the following:
    - Efficiency of the combination of *Moringa* seeds and sunlight on the treatment of water.
    - Combination of alum and *Moringa* in different proportions to establish their synergistic effectiveness in treating raw water.
    - Medicinal value of the components of the seed extract of *Moringa oleifera* in health benefits.

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APPENDICES

APPENDIX A

Table 6: Some physicochemical qualities of stream water from Baasare before and after treatment with indicated volumes of *Moringa* and alum for up to 24 hrs.

	PARAMETERS	CONTROL	MORINGA				ALUM			
			5ml	10ml	15ml	20ml	0.2 ml	0.4 ml	0.6 ml	0.8 ml
Baasare (0 hrs)	pH	7.16	7.29	7.19	7.09	7.0	6.72	6.53	6.34	6.16
	Turb (NTU)	21.56	22.26	20.82	16.13	15.69	17.69	15.31	11.58	11.70
	TDS (mg/L)	71.04	74.57	75.74	79.73	92.99	74.96	97.28	82.26	79.82
	Cond (µs/cm)	144.94	154.91	159.52	165.78	170.89	144.71	151.34	154.76	161.18
Baasare(12 hrs)	pH	7.12	7.16	7.01	6.77	6.94	6.33	6.23	5.85	5.74
	Turb (NTU)	20.18	18.37	16.68	12.07	12.99	5.70	4.36	3.18	2.89
	TDS(mg/L)	71.76	77.77	78.72	78.60	81.11	76.07	78.37	83.63	83.37
	Cond(µs/cm)	149.33	152.40	160.13	165.49	169.24	144.09	150.59	158.90	160.99
Baasare(24 hrs)	pH	7.04	7.04	7.01	6.77	6.80	6.29	6.09	5.73	5.65
	Turb(NTU)	12.79	14.82	11.59	9.05	5.09	3.32	2.22	1.30	1.30
	TDS(mg/L)	73.31	76.70	79.87	71.96	78.38	77.60	78.97	80.02	82.61
	Cond(µs/cm)	155.47	154.76	162.21	162.49	168.80	144.61	152.26	158.70	163.92

Table 7: Some physicochemical qualities of stream water from Pongyaw before and after treatment with indicated volumes of *Moringa* and alum for up to 24 hrs.

COMMUNITIES	PARAMETERS	CONTROL	MORINGA				ALUM			
			5ml	10ml	15ml	20ml	0.2 ml	0.4 ml	0.6 ml	0.8 ml
Pongyaw (0 hrs)	pH	7.04	7.14	7.09	7.03	7.09	6.64	6.54	6.36	6.01
	Turb(NTU)	19.09	20.83	19.56	16.22	19.18	14.61	9.81	6.04	6.82
	TDS(mg/L)	48.90	48.93	52.02	59.03	62.14	51.22	54.73	58.48	59.99
	Cond(µs/cm)	81.83	87.20	100.28	112.63	121.26	94.96	106.14	117.53	126.59
Pongyaw(12 hrs)	pH	6.95	6.98	6.77	6.77	6.69	6.34	6.29	5.92	5.65
	Turb(NTU)	14.80	10.73	9.11	9.87	9.43	10.97	5.72	4.14	3.44
	TDS(mg/L)	51.74	49.38	54.68	62.51	65.21	54.17	57.93	59.40	66.97
	Cond(µs/cm)	85.12	95.0	101.41	119.07	126.94	92.88	111.86	124.26	133.62
Pongyaw(24 hrs)	pH	6.50	6.47	6.55	6.61	6.27	6.18	6.04	5.41	5.25
	Turb(NTU)	9.28	8.32	6.66	7.30	6.66	7.57	4.06	3.0	2.31
	TDS(mg/L)	59.08	45.90	49.04	62.04	62.54	46.56	51.70	52.26	62.86
	Cond(µs/cm)	103.20	87.88	95.97	104.88	112.26	98.53	103.48	113.91	127.72

Table 8: Some physicochemical qualities of well water from Apaah before and after treatment with indicated volumes of *Moringa* and alum for up to 24 hrs.

COMMUNITIES	PARAMETERS	CONTROL	MORINGA				ALUM			
			5ml	10ml	15ml	20ml	0.2 ml	0.4 ml	0.6 ml	0.8 ml
Apaah(0 hrs)	Ph	6.91	6.81	6.68	6.48	6.44	6.70	6.51	6.25	6.04
	Turb(NTU)	12.27	11.86	11.43	9.89	7.74	9.14	8.43	7.66	7.66
	TDS(mg/L)	100.16	105.0	106.16	103.89	106.67	102.13	107.76	101.90	101.90
	Cond(µs/cm)	193.90	199.18	218.88	219.80	217.96	225.22	221.18	216.72	216.72
Apaah (12 hrs)	pH	6.62	6.60	6.51	6.34	6.24	6.51	6.16	5.94	5.68
	Turb(NTU)	10.39	8.69	7.48	6.34	8.26	6.90	5.64	5.33	4.24
	TDS(mg/L)	109.17	124.71	119.0	116.0	114.56	117.46	120.78	113.17	119.13
	Cond(µms/cm)	200.04	212.09	229.82	242.0	230.32	236.78	233.11	232.96	239.72
Apaah (24 hrs)	pH	6.28	6.30	6.26	6.18	6.06	6.13	5.89	5.76	5.27
	Turb(NTU)	6.53	6.80	5.04	6.66	8.49	4.09	3.37	3.07	1.83
	TDS(mg/L)	118.88	123.64	122.24	128.11	126.39	115.21	118.48	124.84	216.19
	Cond(µs/cm)	211.84	213.69	233.22	251.11	232.83	239.44	235.67	234.78	240.44

Table 9: Some physicochemical qualities of well water from Abrakaso before and after treatment with indicated volumes of *Moringa* and alum for up to 24 hrs.

COMMUNITIES	PARAMETERS	CONTROL	MORINGA				ALUM			
			5ml	10ml	15ml	20ml	0.2 ml	0.4 ml	0.6 ml	0.8 ml
Abrakaso (0 hrs)	pH	7.04	7.05	7.01	6.88	6.84	6.38	6.19	6.07	5.92
	Turb(NTU)	11.79	10.34	9.53	8.28	7.52	6.69	4.72	3.21	2.70
	TDS(mg/L)	65.84	68.28	78.89	85.11	90.22	82.89	89.33	96.78	96.56
	Cond(µs/cm)	143.61	141.86	174.42	181.79	184.46	187.33	190.17	192.40	190.51
Abrakaso (12hrs)	pH	6.89	6.90	6.72	6.55	6.29	6.01	6.02	5.74	5.66
	Turb(NTU)	10.16	6.79	6.86	5.77	4.56	4.25	3.52	2.31	1.66
	TDS(mg/L)	71.28	75.44	93.0	95.22	96.56	93.44	94.67	103.11	102.11
	Cond(µs/cm)	150.60	153.21	176.97	185.80	186.29	181.63	193.28	208.23	206.83
Abrakaso (24hrs)	pH	6.61	6.53	6.66	6.27	6.13	5.81	5.90	5.45	5.36
	Turb(NTU)	5.69	6.84	4.93	4.19	4.19	3.0	2.68	1.66	1.10
	TDS(mg/L)	81.94	78.44	101.44	93.69	106.89	94.44	103.0	108.67	108.67
	Cond(µs/cm)	160.69	158.27	179.68	191.08	193.97	186.40	203.60	218.59	219.39

Appendix B

A1: Mean Values for TDS in treated stream samples

Baasare									
Time (hrs)		Moringa				Alum			
	Control	5ML	10ML	15ML	20ML	0.2ML	0.4ML	0.6ML	0.8ML
0	71.04	74.57	75.74	79.73	92.99	74.96	97.28	82.26	79.82
12	71.76	77.77	78.72	78.60	81.11	76.07	78.37	83.63	83.37
24	73.31	76.70	79.87	71.96	78.38	77.60	78.97	80.02	82.61
Pongyaw									
		Moringa				Alum			
	Control	5ML	10ML	15ML	20ML	0.2ML	0.4ML	0.6ML	0.8ML
0	48.90	48.93	52.02	59.03	62.14	51.22	54.73	58.48	59.99
12	51.74	49.38	54.68	62.51	65.21	54.17	57.93	59.40	66.97
24	59.08	45.90	49.04	62.04	62.54	46.56	51.70	52.26	62.86

A2: Mean Total Dissolved Solutes for Well Samples after Treatment

Apaah									
Time (hrs)		Moringa				Alum			
	Control	5ML	10ML	15ML	20ML	0.2ML	0.4ML	0.6ML	0.8ML
0	100.16	105.0	106.16	103.89	106.67	102.13	107.76	101.90	101.90
12	109.17	124.71	119.0	116.0	114.56	117.46	120.78	113.17	119.13
24	118.88	123.64	122.24	128.11	126.39	115.21	118.48	124.84	216.19
Abrakaso									
		Moringa				Alum			
	Control	5ML	10ML	15ML	20ML	0.2ML	0.4ML	0.6ML	0.8ML
0	65.84	68.28	78.89	85.11	90.22	82.89	89.33	96.78	96.56
12	71.28	75.44	93.0	95.22	96.56	93.44	94.67	103.11	102.11
24	81.94	78.44	101.44	93.69	106.89	94.44	103.0	108.67	108.67

Appendix C
B1: Mean Values for Conductivity in treated stream samples

Baasare									
Time (hrs)		Moringa				Alum			
	Control	5ML	10ML	15ML	20ML	0.2ML	0.4ML	0.6ML	0.8ML
0	144.94	154.91	159.52	165.78	170.89	144.71	151.34	154.76	161.18
12	149.33	152.40	160.13	165.49	169.24	144.09	150.59	158.90	160.99
24	155.47	154.76	162.21	162.49	168.80	144.61	152.26	158.70	163.92
Pongyaw									
		Moringa				Alum			
	Control	5ML	10ML	15ML	20ML	0.2ML	0.4ML	0.6ML	0.8ML
0	81.83	87.20	100.28	112.63	121.26	94.96	106.14	117.53	126.59
12	85.12	95.0	101.41	119.07	126.94	92.88	111.86	124.26	133.62
24	103.20	87.88	95.97	104.88	112.26	98.53	103.48	113.91	127.72

B2: Mean Conductivity for well samples after treatment

Apaah									
Time (hrs)		Moringa				Alum			
	Control	5ML	10ML	15ML	20ML	0.2ML	0.4ML	0.6ML	0.8ML
0	193.90	199.18	218.88	219.80	217.96	225.22	221.18	216.72	216.72
12	200.04	212.09	229.82	242.0	230.32	236.78	233.11	232.96	239.72
24	211.84	213.69	233.22	251.11	232.83	239.44	235.67	234.78	240.44
Abrakaso									
		Moringa				Alum			
	Control	5ML	10ML	15ML	20ML	0.2ML	0.4ML	0.6ML	0.8ML
0	143.61	141.86	174.42	181.79	184.46	187.33	190.17	192.40	190.51
12	150.60	153.21	176.97	185.80	186.29	181.63	193.28	208.23	206.83
24	160.69	158.27	179.68	191.08	193.97	186.40	203.60	218.59	219.39

Appendix D

D1: Percentage bacterial removal for treated water from Baasare at 0hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	9	14	21	25	11	20	30	37
2	11	14	19	25	23	29	43	49
3	30	31	42	45	45	48	55	59
4	29	26	42	38	44	49	51	55
5	22	26	33	36	14	21	36	33
6	22	28	35	35	17	23	38	46
7	22	26	39	43	37	42	44	58
8	22	27	36	39	45	54	55	61
9	23	28	40	39	35	38	43	58
mean	21	24	34	36	30	36	44	51

Percentage bacterial removal for treated water from Baasare at 12hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	27	32	41	63	49	55	64	75
2	28	30	50	58	30	49	60	70
3	41	45	59	60	55	63	64	71
4	40	32	49	51	52	59	75	69
5	28	33	55	59	19	50	71	70
6	30	33	46	55	22	53	78	74
7	37	43	66	71	50	57	82	88
8	30	45	60	63	55	61	79	83
9	25	44	61	70	40	50	75	76
mean	32	38	54	61	41	55	72	75

Percentage bacterial removal for water samples from Baasare at 24hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	0	2	13	0	2	8	6	11
2	10	6	5	4	7	8	6	4
3	32	28	11	27	17	21	27	25
4	18	11	6	12	37	23	34	14
5	29	33	38	42	0	3	6	8
6	2	9	0	3	-7	6	9	1
7	11	5	2	10	33	34	32	36
8	0	7	16	21	26	29	24	45
9	4	3	4	1	23	35	35	40
mean	12	11	11	13	15	18	20	20

D2: Percentage bacterial removal for water samples from Pongyaw at 0hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	10	39	41	47	43	49	53	56
2	22	30	46	52	21	36	49	55
3	4	7	14	23	19	22	37	44
4	15	17	28	29	28	37	46	45
5	10	11	22	24	22	25	40	44
6	4	11	14	30	27	30	39	42
7	3	3	22	25	23	26	41	39
8	8	10	28	32	27	30	40	43
9	7	20	22	33	24	27	41	43
mean	9	17	26	33	26	31	43	46

Percentage bacterial removal for water samples from Pongyaw at 12hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	31	52	62	71	63	61	71	79
2	51	57	69	71	71	69	74	79
3	24	27	65	73	48	56	71	73
4	29	46	58	63	55	75	79	85
5	24	27	50	67	59	79	83	85
6	27	31	49	62	54	72	80	85
7	11	17	55	70	38	63	71	82
8	20	22	51	68	41	58	63	80
9	29	33	51	65	57	60	70	76
mean	27	35	57	68	54	66	74	80

Percentage bacterial removal for water samples from Pongyaw at 24hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	26	21	24	30	36	37	39	34
2	8	11	17	14	25	25	30	34
3	10	5	3	1	1	3	1	3
4	14	1	2	6	14	12	4	3
5	7	5	1	2	3	7	13	14
6	2	14	2	10	14	3	2	6
7	2	3	7	5	11	15	11	4
8	33	16	4	1	6	8	1	11
9	24	23	34	30	28	24	48	39
mean	14	11	10	11	15	15	17	16

D3: Percentage bacterial removal for water samples from Apaah at 0hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	28	37	41	48	34	40	50	50
2	27	26	42	41	42	44	49	54
3	16	22	26	36	20	26	32	46
4	18	24	22	31	20	29	39	44
5	8	13	15	20	10	15	18	21
6	24	26	35	35	19	35	36	38
7	10	18	22	20	24	39	42	43
8	4	9	22	24	15	23	36	39
9	9	15	22	24	14	20	26	30
mean	16	21	27	31	22	30	37	41

Percentage bacterial removal for water samples from Apaah at 12hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	36	54	53	55	41	49	62	66
2	32	59	55	52	48	55	56	73
3	27	52	48	48	54	46	55	70
4	25	48	62	39	38	66	68	72
5	7	44	69	30	0	60	65	76
6	29	41	65	45	24	61	61	79
7	26	63	51	46	60	41	69	64
8	31	65	50	47	47	50	61	69
9	21	60	57	32	34	59	63	55
mean	26	54	57	44	38	54	62	69

Percentage bacterial removal for water samples from Apaah at 24hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	23	31	29	22	30	23	20	20
2	6	12	24	30	9	14	15	12
3	6	1	5	15	12	15	13	17
4	1	9	2	14	18	20	26	5
5	2	7	12	10	-2	3	9	3
6	16	6	12	1	5	10	8	11
7	14	18	24	35	31	41	44	46
8	31	26	38	41	37	44	46	47
9	8	18	20	22	20	29	22	24
mean	12	14	18	21	18	22	23	21

D4: Percentage bacterial removal for water samples from Abrakaso at 0hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	14	20	26	41	8	13	39	43
2	6	10	15	25	8	22	24	31
3	20	26	42	45	5	19	46	50
4	9	24	26	31	24	28	30	46
5	29	44	43	41	47	52	54	60
6	22	29	40	43	36	44	47	50
7	10	13	20	22	12	16	33	37
8	21	37	41	44	37	39	44	45
9	20	42	45	38	35	41	46	49
mean	17	27	33	37	24	30	40	46

Percentage bacterial removal for water samples from Abrakaso at 12hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	31	43	57	45	28	46	71	71
2	12	48	61	32	18	29	63	63
3	35	51	50	48	18	54	70	70
4	25	41	43	46	39	54	63	71
5	35	39	52	54	47	60	58	74
6	36	45	55	59	49	63	60	71
7	7	50	55	44	27	53	51	79
8	26	47	49	42	47	60	59	83
9	35	54	63	45	30	54	55	80
mean	27	47	54	46	34	52	61	74

Percentage bacterial removal for water samples from Abrakaso at 24hrs of treatment

sample	5ml	10ml	15ml	20ml	0.2ml	0.4ml	0.6ml	0.8ml
1	24	14	17	28	13	21	23	18
2	18	7	5	2	12	29	26	22
3	17	14	21	5	26	18	23	23
4	2	14	20	24	16	20	26	24
5	6	9	19	17	24	15	8	17
6	9	2	20	17	10	9	7	15
7	30	33	24	31	36	34	37	18
8	21	13	8	3	37	35	36	37
9	10	5	12	5	10	15	21	15
mean	15	12	16	15	20	22	23	21

APPENDIX E

ASSESSMENT OF WATER QUALITY AND SANITATION IN RURAL COMMUNITIES

1. Household heads name……

2. Household number…….

3. Households head gender
   Male……..1
   Female……..2

4. Households head age
   25 – 35……..1
   36 – 45……..2
   46 – 55……..3
   56 – 65……..4
   66 – 75……..5
   Other……6

5. Household heads educational level
   Basic……1
   Secondary……2
   Tertiary……3
   Non formal……4

6. Occupation of household head……...
   Farmer……1
   Trader……2
   Dress maker……3
   Educationist……..4
   Others……5

7. Religion of household head……
   Islam……1
   Christianity……..2
   Traditional……3
   Others……..4

8. Household size……
   One – five……1
   Six – ten……2
   Eleven – fifteen……3
   Other……4

WATER SUPPLY

9. Where do you get your water from?
   Pipe……1
   Well……2

Borehole…….3
Stream……4
Other…….5

10. Why did you choose this source?
Only source available……..1
Drinking water……2
Proximity…….3
By habit……..4

11. Who is in charge of water collection?
Father……1
Mother……..2
Children……3
Other…….4

12. Do you store your water before use?
Yes……1
No…….0

13. For how many days do you store your water?
A day……..1
Two days…….2
Three days……..3

14. What do you use for collecting and storing water?
Bucket……..1
Basin……2
Jerrican……3
Barrel……4
Others (specify)……5

15. Do you treat your water before use?
Yes……..1
No……..0

16. If yes How?
Boiling……..1
Filtration……2
Other…….3

17. Who is in charge of water treatment?
Father……1
Mother……..2
Children……3
Other (specify)……..4

18. Do you use the same source of water for all domestic purposes?
Yes……1
No…….0

SANITATION

19. Do you have a toilet facility in the house?
Yes…….1
No…….0

20. If not where do you defecate?
In the street……..1
Neighbour…….2
Public toilet…….3
Plastic bag……..4

21. Where do you dispose your refuse?
Waste pit in the yard……1
Public waste container…….2
Gutter…….3
Waste ground…….4

Appendix F

F1: One way Analysis of Variance for Baasare pH at the moringa treatment periods

Anova: Single Factor — PH 0HOURS

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	65.58	7.286667	0.0161
Column 2	9	64.67	7.185556	0.018453
Column 3	9	63.83	7.092222	0.021894
Column 4	9	64.5	7.166667	0.02895

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.173344	3	0.057781	2.706481	0.061664	2.90112
Within Groups	0.683178	32	0.021349			
Total	0.856522	35				

Anova: Single Factor — 12HOURS PH

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	64.43	7.158889	0.009086
Column 2	9	63.12	7.013333	0.026
Column 3	9	60.97	6.774444	0.050403
Column 4	9	62.42	6.935556	0.050853

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.692856	3	0.230952	6.775679	0.00115	2.90112
Within Groups	1.090733	32	0.034085			
Total	1.783589	35				

One way Analysis of Variance for Baasare pH at the alum treatment periods

Anova: Single Factor 0 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	60.47	6.718889	0.032811
Column 2	9	58.81	6.534444	0.013028
Column 3	9	57.04	6.337778	0.025369
Column 4	9	55.42	6.157778	0.022519

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.5909	3	0.5303	22.6315	4.75E-08	2.90112
Within Groups	0.749822	32	0.023432			
Total	2.340722	35				

Anova: Single Factor 12 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	56.93	6.325556	0.083703
Column 2	9	56.09	6.232222	0.051219
Column 3	9	52.69	5.854444	0.126678
Column 4	9	51.65	5.738889	0.100386

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.192133	3	0.730711	8.074466	0.000381	2.90112
Within Groups	2.895889	32	0.090497			
Total	5.088022	35				

One way Analysis of Variance for Baasare turbidity at the moringa treatment periods

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	200.3	22.25556	11.92778
Column 2	9	187.4	20.82222	20.48694
Column 3	9	145.21	16.13444	26.37043
Column 4	9	141.2	15.68889	44.38861

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	295.129	3	98.37634	3.814006	0.019178	2.90112
Within Groups	825.3901	32	25.79344			
Total	1120.519	35				

Anova: Single Factor TUR 12 HOURS

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	165.3	18.36667	6.32
Column 2	9	150.1	16.67778	11.34694
Column 3	9	108.6	12.06667	9.55
Column 4	9	116.9	12.98889	30.76861

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	241.1631	3	80.38769	5.545359	0.003511	2.90112
Within Groups	463.8844	32	14.49639			
Total	705.0475	35				

One way Analysis of Variance for Baasare turbidity at the alum treatment periods

Anova: Single Factor 0 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	159.2	17.68889	4.646111
Column 2	9	137.8	15.31111	3.668611
Column 3	9	104.2	11.57778	4.026944
Column 4	9	105.3	11.7	5.015

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	238.1831	3	79.39435	18.29714	4.27E-07	2.90112
Within Groups	138.8533	32	4.339167			
Total	377.0364	35				

Anova: Single Factor 12 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	51.3	5.7	4.2125
Column 2	9	39.2	4.355556	0.917778
Column 3	9	28.64	3.182222	0.788819
Column 4	9	25.97	2.885556	0.518903

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	44.31028	3	14.77009	9.17682	0.000158	2.90112
Within Groups	51.504	32	1.6095			
Total	95.81428	35				

F2: One way Analysis of Variance for Pongyaw pH at the moringa treatment periods

Anova: Single Factor 0 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	64.26	7.14	0.0865
Column 2	9	63.85	7.094444	0.100503
Column 3	9	63.31	7.034444	0.088353
Column 4	9	63.78	7.086667	0.073825

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.050511	3	0.016837	0.192875	0.900475	2.90112
Within Groups	2.793444	32	0.087295			
Total	2.843956	35				

Anova: Single Factor 12 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	62.84	6.982222	0.085444
Column 2	9	60.96	6.773333	0.069425
Column 3	9	60.91	6.767778	0.054844
Column 4	9	60.22	6.691111	0.117036

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.420831	3	0.140277	1.717238	0.183154	2.90112
Within Groups	2.614	32	0.081688			
Total	3.034831	35				

One way Analysis of Variance for Pongyaw pH at the alum treatment periods

0 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	59.78	6.642222	0.166469
Column 2	9	58.9	6.544444	0.234903
Column 3	9	56.31	6.256667	0.367625
Column 4	9	54.13	6.014444	0.369528

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.193089	3	0.73103	2.568339	0.071634	2.90112
Within Groups	9.1082	32	0.284631			
Total	11.30129	35				

Anova: Single Factor 12 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	57.09	6.343333	0.084
Column 2	9	56.64	6.293333	0.1237
Column 3	9	53.3	5.922222	0.098719
Column 4	9	50.81	5.645556	0.189103

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.926378	3	0.975459	7.874192	0.00045	2.90112
Within Groups	3.964178	32	0.123881			
Total	6.890556	35				

One way Analysis of Variance for Pongyaw turbidity at the moringa treatment periods

Anova: Single Factor 0 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	187.5	20.83333	18.195
Column 2	9	176	19.55556	11.47278
Column 3	9	146	16.22222	17.10944
Column 4	9	172.6	19.17778	19.66444

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	102.6564	3	34.2188	2.060081	0.125158	2.90112
Within Groups	531.5333	32	16.61042			
Total	634.1897	35				

Anova: Single Factor 12 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	96.6	10.73333	12.5075
Column 2	9	82	9.111111	5.378611
Column 3	9	88.8	9.866667	6.8425
Column 4	9	84.9	9.433333	1.67

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.35417	3	4.451389	0.674488	0.574033	2.90112
Within Groups	211.1889	32	6.599653			
Total	224.5431	35				

One way Analysis of Variance for Pongyaw turbidity at the alum treatment periods

Anova: Single Factor — 0 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	187.5	20.83333	18.195
Column 2	9	176	19.55556	11.47278
Column 3	9	146	16.22222	17.10944
Column 4	9	172.6	19.17778	19.66444

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	102.6564	3	34.2188	2.060081	0.125158	2.90112
Within Groups	531.5333	32	16.61042			
Total	634.1897	35				

Anova: Single Factor — 12 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	98.7	10.96667	6.755
Column 2	9	51.5	5.722222	1.461944
Column 3	9	37.3	4.144444	0.335278
Column 4	9	30.98	3.442222	4.686169

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	312.4014	3	104.1338	31.46419	1.15E-09	2.90112
Within Groups	105.9071	32	3.309598			
Total	418.3086	35				

F3: One way Analysis of Variance for Apaah pH at the moringa treatment periods

Anova: Single Factor 0 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	61.28	6.808889	0.175886
Column 2	9	60.15	6.683333	0.22385
Column 3	9	58.31	6.478889	0.188061
Column 4	9	57.97	6.441111	0.166336

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.814097	3	0.271366	1.439352	0.249586	2.90112
Within Groups	6.033067	32	0.188533			
Total	6.847164	35				

Anova: Single Factor 12 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	59.4	6.6	0.14295
Column 2	9	58.56	6.506667	0.327275
Column 3	9	57.04	6.337778	0.078219
Column 4	9	56.16	6.24	0.168475

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.7116	3	0.2372	1.32344	0.283907	2.90112
Within Groups	5.735356	32	0.17923			
Total	6.446956	35				

One way Analysis of Variance for Apaah pH at the alum treatment periods

Anova: Single Factor 0 hours

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	60.28	6.697778	0.201094
Column 2	9	58.58	6.508889	0.134986
Column 3	9	56.23	6.247778	0.049744
Column 4	9	54.36	6.04	0.01905

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.254631	3	0.751544	7.424944	0.000657	2.90112
Within Groups	3.239	32	0.101219			
Total	5.493631	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	58.6	6.511111	0.162686
Column 2	9	55.41	6.156667	0.07475
Column 3	9	53.46	5.94	0.024275
Column 4	9	51.14	5.682222	0.055019

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.324031	3	1.10801	13.99309	5.34E-06	2.90112
Within Groups	2.533844	32	0.079183			
Total	5.857875	35				

One way Analysis of Variance for Apaah turbidity at the moringa treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	106.7	11.85556	6.025278
Column 2	9	102.9	11.43333	1.91
Column 3	9	89	9.888889	0.473611
Column 4	9	960	106.6667	215.5

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	61719.53	3	20573.18	367.5277	7.31E-25	2.90112
Within Groups	1791.271	32	55.97722			
Total	63510.81	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	78.2	8.688889	4.068611
Column 2	9	67.3	7.477778	2.286944
Column 3	9	57.1	6.344444	0.437778
Column 4	9	55.4	6.155556	0.950278

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.01111	3	12.33704	6.372757	0.001645	2.90112
Within Groups	61.94889	32	1.935903			
Total	98.96	35				

One way Analysis of Variance for Apaah turbidity at the alum treatment period

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	82.3	9.144444	1.370278
Column 2	9	75.9	8.433333	1.99
Column 3	9	56.23	6.247778	0.049744
Column 4	9	68.9	7.655556	1.455278

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	41.5723	3	13.85743	11.39287	3.04E-05	2.90112
Within Groups	38.9224	32	1.216325			
Total	80.4947	35				

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	62.1	6.9	1.82
Column 2	9	50.8	5.644444	0.390278
Column 3	9	47.94	5.326667	4.2299
Column 4	9	38.2	4.244444	0.537778

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.25591	3	10.75197	6.163393	0.001987	2.90112
Within Groups	55.82364	32	1.744489			
Total	88.07956	35				

F4: One way Analysis of Variance for Abrakaso pH at the moringa treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	63.42	7.046667	0.017275
Column 2	9	63.12	7.013333	0.026025
Column 3	9	61.93	6.881111	0.033936
Column 4	9	61.53	6.836667	0.034425

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.2774	3	0.092467	3.312404	0.032298	2.90112
Within Groups	0.893289	32	0.027915			
Total	1.170689	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	62.06	6.895556	0.016453
Column 2	9	60.49	6.721111	0.039986
Column 3	9	58.99	6.554444	0.055003
Column 4	9	56.65	6.294444	0.012978

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.767475	3	0.589158	18.94104	3.02E-07	2.90112
Within Groups	0.995356	32	0.031105			
Total	2.762831	35				

One way Analysis of Variance for Abrakaso pH at the alum treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	57.46	6.384444	0.032678
Column 2	9	55.67	6.185556	0.176378
Column 3	9	54.65	6.072222	0.227619
Column 4	9	53.29	5.921111	0.354936

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.028986	3	0.342995	1.733151	0.179937	2.90112
Within Groups	6.332889	32	0.197903			
Total	7.361875	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	54.06	6.006667	0.02515
Column 2	9	54.16	6.017778	0.163344
Column 3	9	51.64	5.737778	0.169344
Column 4	9	50.9	5.655556	0.280753

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.927156	3	0.309052	1.935834	0.143635	2.90112
Within Groups	5.108733	32	0.159648			
Total	6.035889	35				

One way Analysis of Variance for Abrakaso turbidity at the moringa treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	93.1	10.34444	4.734853
Column 2	9	85.8	9.533333	2.09
Column 3	9	74.5	8.277778	0.609444
Column 4	9	812	90.22222	446.6944

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	44128.25	3	14709.42	129.5616	5.59E-18	2.90112
Within Groups	3633.03	32	113.5322			
Total	47761.28	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	61.1	6.788889	4.633611
Column 2	9	61.7	6.855556	3.047778
Column 3	9	51.9	5.766667	0.8
Column 4	9	41	4.555556	0.205278

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31.45417	3	10.48472	4.827961	0.006963	2.90112
Within Groups	69.49333	32	2.171667			
Total	100.9475	35				

One way Analysis of Variance for Abrakaso turbidity at the alum treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	60.23	6.692222	1.693719
Column 2	9	42.44	4.715556	1.258153
Column 3	9	28.88	3.208889	0.102611
Column 4	9	24.26	2.695556	0.340253

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	86.91328	3	28.97109	34.13649	4.33E-10	2.90112
Within Groups	27.15789	32	0.848684			
Total	114.0712	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	38.22	4.246667	2.20295
Column 2	9	31.7	3.522222	2.099444
Column 3	9	20.79	2.31	0.14665
Column 4	9	14.97	1.663333	0.055375

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	36.65753	3	12.21918	10.85083	4.48E-05	2.90112
Within Groups	36.03536	32	1.126105			
Total	72.69289	35				

F5: Bacterial removal
One way Analysis of Variance for Baasare moringa treatment period

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	189.7785	21.0865	47.39312
Column 2	9	218.1713	24.24125	39.60513
Column 3	9	306.8103	34.09004	76.88107
Column 4	9	324.8282	36.09202	48.34532

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1452.729	3	484.2429	9.126988	0.000164	2.90112
Within Groups	1697.797	32	53.05616			
Total	3150.526	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	285.1031	31.67812	37.51272
Column 2	9	338.5896	37.62106	43.36344
Column 3	9	486.8427	54.09363	65.42451
Column 4	9	550	61.11111	42.36111

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5122.006	3	1707.335	36.19886	2.12E-10	2.90112
Within Groups	1509.294	32	47.16544			
Total	6631.301	35				

One way Analysis of Variance for Baasare alum treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	273.8844	30.4316	193.4666
Column 2	9	324.8389	36.09321	174.1656
Column 3	9	395.0454	43.89394	71.15526
Column 4	9	456.2774	50.69749	103.5466

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2124.943	3	708.3145	5.224193	0.004755	2.90112
Within Groups	4338.673	32	135.5835			
Total	6463.616	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	373.044	41.44933	205.9241
Column 2	9	496.9865	55.22073	25.92669
Column 3	9	647.6364	71.9596	60.24197
Column 4	9	676	75.11111	42.11111

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6613.632	3	2204.544	26.38562	8.78E-09	2.90112
Within Groups	2673.631	32	83.55096			
Total	9287.263	35				

One way Analysis of Variance for Pongyaw moringa treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	83.34034	9.260037	35.96959
Column 2	9	148.5454	16.50504	130.657
Column 3	9	236.193	26.24367	117.8602
Column 4	9	295.6517	32.85018	102.9582

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2931.929	3	977.3097	10.08979	7.85E-05	2.90112
Within Groups	3099.56	32	96.86125			
Total	6031.489	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	245.4066	27.2674	116.5761
Column 2	9	311.6859	34.63176	185.0671
Column 3	9	509.6166	56.62407	53.50118
Column 4	9	610	67.77778	14.69444

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9593.692	3	3197.897	34.58693	3.7E-10	2.90112
Within Groups	2958.71	32	92.4597			
Total	12552.4	35				

One way Analysis of Variance for Pongyaw alum treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	232.9752	25.88613	51.14143
Column 2	9	281.3282	31.25869	69.09833
Column 3	9	384.3389	42.70432	26.55031
Column 4	9	409.9041	45.5449	33.09573

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2343.039	3	781.0129	17.36686	7.14E-07	2.90112
Within Groups	1439.086	32	44.97145			
Total	3782.125	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	485.8376	53.98195	105.7148
Column 2	9	593.1869	65.90966	66.22575
Column 3	9	662	73.55556	38.02778
Column 4	9	724	80.44444	18.02778

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3471.382	3	1157.127	20.30083	1.49E-07	2.90112
Within Groups	1823.969	32	56.99902			
Total	5295.35	35				

One way Analysis of Variance for Apaah moringa treatment periods

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	142.9759	15.88621	79.06142
Column 2	9	191.2078	21.24531	69.62281
Column 3	9	246.5052	27.38947	87.41983
Column 4	9	279.2994	31.03327	96.29047

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1208.948	3	402.9826	4.849449	0.006819	2.90112
Within Groups	2659.156	32	83.09863			
Total	3868.104	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	231.8353	25.75948	68.72344
Column 2	9	353.2955	39.25505	72.97638
Column 3	9	422.5628	46.95142	404.2005
Column 4	9	393.4862	43.72069	74.19947

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2347.756	3	782.5852	5.048125	0.005627	2.90112
Within Groups	4960.798	32	155.0249			
Total	7308.554	35				

One way Analysis of Variance for Apaah alum treatment period

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	196.3748	21.81942	101.3193
Column 2	9	270.286	30.03177	97.60842
Column 3	9	328.7503	36.52781	109.6693
Column 4	9	365.6017	40.62242	103.183

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1819.03	3	606.3433	5.889973	0.00255	2.90112
Within Groups	3294.24	32	102.945			
Total	5113.27	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	299.9184	33.32426	104.1891
Column 2	9	345.4805	38.38672	321.8866
Column 3	9	439.9734	48.88593	126.2506
Column 4	9	460.3073	51.14525	114.4163

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1942.874	3	647.6247	3.885306	0.017828	2.90112
Within Groups	5333.941	32	166.6856			
Total	7276.815	35				

One way Analysis of Variance for Abrakaso moringa treatment period

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	151.9234	16.88037	57.25642
Column 2	9	246.1567	27.35075	144.4881
Column 3	9	297.8329	33.09255	130.7484
Column 4	9	329.4547	36.60608	75.07953

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2008.217	3	669.4057	6.569686	0.00138	2.90112
Within Groups	3260.579	32	101.8931			
Total	5268.796	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	241.0387	26.78208	114.8543
Column 2	9	418.7296	46.52552	23.6113
Column 3	9	484.2025	53.80028	36.79103
Column 4	9	415.2593	46.13992	56.1632

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3614.096	3	1204.699	20.82274	1.15E-07	2.90112
Within Groups	1851.358	32	57.85495			
Total	5465.454	35				

One way Analysis of Variance for Abrakaso alum treatment period

Anova: Single Factor 0 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	212.3585	23.59539	250.0557
Column 2	9	273.1286	30.34762	192.8733
Column 3	9	364.184	40.46489	92.27723
Column 4	9	411.1572	45.68413	69.05619

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2661.51	3	887.17	5.872746	0.002591	2.90112
Within Groups	4834.1	32	151.0656			
Total	7495.609	35				

Anova: Single Factor 12 hrs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	9	301.7593	33.52881	149.5946
Column 2	9	472.4725	52.49695	106.0711
Column 3	9	550	61.11111	42.36111
Column 4	9	662	73.55556	38.02778

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7639.306	3	2546.435	30.30978	1.78E-09	2.90112
Within Groups	2688.437	32	84.01364			
Total	10327.74	35				