INVESTIGATING THE SYNERGISTIC EFFECTS OF *MORINGA OLEIFERA* SEED CAKE EXTRACT AND *OPUNTIA STRICTA* (CACTUS) MUCILAGE IN SURFACE WATER TREATMENT

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DECEMBER, 2016

Declaration

I declare that the work in this dissertation titled "**INVESTIGATING THE SYNERGISTIC EFFECTS OF *MORINGA OLEIFERA* SEED CAKE EXTRACT AND (*OPUNTIA STRICTA*) CACTUS MUCILAGE IN SURFACE WATER TREATMENT**" was carried out by me in the Department of Chemical Engineering, Ahmadu Bello University, Zaria, under the supervision of Dr. Muhammad Abubakar Jaju and Prof. B.O Aderemi of the Department of Chemical Engineering, Ahmadu Bello University, Zaria. The information derived from the literature has been duly acknowledged in the text and a list of reference provided. No part of this dissertation was previously presented for another degree in this University or any other Institution.

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Name of Student	Signature	Date

Certification

This dissertation entitled "**INVESTIGATING THE SYNERGISTIC EFFECTS OF *MORINGA OLEIFERA* SEED CAKE EXTRACT AND (OPUNTIA STRICTA) CACTUS MUCILAGE IN SURFACE WATER TREATMENT**" by Abraham THOMAS, meets the regulations governing the award of the degree of Master of Science (M.sc) in chemical engineering of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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Abstract

This research investigated the synergistic effects of *Moringa oleifera* seed cake extract and*Opuntia stricta*(cactus) mucilage in surface water purification.The synergistic effects of the two coagulants on turbidity,conductivity, total dissolved solid(TDS), pH, chemical oxygen demand (COD),biological oxygen demand (BOD) and bacteria (E.coli)were successively determined. The chemical composition analysis of *Moringa oleifera* and *Opuntia stricta*(cactus) was carried out. *Moringa oleifera* contains 0.70% of K, 0.02% of Na, 0.114% of Ca and 0.074% of Mg while*Opuntia stricta*(cactus) contains 0.35% of K, 0.18% of Na, 1.522% of Ca and 0.083% of Mg. For raw surface water with turbidity of 44 NTU, the optimum doses of *Moringa oleifera* and *Opuntia stricta*(cactus)were found to be, 3 mL and 2 mL respectively. Using *Moringa oleifera and Opuntia stricta*(cactus) 88.6%, and 42.7% reduction in turbidity was achieved, respectively after coagulation. Also, 86.1% turbidity reduction was recorded for the blend of cactus mucilage and*Moringa oleifera* at blending ratio of 40:60.The conductivity and TDS of *Moringa oleifera* water treatment increased from 80.6 to 154.3 µS/cm andfrom 42.6 to 92.8 mg/L respectively. The conductivity and TDS of cactus mucilage water treatment increased from 115.2 to 171.1 µS/cm and from 69.4 to 113 mg/L respectively. The blend of *Moringa oleifera* andcactus mucilage treatment increased the conductivity and TDS of the water from 109.8 to 112.8 µS/cm and from 66.1 to 68.1 mg/L respectively.*Moringa oleifera* increased the pH of the surface water from 6.69 to 7.1 while *Opuntia stricta* (cactus) reduced the pH from 6.69 to 5.9. The pH for the blend of *Moringa oleifera* and cactus mucilage was from 6.57 to 6.65. The highest percentage synergistic effects for the blend of *Moringa oleifera* and*Opuntia stricta*(cactus) on COD and BOD was recorded to be 77.1% and 64.9% respectively. Bacterial count was reduced from 82 cells per 100 ml to 7 cells per 100 ml for *Moringa*, to4 cells per 100 ml for cactus and to 2 cells per 100 ml for the blend. On the other hand, the elongation of the coagulated treated surface water with *Moringa oleifera*, *Opuntia stricta*(cactus) and the blend*Moringa oleifera* and*Opuntia stricta*(cactus) were 3 days, 3 days and 5 days, respectively.

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List of Abbreviations and Notations

$a-a'$ = distance of colloidal particle

Al*opt* = optimum alum dose

APHA = American Public Health Association

ABUD = Ahmadu Bello University Dam

AWWA = American Water Works Association

BGLB = brilliant green lactose broth

BOD = biochemical oxygen demand (mg/L)

CFU = coliform faecal unit

COD = chemical oxygen demand (mg/L)

CST = capillary suction time (s)

DBP = disinfection by-product

DO = dissolved oxygen (mg/L)

DO_F = final dissolved-oxygen concentrations (mg/L)

DO_I = initial dissolved-oxygen concentrations (mg/L)

EDTA = ethylenediamine tetraacetic acid

EBCT = empty bed contact time (s)

EC = electrical conductivity, µS (microsiemens)

EPA = Environmental Protection Agency

G = mean velocity gradient (m/s)

GAC = granular activated carbon

*K*ow = water solubility and octanol/water partition coefficient

MPN = most probable number

MTF = multiple tube fermentation

N = particle concentration at any time t (mol./dm^3)

N_O = initial particle concentration (mol./dm^3)

NOM = natural organic matter

NTU = nephelometric turbidity unit(s)

P = fractional purity

PAC = polyaluminium chloride

PAM = meningoencephalitis

PASS = poly-aluminum silico sulphate

π = pie (3.14)

ppm = parts per million

£ = pound

N = naira

KSWB = Kaduna State Water Board

KSWC = Kwara State Water Corporation

rpm = revolutions per minute

SG = specific gravity

sp_{Al} = represent all the species that contain aluminum atom standing in solution

SRF = specific resistance to filtration

t = time (s)

TDS = total dissolved solids (mg/L)

THM = trihalomethane

TOC = total organic carbon (mg/L)

TOD = total oxygen demand (mg/L)

ThOD = threshold odour

UV = ultra-violet

WPCF = Water Pollution control Federation

WHO = World Health Organization

WREE = Water Resources and Environmental Engineering

CHAPTER ONE

INTRODUCTION

1.1 Preamble

Unprotected water sources such as ground water and surface water receive pollutants from surface runoff. The pollutants from surface runoff are waste from sewage and industries among others. Despite the improvement in water treatment processes, it is untenable and unbelievable under all situations that waterborne diseases still kill on the average of 22,000 people every day in developing countries while millions suffer the debilitating effects of these diseases (WHO, 2011). Children bear the greatest health burden associated with unsafe water supplies through preventable diseases like diarrhoea. In developing countries about 2 million people die every year due to diarrhoeal disease; most are children of less than 5 years of age (WHO, 2011). Other water related diseases reported in Nigeria are trachoma, schistosomiasis, ascariasis, trichuriasis, ancylostomiasis (hookworm), malaria and encephalitis (Sridhar and Oloruntoba, 2008). Therefore, water from all sources must have some form of purification before consumption because portable water should be free from contaminants.

Various methods are used to make water safe and attractive to the consumer. The method employed depends on the characteristic of the raw water. The common methods of household water treatment require coagulation / flocculation followed by sedimentation, filtration and disinfection. Several coagulants have been used in conventional water treatment processes for portable water production. These coagulants can be classified into inorganic, synthetic organic polymer and naturally occurring coagulants (Okuda *et al.,* 2000). Synthetic polyelectrolytes are used as primary coagulants as well as coagulant aid to improve the strength of particles

aggregates, enhance coagulation and deposition (filtration). Naturally occurring coagulants are presumed safe for human health while there is a fear that inorganic may induce Alzheimer's disease(Miller *et al*1984). Coagulation is an essential process in the treatment of both surface water and industrial waste water. Its application includes removal of dissolved chemical species and turbidity from water, via addition of conventional chemical-based coagulants, namely, alum (Aluminium sulphate), ferric chloride ($FeCl_3$) and polyaluminium chloride (PAC). While the effectiveness of these chemicals as coagulants is well-recognized, there are, nonetheless, disadvantages associated with usage of these coagulants such as ineffectiveness in low-temperature water, relatively high procurement costs, detrimental effects on human health, production of large sludge volumes and the fact that they significantly affect pH of treated water (Najm *et al.*,1998). Also, there is fear that aluminum may induce strong carcinogenic properties (Crapper *et al.,* 1973; Malleavialle *et al.,* 1984).

Natural coagulants from vegetable and mineral origin were in use in water treatment before the advent of chemical salts, but they have not been able to compete effectively because of the fact that a scientific understanding of their effectiveness and mechanism of action was lacking. Thus far, use of natural coagulants has been discouraged without any scientific evaluation (Peter and Sue, 2009). They have succumbed progressively under modernization and survived only in remote areas of some developing countries. Recently, however, there has been a resurgence of interest in natural coagulants for water treatment in developing countries (Ndabigengesere and Narasiah, 1998; Fahey, 2005).

There is evidence that the use of extracts from plant species possessing both coagulating and antimicrobial properties are safe for human health (Muyibi and Okuofu, 1995; Okuda *et al.*,2000; Ali *et al.*,2004); Akinnibosun *etal.*,2009). It is therefore desirable to replace these chemical

coagulants with plant-based coagulants to counteract the aforementioned drawbacks. The advantages of using natural plant-based coagulants as point- of- use (POU) water treatment material are apparent; they are cost effective, unlikely to produce treated water with natural synthetic difference in pH and are highly biodegradable. Most studies show that residual turbidities in water treated with cactus flocculants were still too high for applications in potable water production. This shows that additional optimization and possible further treatment may be necessary prior to the direct application of cactus mucilage as a coagulant in drinking water treatment. Increased removal could be achieved either by the use of a secondary treatment, such as a coarse filter, or possibly by adding a second dosage of flocculant. Of the large number of plant materials that have been used over the years, the seeds from *Moringa oleifera* have been shown to be one of the most effective primary coagulants for water treatment especially in rural communities (Folkard *et al.*,2000; Doer, 2005; Onwuliri and Dawang, 2006). The active ingredient for coagulation in *Moringa* is cationic protein and iso-electric point of between 10 and 11 whereas the active ingredient in cactus mucilage consist of negatively charge ions containing arabinose, xylose,galacturonic acid, galactose and rhamnose. The presence of uronic acids gives the mucilage an overall negative charge (Ndabigengesere *et al.*,1995; Goycoolea and Cardenas, 2003). Thus, combining *Moringa* and cactus may lead to attraction thereby leading to more coagulation activity. While separate studies have been conducted on identifying the antibacterial activity of *Moringa oleifera* and cactus, little work was reported to elucidate their combined bactericidal effects (Fox*et al.*, 2012). This study is based on the hypothesis that a solution of these two antibacterial agents together will have a greater range of bactericidal activity than solutions of the individual biocides.

The present research investigates the proximate profiles of *Moringa oleifera* seeds and cactus mucilage and the synergistic effect of their blend in surface water treatment.

1.2 Research Problem Statement

In developing countries (including Nigeria), water treatment agencies such as states water works, and regulatory agencies face a lot of problems. For instance, conventional water treatment uses chemicals that cause Alzheimer's disease and the sludge produced is not only voluminous but also non-biodegradable after treatment. A lot of research works on the potential of *Moringa oleifera* and *Opuntia stricta* (cactus) as substitute conventional water treatment chemicals have been reported. The various findings indicated that *Moringa oleifera* performed satisfactorily in reducing water turbidity to acceptable level, but found ineffective in microbial count reduction with rapid microbial regrowth; while cactus on the other hand showed less ability in terms of turbidity control but effective in microbial control property. However, little work has been reported on surface water treatment with *Moringa oleifera* and cactus mucilage blend.

1.3 Research Justification

Moringa oleifera and cactus are biodegradable, abundant and easily available. Moreover,*Opuntiastricta* (cactus) is a local plant species which is fast growing with high yield of mucilage. There is evidence that the use of extracts from plant species in water treatment possess both coagulating and antimicrobial properties.Naturally occurring coagulants are usually presumed safe for human health. Also, Production of biocompost/ bio-fertilizer from sludge produced after treatment with natural coagulants.

1.4Aim and Objectives

The aim of this research is to investigate the synergistic effect of processed *Moringa*seed cake extract with opuntia *stricta*(cactus) Mucilage in surface water treatment.

The specific objectives are to:

1. Extract and characterize*Moringa oleifera* seed cake extract and *opuntiastricta*(cactus) mucilage using FTIR
2. Investigate the coagulation effect of *Moringa oleifera* seed cake extract with respect to surface water on turbidity,conductivity,TDS,pH, COD, BOD and bacteria (coliform count).
3. Study the effectiveness of*opuntiastricta*(cactus) mucilage on the turbidity,conductivity,TDS,pH, COD, BOD and bacteria (coliform count) content of surface water.
4. Investigate the coagulation effect of *Moringa oleifera* seed cake extract and cactus blend onturbidity,conductivity,TDS,pH, COD, BOD and bacteria (coliform count).
5. Study the elongation of the coagulated treated surface water.

1.5 Research Scope

The research was limited to the extraction and characterization of*Opuntia* stricta(cactus) and *Moringa oleifera*. The study was also limited to the determination of the effectiveness of *Moringa oleifera* seed cake extract,*Opuntiastricta* (cactus) mucilage and blends of the duo in the treatment of surface water.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Water treatment companies in developing countries face a myriad of problems. Some of these are, high cost of water treatment chemicals which constitute between 35 to 70% of recurrent expenditure, inadequate supply of chemicals for water treatment, inadequate funding, low revenue base, inadequate skilled manpower, poor operational and maintenance schedules, adoption of inappropriate technology. The effects of some of these problems are, supply of inadequate water and poor quality water, and the frequent breakdown of plant and equipment (Muyibi, 1995). Therefore, it is so important to think about this problem seriously and try to solve it by understanding the processing, the materials used, its availability, and how far the economy of developing countries can bear the costs of the chemicals needed for water processing, and what alternative chemicals can be sourced or developed to replace and or complement the existing water treatment chemicals.

Coagulation-flocculation followed by sedimentation, filtration and disinfection, often by chlorine, is used worldwide in the water treatment industry before distribution of treated water to consumers (Ndabigengesere and Narasiah, 1998). Many coagulants are widely used in conventional water treatment processes for potable water production. These coagulants can be classified into inorganic coagulant, synthetic organic polymer and naturally occurring coagulant. Synthetic polyelectrolytes are used as primary coagulant as well as coagulant aid to improve the strength of particle aggregates, enhance coagulation and deposition (filtration) (Muyibi, *et al.*, 2001). These coagulants are used for various purposes depending on their chemical

characteristics. An inorganic polymer “PAC” (poly-aluminium chloride), poly-aluminium silico-sulphate (PASS) Ndabigengesere and Narasiah, (1998), and inorganic salt “alum” (aluminium salt) are the most widely used coagulants in water treatment (Van Benchosten and Edzwald, 1990; Boisvert *et al*., 1990; Najm *et al*., 1998). Recently, synthetic organic polymers became widely used for water treatment (Robinson, 1979; Teh and Ghosh, 1981; Lee *et al*., 1998).

Naturally occurring coagulants are usually presumed safe for human health. Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from micro-organisms, animals or plants (Kawamura, 1991; Lee *et al*., 1995; Ganjidoust *et al*., 1997).

Natural coagulants from vegetable and mineral origin were in use in water treatment before the advent of chemical salts, but they have not been able to compete effectively because of the fact that a scientific understanding of their effectiveness and mechanism of action was lacking. Thus far, use of natural coagulants has been discouraged without any scientific evaluation. They have succumbed progressively under modernization and survived only in remote areas of some developing countries. Recently, however, there has been a resurgence of interest in natural coagulants for water treatment in developing countries (Ndabigengesere and Narasiah, 1998).

2.2 Water Treatment Problems in Developing Countries

The cost of chemicals used in water treatment has been increasing at an alarming rate for the developing countries and most of the water treatment companies cannot cope with the high costs due to declining revenues and funding coupled with the inability of local supplies to satisfy the demand, and due to the foreign exchange problem for imported chemicals (Muyibi, 1994). In addition to alum, lime is also added to raise the pH of the water in situations where high

concentrations of alum are needed, thereby facilitating the treatment (Muyibi and Okuofu, 1995), and this is an extra cost that developing countries are finding difficult to cope with. For example, in Nigeria, big municipalities like Ibadan and Kano are spending 42 % and 65 % of their annual recurrent costs respectively, on water supply (Muyibi and Okuofu, 1995).

Furthermore, there is a fear that aluminium (the major component of Polyaluminium chloride (PAC) and alum) may induce Alzheimer's disease (Crapper *et al.*, 1973; Miller *et al.*, 1984; Martyn *et al.*, 1989), strong carcinogenic properties (Dearfield *et al.*, 1964; Mccollister *et al.*, 1964; Mallevialle *et al.*, 1984). Synthetic polymers may contain contaminant formulations during the manufacturing process, such as acrylamide and epichlorohydrin, which are all residual (un-reacted) monomers, are known to be carcinogenic, whilst acrylamide is a neuro-toxin that may accumulate with continuous ingestion. Aluminium has also been indicated to be a causative agent in neurological diseases such as pre-senile dementia (Mallevialle *et al.*, 1984). There is also the problem of reaction of alum with natural alkalinity present in water leading to reduction of pH and a low efficiency in coagulation of cold waters (Ndabigengesere and Narasiah, 1998). Besides that, using alum produce large sludge volumes (Ndabigengesere and Narasiah, 1997; Muyibi and Alfugara, 2003).

Moringa oleifera seed crude extract is used instead of alumin Sudan by rural women to treat highly turbid Nile water because of a traditional fear of alum, which is believed to cause gastro-intestinal disturbances due to overdosing with the resultant fear of possible abortions in pregnant women (Jahn, 1988).

The use of alum (aluminium salts) may also lead to increase concentrations of aluminium ions (Al), which leads to water quality and supply problems (Miller,*et al* 1984). Supply problems associated with increased Aluminium concentrations include formation of hydrous Aluminium

precipitate in the distribution system that may increase the turbidity as well as decrease the carrying capacity of the pipes. Aluminium floc in the system may also interfere with the disinfection process (residual chlorine) by protecting the micro-organisms.

Ferric salts and synthetic polymers have also been used as coagulants but with limited success because of the same disadvantages manifested in the use of aluminium salts. In addition to these problems, chemicals used for water treatment in developing countries constitute a high percentage of annual running expenditure of water treatment companies (Muyibi, 1994). Local companies are not manufacturing them in adequate quantities due to demand for these chemicals in other industrial applications. Therefore the shortfall has to be imported using scarce convertible foreign currency. These problems force many water treatment companies to resort to under-dosing of chemicals so as to meet the increasing water demand. The result is to supply low quality water, especially during the rainy season, when suspended solids and other polluted loads in surface water are very high (Muyibi,*et al.,* 2003).

In these circumstances, many water supply companies tend to under dose the chemicals, resulting in the production of low quality drinking water. Such under dosing is inevitable if the water authorities are to meet the water requirements of their teeming population. Therefore, where cheaper alternatives can be found, to replace or supplement the conventional treatment chemicals, their use would be a welcome benefit for the developing countries. The use of a natural plant material like *Moringa oleifera* either as a primary coagulant or as coagulant aid would therefore help ameliorate the economic situation (Muyibi and Evison, 1995).

2.3Naturally Occurring Coagulants

Natural coagulants from plant families, such as *Capparidaceae* and *Papilionaceae*,have been traditionally used to clean water in private households. Branches and bark of *Boscia senegalensis* of the *Capparidaceae* family for example, have been added to the water for clarification. In Egypt and North Sudan, seeds of Papilioaceae including the genera Phaseolus (various bean cultivars), Pisum (peas), Arachis (peanuts), and Lupinus (lupines) are used, although their clarifying effect are low. Naturally occurring coagulants are usually presumed safe for human health. Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from micro-organisms, animals or plants. Natural coagulants from vegetable and mineral origin were used for water treatment before knowing of chemical salts. They have not been able to compete effectively because of the fact that a scientific understanding of their effectiveness and mechanism of action is still lacking. One of these alternatives is *Moringa oleifera (Zogale)* seeds.

There are about 250,000 higher plants species on earth, out of these, more than 80,000 are medicinal (Joy *et al.,* 1998). Sofowora, (1993) reported that Africa has as much as 300, 000 medicinal plants. Historical accounts of traditionally used medicinal plants depict that different medicinal plants were in use as early as 5000 to 4000 BC in China, and 1600 BC by Syrians, Babylonians, Hebrews and Egyptians (Dery *et al.,* 1999). Considerable indigenous knowledge system, from the earliest times, is found linked with the use of traditional medicine in different countries (Farnsworth, 1994).

Beyond their human health and livestock treatments plants have been used historically for water treatment and there is evidence to suggest that communities in the developing world have used plant based materials as one strategy for purifying drinking water (Sarah *etal*., 2008). Therefore,

natural coagulants and disinfectants can play a vital role for water sector that facing challenge today on how to give more people access to clean drinking water by cost effective means, especially the rural poor who cannot afford any water treatment chemicals, without affecting the health of their environment (Davy, 2001).

2.3.1 Plant parts used to treat turbid water

Natural plant extracts have been used for water purification for many centuries. Most of these extracts are derived from the seeds, leaves, pieces of bark or sap, roots and fruit extracts of trees (Pritchard *et al*., 2010). In the review, the highest number of species 22 (55%) were reported to be used for their seeds these were followed by leaves 7(17.5%), fruits 6(15%) and 5 others (calyx, flower, pod and bark) representing 12.5% (Table 2.1).

Table 2.1.List of plant species used as coagulants and disinfectants.

Scientific name	Family	Genera	Plant parts	Habit	Reference	Uses
Moringa oleifera	Moringaceae	Moringa	Seed	Tree	Ndabigengesere *et al.*, 1995 Ghebremichael *et al*., 2005	Coagulation and Disinfection
Phaseolus vulgaris	Fabaceae	Phaseolus	Seed	Herb	Sciban *et al*., 2006	Coagulation
Opuntia ficus indica Mill.	Cactaceae	Opuntia	Leaves	Shrub	Shlipa *et al*., 2012 *Zhang et al.,* 2006	Coagulation and disinfection
Opuntia stricta	Cactaceae	Opuntia	Leaves		Alcantar et al., 2007	Coagulation and disinfection
Dolichos Lablab	Fabaceae	Lablab	Fruit	Herb	*Zhang et al.,* 2006	Disinfection
Senna alata Roxb.	Fabaceae	Senna	Leaves	Shrub	Aweng *et al*., 2012	Coagulation
Castanea sativa Mill.	Fagaceae	Castanea	Seeds	Tree	Sciban *et al*., 2009	
Coccinia indica (L.) Voight	Cucurbitaceae	Coccinia	Fruits	Vine	Patale and Pandya, 2012	Coagulation
Cicer arietinum L.	Fabaceae	Cicer	Seeds	Herb	Choubey *et al*., 2012	Coagulation and Disinfection
Phoenix spp.	Arecaceae	Phoenix	Seeds	Tree	Alsemirey, 2012	Coagulation
Azadirachta indica A.Juss.	Meliaceae	Azadirachta	Fruit	Tree	Sowmeyan *et al*., 2011	Coagulation
Luffa cylinderca M.Roem.	Cucurbitaceae	Luffa	Fruit	Vine	Sowmeyan *et al*., 2011	Coagulation
Aloe barbadensis Mill.	Alloaceae	Aloe	Seeds	Herb	Yongabi *et al*., 2011a	Coagulation and Disinfection
Jatropha curcas L.	Euphorbiaceae	Jatropha	Seeds	Tree	Yongabi *et al*.,	Coagulation and

					2011b	Disinfection
Citrus aurantifolia (Chrism.) Swingle	Rutaceae	Citrus	Fruit	Tree	Yongabi *et al*., 2011b	Coagulation and Disinfection
Hibiscus sabdarifa L.	Malvaceae	Hibiscus	Calyx	Herb	Yongabi *et al*., 2011b	Coagulation and Disinfection
Garcinia kola Heckel	Guttiferae	Garcinia	Seeds	Herb	Qureshi *et al*., 2011	Coagulation and Disinfection
Carica papaya L.	Caricaceae	Carica	Seeds	Tree	Qureshi *et al*., 2011	Coagulation and Disinfection
Mangifera Indica L.	Anacardaceae	Mangifera	Fruit	Tree	Qureshi *et al*., 2011	Coagulation
Parkinsonia aculeata L.	Fabaceae	Parkinsonia	Seed	Tree	Marhobe and Gunaratna 2012	Coagulation and disinfection
Vigna unguiculata (L.) Verdc.	Fabaceae	Vigna	Seed	Herb	Yongabi *et al*., 2011a	Disinfection
Trigonella foenum-graecum L.	Fabaceae	Trigonella	Seed	Tree	Ramamurthy *et al*., 2012	Coagulation
Strychnos potatorum	Loganiaceae	Strychnos	Seed	Tree	Ramamurthy *et al*., 2012	Coagulation
Cyamopsis tetragono	Fabaceae	Cyamopsis	Seed	Herb	Pritchard *et al*., 2009	Coagulation and Disinfection
Zea mays L.	Poaceae	Zea	Seed	Herb	Guranatra *et al*., 2007	Coagulation
Abelmoschus esculentus (Moench)	Malvaceae	Abelmoschus	Gum	Herb	Renuka *et al.,* 2013	Coagulation
Manihot esculenta crantz	Euphorbiaceae	Manihot	Root	Shrub	Vara, 2012	Coagulation and Disinfection
Ocimum sanctum L.	Lamiaceae	Ocimum	Leaves	Shrub	Sunil *et al*. 2011	Disinfection

Protein is reported to be the main component responsible for coagulation-flocculation process thus studies reported that seed is the place where high level of protein is accumulated (Booth *et al*., 2010). For instance seeds of *Moringa oleifera, Caricapapaya* and *Dolichos lablab are* reported to have coagulation and disinfection activities (Yongabi, 2011b) and seeds are frequently cited plant parts used in water treatment. However, other plant parts are also used like leaves of *Solanum incunum* and *Ocimum sanctum* (Kihampa *et al*., 2011). According to Amagloh and Benang, (2009) mature seed extracts of *Moringa oleifera* are more effective in turbid waters than immature seed extracts.

2.3.2 Performance of plant species on turbidity

It was reported in various literature that plant species have capability of turbidity reduction though their performance varies. The dosage required depends on turbidity ranges mean that as initial turbidity of water sample increased, the required optimum dosage of coagulant also increased (Katayon *et al*., 2006). All of the reported natural coagulants were more efficient in higher turbidity ranges than lower and medium turbidity waters either in artificially prepared or natural turbid raw water including surface and ground water (Nkurunziza *et al*., 2009; Asraffuzaman *et al*., 2011, Kihampa *et al*., 2011, Yongabi *et al*., 2011; Mangale *et al*., 2012a; Mangale *et al*., 2012b). The residual turbidity decreases to a certain dosage of natural coagulants, which is referred to as the optimized dose and above the optimum results in increased turbidity (Blix, 2011). For example, the result of (Kihampa *et al*. 2011) showed the extracted dose of *Solanum incanum* displayed an optimal dose of 2 ml (2×10^{-5} g/ml) for treating turbid water samples of initial turbidities of 450, 300 and 105 NTU. The corresponding average percentage removals were 99.78, 99.11 and 97.14 at residue turbidities of 1, 2.67 and 3 NTU, respectively

and Shilpa *et al*., (2012) reported the optimum dosage of *Opuntia ficus indica* and *Dolichos lablab* to be 20mg/L, removal efficiency was found to be 89.03% and 77.10% respectively.

Increasing dosage of coagulants beyond certain limit do not improve on the reduction of turbidity; in fact, its increase the residual turbidity of the coagulated sample water significantly(Katayon *et al*., 2006). Muyibi and Evison, (1995) explained that as overdosing resulted in the saturation of the polymer bridge sites and caused restabilization of the destabilized particles due to insufficient number of particles to form more interparticle bridges.

2.3.3 Performance of plant species against bacteria

Plant species also showed promising result in antimicrobial effect. Comparing with coagulation properties of plant species, little is known about the potential existence of natural disinfectants (i.e., substances with the ability to kill or inactivate pathogenic microorganisms), even though many herbs and plant extracts are used in traditional medicine and as pesticides in developing countries (Robert *et al*., 2009). Researchers reported antimicrobial activity of *Dolichos lablab, Moringaoleifera, Azadirachta indica* and other plant species (Table 2.1). Yongabi *et al.*,(2011) found that *Moringaoleifera, Jatropha curcas* and *Hibiscus* showed a better coagulation and disinfection activity with the methanol extracts. The antimicrobial effect could be attributed to both flocculation (Nwaiwu and Lingmu, 2011) and bactericidal action (Oluduro *et al*., 2010).

2.3.4 Active component of the plant materials

In coagulation and disinfection, a substantial number of active compounds have been isolated from various parts of plant species. Even researchers tried to investigate the specific part where the active agent is located. For instance, Ndabigengesere *et al*., (1995) reported that the active agents of *Moringa oliefera* are located in the seed kernel rather than seed bark.

Sarah *et al*. (2008) in their study on Oppuntia spp. found that the active agents are located in whole pads without skin of the cactus. Thus, isolating the active component is critical not only to understand the coagulation mechanism, but also to develop pretreatment practices for potential field implementation (Sarah *etal*., 2008). The coagulation mechanism of *Moringaoliefera* was reported to be through charge neutralization (Ndabigengesere *et al*., 1995) whereas the predominant coagulation mechanism for *Opuntia* spp. is adsorption and bridging, whereby clay particles do not directly contact one another but are bound to a polymer-like material form (Sarah *et al*., 2008).

The active coagulating component can be extracted from the plant parts and used in pure or semi pure form, thus reducing the total amount of organic material added to the treatment process which may resulting in the possibility for undesired and increased microbial activity (Ghebremichael *et al*., 2005; Sarah *et al*., 2008). The chemical composition of the active coagulating agent of *Moringa oleifera* has been debated (Sarah *et al*., 2008) for instance water extraction of *Moringa oleifera* has been shown that the active agent in extracts is cationic proteins that harbors very good coagulation properties which is used in extremely low dosages than that used for crude seed extract.Ndabigengesere *et al*., (1995) and Gassenschmidt *et al*., (1995) identified the active component cationic peptides of molecular weight ranging from 6 to 16 kDa and isoelectric pH value of 10. Whereas Okuda *et al*., (2001) reported that the active component from an aqueous salt extraction was not a protein, polysaccharide or lipid, but an organic polyelectrolyte with molecular weight of about 3.0 kDa. However, Ghebremichael *et al*., (2005) determine that both water and salt extract are cationic proteins with molecular weights less than 6.5 kDa. This suggests that the water and salt extract may be of different nature (Ghebremichael *et al*., 2005).

The active agent of other species other than *Moringa oleifera* was also identified by Sarah *et al*., (2008),they come up with a result that mucilage is suspectedactive agent which contribute to the coagulationbehavior of *Opuntia* spp. Moreover, they reportedthat the galacturonic acid can be a component whichplays a role in turbidity reduction by *Opuntia* spp.and independently, arabinose, galactose, andrhamnose were displayed no coagulation activity;however, added in combination with galacturonicacid, these sugars were able to reduce turbiditybetween 30% and 50%. Galacturonic acid addedindependently was able to reduce turbidity by morethan 50%.

Comparing salt and water extracts, Gunaratna *et al*. (2007) and Sarpong and Richardson (2010) reported that salt extraction of powdered *Moringa oleifera* seeds substantially improves overall coagulation efficiency than water extract and Gunaratna *et al*., (2007) explained the possibility of having high coagulation activity is due to the fact that salt is thought to associate with opposite charged groups in the protein.

2.3.5 Purification of natural coagulants

The limitation of natural coagulants and disinfectants include organic load and residual (storage). Therefore, Purification of natural coagulants is vital in order to reduce organic load (Ndabigengesere *etal*., 1995; Ghebremichael *et al*., 2005) and helps to use in a large scale because of the fact that the crude extract is not generally suitable for large water supply systems where the hydraulic residence time is very high (Ghebremichael *et al*., 2005) and this is indicated in the result of Katayon *et al*., (2006) who reported coagulation efficiency of *Moringa oleifera* decreased as storage duration increased.

Another disadvantage of natural coagulants for example *Moringa oliefera* is its efficacy only for highly turbid water (Gunaratna *et al*., 2007). Therefore, active agents should be purified and characterized using different techniques, namely dialysis, ultrafiltration, lyophilisation, ion-

exchange, chemical precipitation, SDS-PAGE and electrophoresis (Ndabigengesere *et al*., 1995). Isolating the active component is critical not only to understand the coagulation mechanism, but also to develop pretreatment practices for potential field implementation (Sarah *et al*., 2008).

Ghebremichael *et al*. (2005) came up with a simple and rapid method of extraction and purification of *Moringa oliefera* coagulating proteins. They purified using High-trap CM FF 1 mL cation exchanger column on an Akta explorer (Pharmacia Biotech) and *Moringa oleifera* cake powder (MOCP) is highly thermostable and reduces microbial populations.

A study on purification of the coagulant protein from *Moringa oleifera* seed by single step ion exchange by Ghebremichael *et al*., (2005) was able to reduce COD values of 12 000 mg/L to 96 % after purification.

2.3.6 Advantages of plant coagulants and disinfectants

Natural coagulants and disinfectants have enormous advantages in water treatment. Natural coagulants produce less sludge volume compared with Alum (Ndabigengesere *et al*., 1995; Blix, 2011) and they require no pH adjustment (Ndabigengesere *et al*., 1995). They are great interest for low cost water treatment (Ghebremichael *et al*., 2005) and help to provide pure water for world population especially for developing countries who hardly get pure water and an additional benefit of using coagulants derived from natural products like *Moringa oleifera,* is that a number of useful products may be extracted from the seed. In particular, edible and other useful oils may be extracted before the coagulant is fractionated. Residual solids may be used as animal feed and fertilizer, while the shell of the seed may be activated and used as an adsorbent. The coagulant is thus obtained at extremely low or zero net cost (Ghebremichael *et al*., 2005).

Usage of natural products also reduces the formation of disinfectants that deteriorate human health and their by-products are organic and biodegradable and reduced risk of handling (Ndabigengesere *et al*., 1995; Yongabi *et al*., 2011). Moreover, Grabow *et al.* (1985) indicated that use of *Moringa oleifera* as a primary coagulant does not pose a human health threat.

2.4 Natural Plant-Based Coagulants and Coagulation Mechanisms

Polymeric coagulants can be either cationic, anionic or nonionic, in which the former two are collectively termed as polyelectrolytes(Bolto *et al*., 2007). Many studies concerning natural coagulants referred to them as 'polyelectrolytes' even though many of these studies did not actually conduct in-depth chemical characterization to determine their ionic activity. As such, this term should be used carefully, and be applied only after ionic activity is determined to be present in the coagulant. Natural coagulants are mostly either polysaccharides or proteins. In many cases, even though polymers labeled as non-ionic are not necessarily absent of charged interactions, as there may be interactions between the polymer and a solvent within a solution environment as the polymer may contain partially charged groups including –OH along its chain.

It is imperative to fully grasp the underlying coagulation mechanisms associated with these natural coagulants so that complete understanding of their usage can be realized. Aggregation of particulates in a solution can occur via four classic coagulation mechanisms: double layer compression, adsorption, charge neutralization, sweep flocculation and interparticle bridging (Crittenden *et al*., 2005). The presence of salts or suitable coagulants can cause compression of the double layer which destabilizes the particulates(Packham *et al*., 2010). Sweep flocculation occurs when a coagulant encapsulates suspended particulates in a soft colloidal floc. Adsorption and charge neutralization refer to the sorption of two particulates with oppositely charged ions while interparticle bridging occurswhena coagulant provides a polymeric chain which sorbs

particulates(Miller*et al*.,2008). Polymeric coagulants are generally associated with mechanisms adsorption, charge neutralization and interparticle bridging as their long-chained structures (especially polymers with high molecular weights) greatly increase the number of unoccupied adsorption sites. It appears that these two mechanisms provide underlying principles to the inner workings of organic coagulants as well and they are the focus of discussion in the following sections. The existence of background electrolytes in aqueous medium can facilitate the coagulating effect of polymeric coagulants since there is lesser electrostatic repulsion between particles. Although many plant coagulants have been reported, only four types are generally well-known within the scientific community, namely, nirmali seeds (Strychnos potatorum), Moringa oleifera, tannin and cactus.

2.4.1 Nirmali seeds

Strychnos potatorum (nirmali) is a moderate-sized tree found in Southern and central parts of India, Sri Lanka and Burma, used predominantly as a traditional medicinal extract(Jayaram *et al*., 2009). Sanskrit writings from India reported that the seeds were used to clarify turbid surface water over 4000 years ago which indicated that they were the first reported plant-based coagulant used for water treatment(Shultz *et al*., 1984). Most studies concerning its use as coagulant seem to be limited within the Indian subcontinent(Sarawgi *et al*., 2009). Nirmali seed extracts are anionic polyelectrolytes that destabilize particles in water by means of interparticle bridging(Tripathi *et al*., 1976). Previous studies by Tripathi *et al*.(1976) have established that the seed extracts also contain lipids, carbohydrates and alkaloids containing the –COOH and free –OH surface groups which enhance the extracts' coagulation capability. Adinolfi *et al*.(2010) reported that a mixture of polysaccharide fraction extracted from S. potatorum seeds contained galactomannan and galactan capable of reducing up to 80% turbidity of kaolin solution. In all

cases, the galactomannans are made up of a main chain of 1,4-linked -d-mannopyranosyl residues bearing terminal -d-galactopyranosyl units linked at the 0–6 position of some mannose residues(Corsaro *et al*., 1995). Although the specific coagulation mechanism associated with nirmali seed extracts has not been extensively investigated, one can surmise that the presence of copious amount of –OH groups along chains of galactomannan and galactan provides weakly but abundant adsorption sites that ultimately lead to the aforesaid coagulant interparticle bridging effect. Since both ionic (–COO−H+) and comparatively non-ionic (galactomannan) groups or substances are suggested to be present in the extract, the author deems that its designation as 'anionic polyelectrolytes' is premature, as there are no identified studies that provide detailed elucidation of its coagulation mechanisms and percentage composition of the extract. As such, further studies are required in this aspect.

2.4.2 *Moringa oleifera*

Moringa oleifera (horseradish or drumstick tree), a non-toxic (at low concentrations) tropical plant found throughout India, Asia, sub Saharan Africa and Latin America(Jahn *et al*., 1988) whose seeds contain an edible oil and water soluble substance(Ndabigengesere *et al*., 1995), is arguably the most studied natural coagulant within the environmental scientific community. It is widely acknowledged as a plant with numerous uses with almost every part of its plant system can be utilized for beneficial purposes. Moringa is most frequently used as food and medicinal sources within less-developed communities. A succinct summary of its various uses afforded by its different plant parts such as leaves, flowers, seeds, roots and bark is provided by Anwar *et al*.(2003). It has been reported that rural communities in African countries utilize its crude seed extracts to clear turbid river water.

Since then, there has been several studiesMuyibi *et al*.(1995) conducted to optimize its usage as low-cost water treatment technology, with emphasis on application within the African continent. However, research on natural coagulants in the 80s and early 90s was still scarce as information on their efficacies had been limited to anecdotal reports and few academic journal articles.

The seminal paper by Ndabigengesere *et al*.(1995) is the first literature that comprehensively elucidates the basic coagulation mechanisms inherent in *Moringa oleifera* as applied for turbid water treatment and it essentially sparked widespread interests among environmental scientific community from then onwards. It is suggested that its active coagulating agents are dimeric cationic proteins with molecular mass of 12–14 kDa and isoelectric point (pI) between 10 and 11 and its main coagulation mechanism is adsorption and charge neutralization. Since then, however, there have been conflicting reports on the exact nature of the active coagulating agent present in *Moringa*. Gassenschmidt *et al*.(1995), reports that the coagulating agent is a protein with amolecular mass of 6.5 kDa and pI greater than 10 while Ghebremichael *et al*.(2005) suggests that it is a cationic protein with pI greater than 9.6 and molecular mass less than 6.5 kDa. Conversely, Okuda *et al*.(2001), argued that the active component from an aqueous salt extraction is not a protein, polysaccharide or lipid, but an organic polyelectrolyte with molecular weight of approximately 3.0 kDa. Although most research groups seem to agree that the active agent is cationic protein, the findings by Okuda *et al*.(2001), should not be disregarded as there could be a myriad of unidentified coagulating agents in *Moringa*, albeit the degree of their coagulating capability may be slighter compared to the cationic protein.

In many cases, impurity particles are negatively charged and cationic polyelectrolytes are the most efficient coagulants, which augur well for usage of *Moringa* as coagulation agent. It is well-established that electrostatic interaction provides strong adsorption in these systems and that

neutralization of the particle surface and even charge reversal can occur(Bolto *et al*., 2007). All these technical factors ultimately attract the interest of the scientific community to continue on research of using Moringa to treat a wide spectrum of turbid waters or even industrial wastewaters. Its coagulating capability can be further enhanced by addition of cations. In a study conducted by Okuda et al.(2001), it is established that bivalent cations (e.g. Ca^{2+} and Mg^{2+}) significantly enhance the coagulating effect of *Moringa oleifera* extracts in which the cations may have adsorbed to the active components to form insoluble net-like structure to capture suspended kaolin particles.

2.4.3 Tannin

Tannin is a general name given to large polyphenol compounds obtained from natural materials, for example, the organic extract from bark and wood(Graham *et al*., 2008) of trees such as Acacia, Castanea, or Schinopsis(Beltran *et al*., 2009). It is a polymer with molecular weights ranging from hundreds to tens of thousands and traditionally used as a tanning agent in the leather industry. There have been conflicting reports on the effect of tannin on human health(Chung *et al*., 1998) and its portrayal in this negative light may have limited its application as natural coagulant for water treatment. Nonetheless, such application is still a preferred research area for many researchers. Ozacar *et al.*(2002) have been studying the application of tannin as either standalone coagulant or coagulant aid for water treatment. Figure2.1, shows aschematic representation of basic tannin structure in aqueous solution and possible molecular interactions.

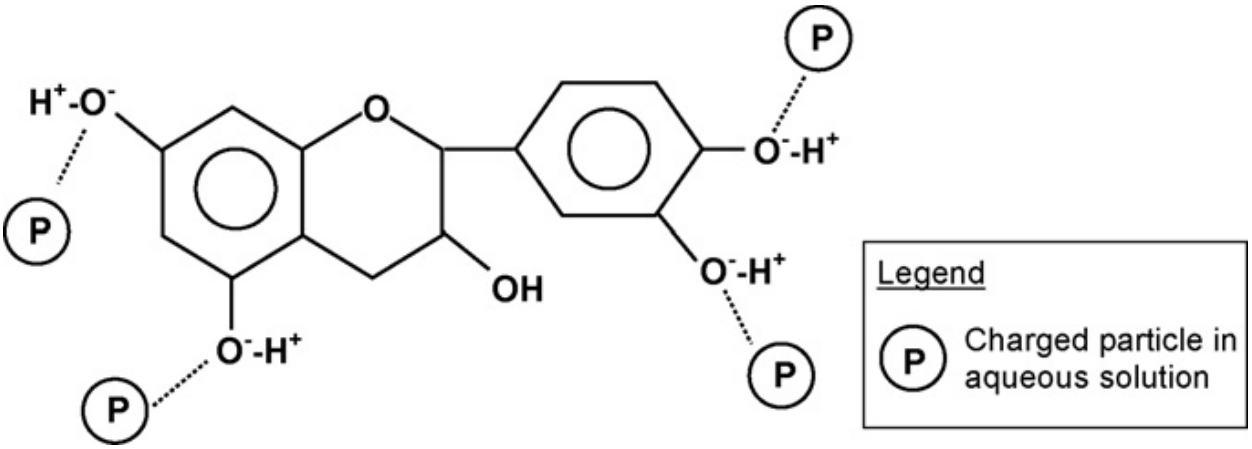


Figure 2.1.Schematic representation of basic tannin structure in aqueous solution and possible molecular interactions(Davis, 2010).

The tannin used in their study is extracted from valonia, which is obtained from the corn cup of the oak that grows in Asia Minor. They conclude that tannin is an excellent substitute to chemical coagulants.

The effectiveness of tannin as a natural coagulant for water treatment is influenced by the chemical structure of tannins that have been extracted from plant and degree of tannin modification(Ozacar *et al.,* 2000). The presence of phenolic groups in tannin clearly indicates its anionic nature since it is a good hydrogen donor. Figure 2.1, illustrates the schematic representation of basic tannin structure in aqueous solution and possible molecular interactions that induce coagulation. It is common knowledge that phenolic groups can easily deprotonate to form phenoxide which is stabilized via resonance. This deprotonation is attributed to delocalization of electrons within the aromatic ring which increases the electron density of the oxygen atom. This provides an indication that the more phenolic groups are available in a tannin structure, the more effective its coagulation capability. An interesting study on application of a

commercial tannin containing both amine and phenonic groups for water treatment conducted by Graham *et al*., (2008) suggests that their tannin is cationic in nature since there is a single tertiary amine group per monomer, giving a charge density of approximately 3 meq/g. This tannin also exhibits amphoteric nature as a consequence of presence of phenolic groups.

2.4.4 Cactus

Application of cacti species for water treatment is rather recent compared to other natural coagulants such as nirmali or *Moringa oleifera*. The most commonly studied cactus genus for water treatment is Opuntia which is colloquially known as 'nopal' in Mexico or 'prickly pear' in North America. This cactus type has long been associated with its medicinal properties(Ibanez *et al*., 1983) and dietary food sources(Kossori *et al*., 1998). Besides Opuntia, other cactus species including Cactus latifaria(Diaz *et al*., 1999) have also been successfully used as natural coagulants.

The high coagulation capability of Opuntia is most likely attributed to the presence of mucilage which is a viscous and complex carbohydrate stored in cactus inner and outer pads that has great water retention capacity(Saenz *et al*., 2004). Previous studies have established that mucilage in cactus Opuntia contains carbohydrates such as l-arabinose, d-galactose, l-rhamnose, d-xylose, and galacturonic acid(Trachtenberg *et al*., 1981). Miller*et al*., (2008), recently report that galacturonic acid is possibly the active ingredient that affords the coagulation capability of Opuntia spp. though it should be noted that it only accounts for only 50% of turbidity removal. Nonetheless, this is still a significant quantum and therefore, this compound deserves further evaluation on its contribution to the overall coagulation capability of cactus. They suggest that Opuntia spp. operates predominantly through a bridging-coagulation mechanism where solution particulates do not directly contact one another but are bound to a polymer-like material that

originates from the cactus species. Relevant dominant molecular interactions associated with adsorption and bridging in coagulation are shown in Figure 2.2.

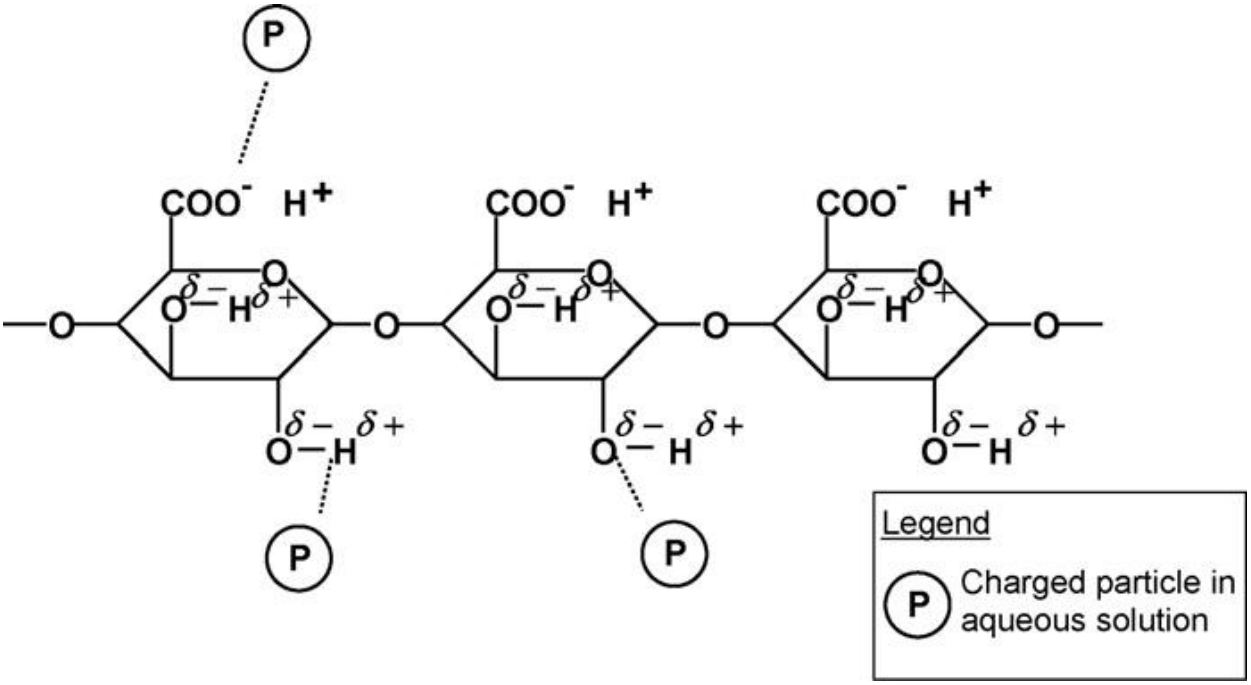


Figure 2.2.Schematic representation of polygalacturonic acid in aqueous solution and possible dominant molecular interactions associated with adsorption and bridging(Davis, 2010).

Interestingly, galacturonic acid was also reported by Japanese researchers in the late 90s to be present in natural microbial-based coagulants produced by Enterobacter sp.(Yokoi *et al*., 1997)and Pseudomonas sp.(Yokoi *et al*., 1998). All these studies point to the importance of galacturonic acid which possibly acts as one of the major active coagulating agents in plants and therefore, deserves further technical assessment.

Though not extensively reported in open literatures, it is highly possible that galacturonic acid a major constituent of pectin in plants exists predominantly in polymeric form as polygalacturonic acid.Manunza *et al*., (1997) that provides a 'bridge' for particles to adsorb on. The polygalacturonic acid structure evidently indicates that it is anionic due to partial deprotonation

of carboxylic functional group in aqueous solution. The existence of such functional groups along the chain of polygalacturonic acid implies that chemisorption between charged particles and –COO− may occur although this requires further empirical substantiation. The presence of –OH groups along its polymeric chain also infers possible intramolecular interactions which may distort the relative linearity of the chain, though this is not extensively investigated by Miller*et al*.,(2008).

2.5 Drinking Water Quality

The term "Water quality" is a widely used expression, which has an extremely broad spectrum of meaning. Each individual has vested interest in water for his particular use, which may involve commercial and industrial uses or recreational pursuits. All other uses must be subordinates to man's need for a healthful fluid for his consumption. Water for drinking and food preparation must be free organisms capable of causing disease and from mineral and organic substance producing adverse physiological effects(Metcalf and Eddy.,2004). To encourage man to drink this health-promoting liquid, the water must be aesthetically acceptable. Such water is term "potable" meaning that it may be consumed in any desired amount, without concern for adverse effects on health AWWA, (1971).

A division of Nigerian Industrial Standard (NIS), Nigerian Standard for Drinking Water Quality (NSDWQ), had prepared a table showing water quality parameters and their maximum permissible limits (MPL) and had stipulated that in preparing the table, care has been taken to ensure flexibility is carefully managed and balanced taking into consideration water system economic viability without unduly compromising the health of the consumers. The substances in Nigerian Standard for Drinking Water Quality are simply divided into physical/organoleptic,

chemical organic and inorganic constituents, disinfectants and disinfectants by-products, radionuclides and microbiological parameters (NIS 554:2007).

All drinking water shall at any time meet the minimum requirements set out in the table. All water sources intended for human consumption shall comply with Nigerian Standards for Drinking Water Quality and shall receive authorization from ministry of Heath before Ministry of Heath before being supplied to the population (NIS 554:2007).

2.5.1 Physical water quality parameters

2.5.1.1 Total dissolved solids (TDS)

Total dissolved solids in natural water are due to inorganic salts such as principally calcium, magnesium, potassium, sodium bicarbonates, chlorides and sulphates, and some small quantity of organic matter that are dissolved in water. Inorganic substances which may be dissolved in water also include minerals, metals and gases. TDS in drinking water develops from natural sources, urban runoff, industrial wastewater, sewage, and chemicals used in the water treatment process, and the nature of the piping or the plumbing. In rivers and lakes, the concentration of TDS in water will vary depending on the time of year, local geological conditions, climate and waste discharges(FEPA and FMENV, 1991). It reduces the water quality it enters, reduces the capacity of reservoir and may deposits sterile materials on productive croplands. Classification of water into fresh, brackish, saline, and sea water is usually based on the content of TDS (1000-5000, 5000-30000, and 30000-35000 mg/l respectively). The TDS concentration in rivers and lakes is generally less than 200 mg/l. TDS is not a measure of the safety or harmfulness of water but it is tied to a secondary or aesthetic standard. The WHO and EPA recommends a maximum of 500 mg/l TDS in drinking water (WHO, 2008). The presence of dissolved solids in water may affect its taste. The palatability of drinking water has been rated by panels of tasters in relation to

its TDS level as follows: excellent, less than 300 mg/l; good, between 300 and 600 mg/l; poor, between 900 and 1200 mg/l; fair, between 600 and 900 mg/l; and acceptable, greater than 1200 mg/l. Water with extremely low concentration of TDS may also be unacceptable because of its flat, insipid taste (WHO, 2008).

2.5.1.2 Conductivity

The electrical conductivity of specific conductance of water is related to TDS. It is a measure of the ability of water to conduct an electrical current. Its unit is microsiemens per centimeter µS/cm or parts per million (ppm). The relationship between conductivity and TDS is nearly linear, depending on TDS concentration. The relationship is expressed as:

$$TDS=K\times EC \quad \text{……2.1}$$

Where

TDS= total dissolved solids, mg/L

EC=electrical conductivity, µS/cm

K=constant

The value of K varies from 0.5 to 0.9 depending on TDS and water temperature. Typical value of K for most water is 0.64. The conductivity of water is determined by means of a potable ionic water tester(Muhammad, 2011).

2.5.1.3 Turbidity

Turbidity may be caused when light is blocked by large amounts of silt, microorganisms, plant fibres, sawdust, wood ashes, chemicals and coal dust. Any substance that makes water cloudy will cause turbidity. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample(Metcalf and

Eddy, 2004). Correlation of turbidity with the weight concentration of suspended matter is difficult because the size, shape, and refractive index of the particulates also affect the light-scattering properties of the suspension (APHA/ AWWA/WPCF, 1985). According to WHO (2011), the turbidity of drinking water should not exceed 5 NTU and should ideally be less than 1 NTU. Other physical parameters include, colour, taste, odour etc.(Muhammad, 2011).

2.5.1.4 pH

The pH value determines whether the water is hard or soft. pH as defined by Sorenson is – log[H+]; it is the "intensity" factor of acidity. Water with pH lower than 7 is considered acidic, water with pH greater than 7 is considered basic. The pH of pure water is 7. The normal range for pH of surface water is 6.5 to 8.5 and for ground water system is 6 to 8.5. Technically speaking, water with low pH<6.5 could be acidic, soft and corrosive. Therefore, the water could contain elevated level of toxic metals such as lead, copper. Zinc, iron and manganese. These could lead to premature damage to metal piping, and associated aesthetical problems such as metallic or sour taste, staining laundry, and characteristic "blue green" staining of sinks and drains. The impacts of these are associated health risk of these toxics. On the other hand, water with high pH > 8.5 could indicates that the water is hard. It does not pose a health risk, but can cause aesthetic problems which include alkali taste to the water (making morning coffee taste bitter), deposit formation on dishes, utensils and laundry basins, difficulty in getting leather with soaps and detergents, and formation of insoluble precipitates on clothing. Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically, every phase of water supply and wastewater treatment, e.g., acid-base neutralization, water softening, precipitation, coagulation, disinfection, and corrosion control, is pH dependent(Metcalf and Eddy, 2004).

2.5.2 Chemical/Biological water quality parameters

Water has long served as a mode of transmission of diseases. The most important of the water-borne diseases are those of the intestinal tract, including typhoid fever, paratyphoids, dysentery and some parasitic worm diseases. All members of the biological community are, to some extend, water-quality parameters. Major groups of organisms of interest in water purification are bacteria, viruses, fungi and mold, algae, protozoa, and helminthes. The most important parameter is microbial load (Lumb*et al*., 2006).

2.5.2.1 Coliform counts

Water pollution caused by faecal contamination is a serious problem due to the risk associated with contacting disease from pathogens (disease causing organisms). Since it's not always easy to monitor the disease-carrying organism directly, the presence of pathogens is determined with indirect evidence by testing for an "indicator" organism such as coliform bacteria. These common harmless forms of bacteria are normal constituents of human intestines and are found in all human waste. They are also found in plant and soil material(Kowalkowski *et al*., 2007). Coliforms come from the sources as pathogenic organisms. Coliforms are relatively easy to identify, are usually present in larger numbers than more dangerous pathogens, and respond to the environment, wastewater treatment, and water treatment similarly to many pathogens(Khan *et al*., 2003). As a result, testing for coliform bacteria can be a reasonable indication of whether other pathogenic bacteria are present. According to WHO (2011), the maximum permissible level of total coliform counts in drinking water is 0/100 ml.

2.5.2.2 Chemical oxygen demand (COD)

The chemical oxygen demand (COD) test is widely used in measuring the pollution strength of both domestic and industrial wastes. It allows for measurement of waste in terms of oxygen required to oxidize organics to carbon dioxide and water thus:

$$C_nH_aN_c + \left(\frac{n+a}{4} - \frac{b}{2} - \frac{3c}{4}\right)O_2 \Longrightarrow nCO_2\frac{a}{2} - \frac{3c}{2}H_2O + cNH_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.2$$

The application of COD test is based on the fact, with few exceptions: all organic compounds can be oxidized by strong oxidizing agents in acid conditions. From the equation above, amino nitrogen is converted to ammonia nitrogen whereas organic nitrogen in higher oxidation states would be converted to nitrates(Muhammad, 2011).

The main limitation of the COD test is that does not differentiate biologically oxidisable from biologically inert organic matter. Also, it does not give any evidence of the rate at which the biologically active material would be stabilized under natural conditions.

In COD determinations, organics are converted to carbon dioxide and water irrespective of whether the substances is biologically assimilable or not,. For example, glucose and lignin are both completely oxidized. Hence, COD values tend to be higher than BOD values.

The COD test however has the advantage of time saving because of the short time required for the test 3 hours or slightly more rather than 5 days required for BOD. Because of this, it is often used as a substitute for BOD test(Muhammad, 2011).

The test is used extensively in the analysis of industrial wastes and is very useful in surveys for determining and controlling losses to sewer systems. Combined with the BOD test. COD data may be used to indicate toxic conditions and the presence of biologically resistant substances.

2.5.2.3 Biological oxygen demand (BOD)

Biochemical (Biological) oxygen demand (BOD) is defined as that amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. It is relevant to state here that "decomposable" as used here means that the organic matter can be assimilated by the microbes.

The BOD test is used to determine the strength of domestic and industrial effuents and expresses the amount of oxygen required to stabilize them if discharged into natural waters with aerobic conditions. The test is important in the control of stream pollution, in the regulatory work and in studies designed to evaluate the purification capacity of receiving waters. BOD is a bio assay procedure which measures the oxygen consumed by bacteria while utilizing the organic matter present in waters under conditions as close as possible to nature. The quantitative value of results depends importantly on the protection of samples from air to avoid re-aeration as dissolved oxygen levels diminish. Oxygen has a limited solubility in water (9mg/L at $20^{O}C$). So strong waste must be diluted to demand levels in keeping with this value. This ensures that dissolved oxygen will be present throughout the period of the test. It is very important that the environmental conditions of the test are suitable for living organisms (bacteria), to function unhindered at all times. Hence, toxic substances must be precluded and the nutritional requirements for bacterial growth nitrogen, phosphorus, and certain trace elements must be present(Muhammad, 2011).

The biological stabilization of organics involves action by some diverse microbial flora which carries out the oxidation to completion (i.e to carbon dioxide and water). Therefore, a mixed group of organisms the "seed" needs to be present in the test.

There is a quantitative relationship between the amounts of oxygen required to convert a definite amount of any given organic to carbon dioxide, water and ammonia. The relationship is expressed in the general equation.

$$C_nH_aN_c + \left(\frac{n+a}{4} - \frac{b}{2} - \frac{3c}{4}\right)O_2 \Longrightarrow nCO_2\frac{a}{2} - \frac{3c}{2}H_2O + cNH_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.3$$

Consequently, BOD data can be interpreted in terms of organic matter as well as the amount of oxygen used in oxidation. This is fundamental to an understanding of the rate at which BOD is exerted.

Being a biological process,the rate of the oxidative reactions in the BOD test are affected by the population size of the microbes and by the temperature can by the temperature of the system. The effects of temperature can be held constant by performing the test at 20^{O}C, being more or less a medium value as far as natural waters are concerned. As the microbial flora active in BOD tests are generally soil inhabitants, the rate of their metabolic activity at 20^{O}C under the conditions of the test is such that time must be reckoned in days in BOD determinations. Although it may take up to 20 days to completely stabilize an organic in water, that time period is too long to wait for results. It is found by experienced that a reasonably large percentage of the waste are oxidized within 5 days and so the test has been developed on the 5-days standard incubation period. It should be noted therefore that 5 days BOD values represent only a fraction of the total BOD, the exact percentage depending on the nature of the "seed" and of the organic matter to be stabilized. This fraction can only be determined experimentally. The 5 days incubation period also helps to minimize interferences from ammonia oxidation(Muhammad, 2011).

BOD data are widely used in environmental engineering practice especially in determining the strengths of both domestic and industrial wastes. It is the only test that gives a measure of the amount of biologically oxidisable organic matter present that can be used to determine the rates at which oxidation will occur or BOD be exerted in receiving waters. It is therefore the major criterion used in stream pollution control where organic loading must be restricted to maintain desired dissolved oxygen levels. BOD determinations are used in studies to measure the purification capacity of streams, providing the means by which quality of discharge effluents can be checked. The design of treatment facilitates relies on BOD information and such information is an important factor in the choice of treatment methods. BOD data are used to determine the size of certain treatment units like trickling filters and activated sludge unit as in the evaluation of plant efficiency(Muhammad, 2011).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

In this chapter, the materials, methods and procedures employed during this work are presented.

3.2 Materials and Laboratory apparatus

The materials and laboratory apparatus used during this research are shown in Table 3.1

Table 3.1: Materials and apparatus

Materials and Apparatus	Availability
Single distillation water still (14WSC)	Dept. of Agricultural Science A.B.U
Jar test apparatus (SW 6 Model)	A.B.U water works
Turbidimeter (HACH 2100P model)	A.B.U water works
pH meter (KENT EIL 7055)	Dept. of Chemical Engineering A.B.U
Conductimeter (JENWAY 4010)	A.B.U water works
FTIR Spectroscope (Model-1601 PC)	NARICT, Zaria
Magnetic stirrer (PC 351)	Dept. of Agricultural Science A.B.U
Test tubes (3D model)	Dept. of Chemical Engineering A.B.U
Oven (JC Penney)	Dept. of Agricultural Science A.B.U
Berzelius beaker (200L) (Model 500EA)	Dept. of Agricultural Science A.B.U
Pipette (3D model)	Dept. of Agricultural Science A.B.U
Erlenmeyer flask (250mL) (3D model)	Dept. of Agricultural Science A.B.U
Measuring cylinder (500mL) (Model B6)	A.B.U water works
Hot plate (model PC-600)	Dept. of Agricultural Science A.B.U
Electrometric titrator (model 301)	A.B.U water works

Soxhlet apparatus (multiple units model)	Dept. of Chemical Engineering A.B.U
Glass beaker (10mL) (3D model)	Dept. of Agricultural Science A.B.U
Volumetric flask (50mL) (3D model)	Dept. of Agricultural Science A.B.U
Dry *Moringa oleifera*	Samaru, Zaria
Opuntia stricta (Cactus)	Samaru, Zaria.
Flame Photometer (Sherwood 410)	Dept. of Agricultural Science A.B.U
Atomic Absorption Spectrophotometer (Perkin Elmer 306)	Dept. of Agricultural Science A.B.U
Petri dishes (model 1368S)	Dept. of Agricultural Science A.B.U
Whatman filter (Model 125)	Samaru, Zaria
Condenser (38TA042)	Dept. of Agricultural Science A.B.U
Incubator (*Models*by José Alberto Sampaio Aranha)	Vet. medicine, dept. of public health A.B.U
Surface water	A.B.U dam Zaria

3.2.1Reagents

The reagents used during this research are shown in Table 3.2

Table 3.2: Reagents

Reagents	Grade	Suppliers
Sodium hexametaphosphate	Analar	British drug house (BDH) chemicals Ltd Poole England
Ethanol	Analar	British drug house (BDH) chemicals l.t.d Poole England
Sodium chloride	Analar	Fine chemicals l.t.t
N-hexane	Analar	Fine chemicals l.t.t
Hydrochloric acid	Analar	British drug house (BDH) chemicals l.t.d Poole England
Buffer solution (NH_4Cl, conc. NH_4OH, magnesium salt of	Analar	British drug house (BDH) chemicals l.t.d Poole England

EDTA and distilled water)		
Sodium hydroxide	Analar	British drug house (BDH) chemicals l.t.d Poole England
Perchloric acid (60%)	Analar	Fine chemicals l.t.t
Concentrated nitric acid	Analar	British drug house (BDH) chemicals l.t.d Poole England
Concentrated tetraoxosulphate (vi) acid	Analar	British drug house (BDH) chemicals l.t.d Poole England
Deionized water	Analar	Department Agriculture A.B.U Zaria.
Mercury tetraoxosulphate (vi) acid	Analar	British drug house (BDH) chemicals l.t.d Poole England
Conc. Tetraoxosulphate (vi) acid	Analar	British drug house (BDH) chemicals l.t.d Poole England
silver tetraoxosulphate (vi) acid	Analar	British drug house (BDH) chemicals l.t.d Poole England
potassium dichromate	Analar	Fine chemicals l.t.t
ferrous ammonium sulphate	Analar	British drug house (BDH) chemicals l.t.d Poole England
Potassium bromate	Analar	Fine chemicals l.t.t
Lactose broth	Analar	British drug house (BDH) chemicals l.t.d Poole England
Brilliant green bile broth	Analar	British drug house (BDH) chemicals l.t.d Poole England
MacConkey agar	Analar	British drug house (BDH) chemicals l.t.d Poole England
Nitric acid	Analar	Fine chemicals l.t.t
Potassium nitrate	Analar	Fine chemicals l.t.t
Sodium nitrate	Analar	Fine chemicals l.t.t

3.3 Experimental Procedures

The procedures for the general methodology, extraction of cactus mucilage and *Moringa oleifera* are presented in Subsections 3.3.1, 3.3.2 and 3.3.3. Also, the methods for jar test, turbidity, pH, conductivity, total dissolved solid, chemical oxygen demand, biological oxygen demand, Fourier transform infrared (FTIR) spectroscopy, bacteria analysis, calcium, magnesium, sodium andthe elongation of the coagulated treated surface water were employed and discussed in the subsections.

3.3.1 General methodology of water treatment.

The general methodology employed during the course of this research ispresented as shown in Figure 3.1.

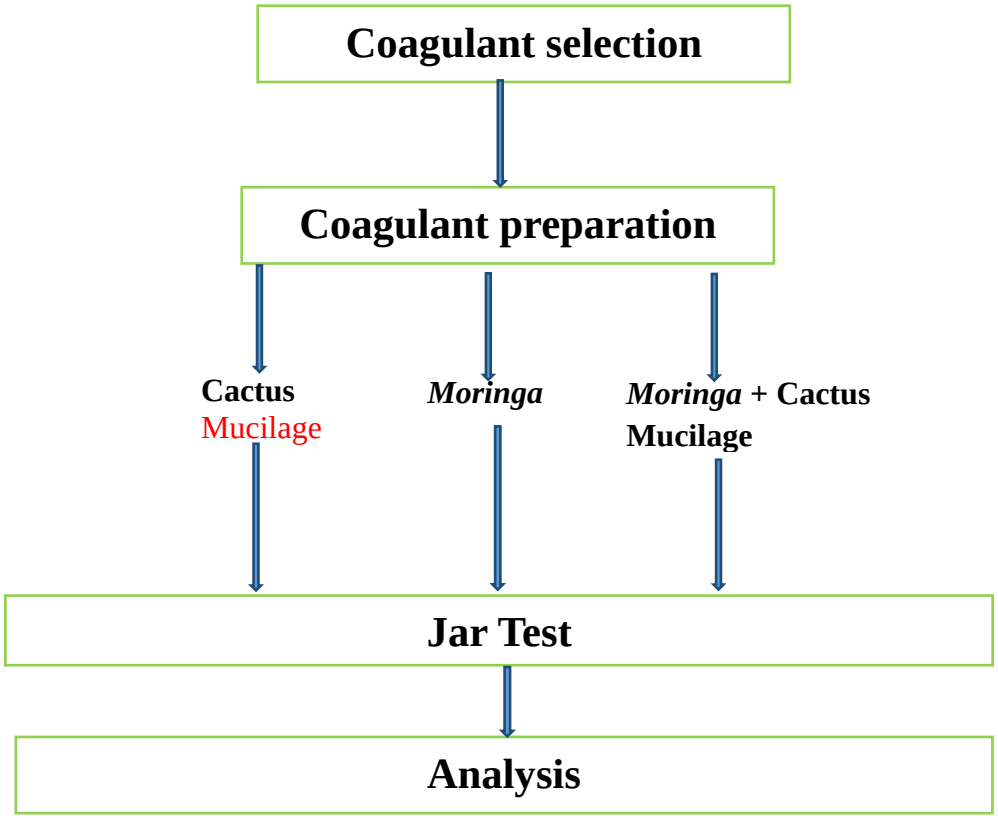
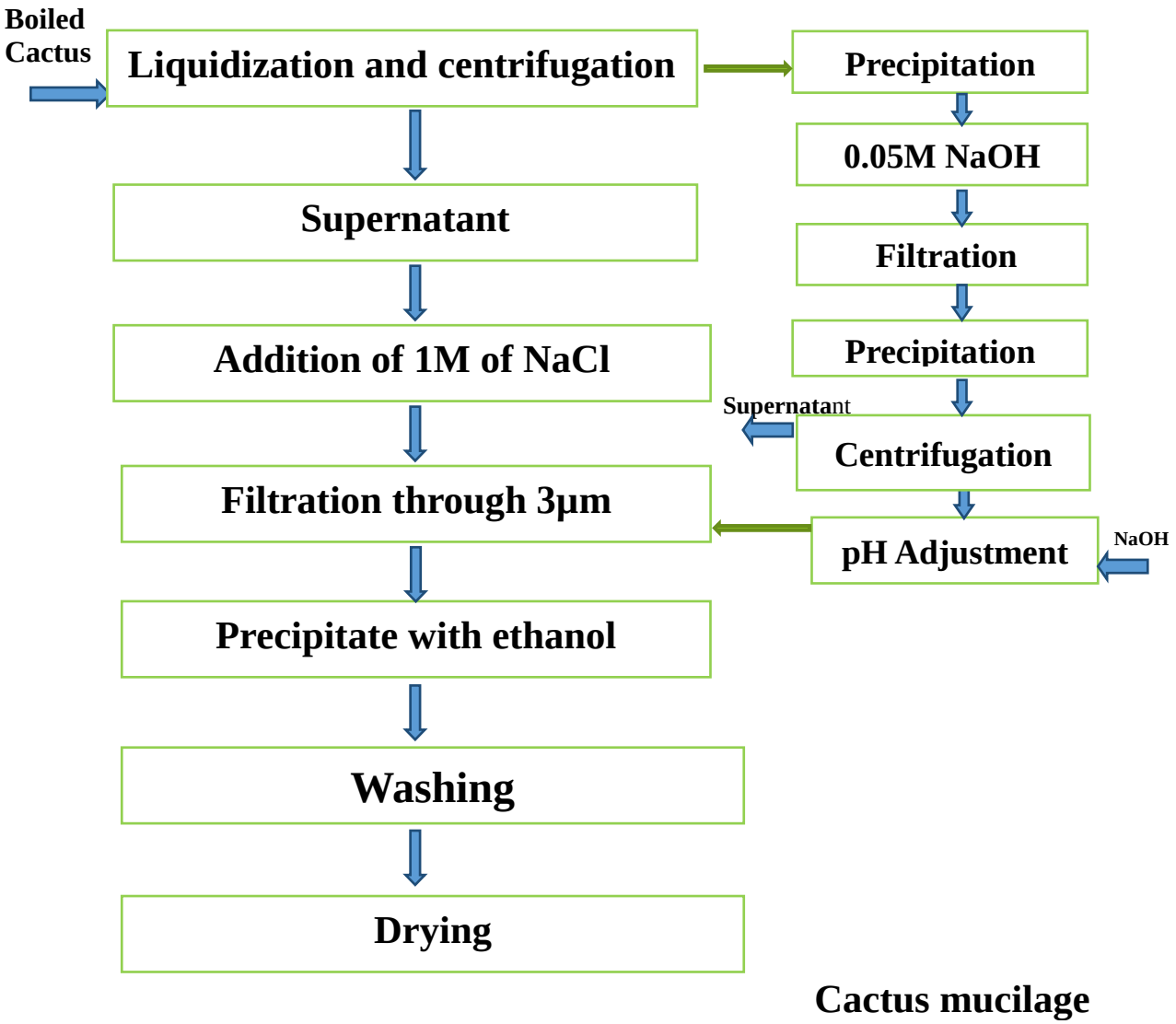


Figure 3.1: General methodology of water treatment

The coagulants selection involved the selection of *Opuntia stricta*(cactus) and *Moringa oleifera*. Thereafter, the coagulants were prepared and grounded to powder. Jar test analysis was performed for the treatment using *Opuntia stricta*(cactus), *Moringa* and the blend. Then, total dissolved solid, conductivity, BOD, COD, pH and bacteria analysis were performed on the treated surface watersample.

3.3.2 Extraction of *Opuntia stricta*species(cactus) mucilage

Opuntia stricta (cactus) pads were obtained from Jos Plateau State. Mucilage were isolated from cactus pads using a procedure modeled from the extractions of *Opuntia stricta*(cactus) mucilage by (Goycoolea and Cardenas, 2003; Turquois *et al*. 1999 and Medina-Torres *et al*. 2000). The process block diagram for the extraction methods is presented in Figure 3.2.



Cactus mucilage



Figure 3.2: Process block diagram for the preparation of cactus mucilage

Fresh cactus pads were cleaned (thorns removed), diced into 1" cubes, and boiled in deionized water for 30 minutes at 85^{O}C. Heating the pad caused a great deal of mucilage secretion. This could potentially be due to the viscosity reduction that one would expect to occur when the mucilage is heated, allowing it to flow out of the pad more easily. The mixture was then blended with a household blender. The pH was altered to 7 to 7.5 with 1.0 M NaOH, and the resulting mixture was centrifuged at 125 rpm for 10 minutes with a Fisherbrand accuSpin 400 centrifuge with a swing bucket rotor. The supernatant was separated from the solids and the solids were reserved for the extraction of the precipitate. Deionized water (A10, MilliPore) with 1.0 M NaCl was added to the supernatant, which was highly viscous, until filtration through a #41 Whatman filter was possible. This filtration removed any remaining pad tissue from the supernatant solution. After filtration, the mucilage was precipitated from the water using ethanol (1:1 v/v). Upon addition of ethanol, precipitation began almost immediately and the mucilage accumulated at the ethanol-air interface. The mucilage was then scooped from the ethanol phase. The recovered mucilage was washed with ethanol. After approximately 10 minutes, the ethanol was decanted and the mucilage was spread on sterile Petri dishes and dried in an oven at 50^{O}C. Once brittle, the mucilage was ground with a mortar and pestle resulting in a powder that was stored on the bench top in sealed containers at room temperature.

To isolate the precipitate, which has been previously classified as pectin, the solids retained from the centrifugation step were transferred to a beaker and covered with 0.05M NaOH solution containing 75% sodium metaphosphate. This solution acted as a calcium sequestering agent used to promote the release of the mucilage pectin from the cell walls of the cactus, as was previously

outlined by Turquois *et al.* (1999). After 30 minutes of stirring, the pH was reduced to 2.0 with HCL, and the suspension was centrifuged at 125 rpm for 10 minutes. Upon centrifugation, the supernatant was discarded and the precipitate was covered with deionized water and the pH increased to 8.0 with 1.0 M NaOH. Filters were created from cloth sheets with large pore sizes and the cactus suspension was filtered to remove large solids from the mucilage solution. The filtrate was collected and the solids discarded. Ethanol was added to the filtrate (1:1 v/v) to isolate the mucilage from the water. Upon initial contact, mucilage began moving to the ethanol phase. The mucilage was left to precipitate. The mucilage was washed in ethanol and dried on sterile Petri dishes in an ovenat 50^{O}C. The mucilage was then ground with a mortar and pestle and stored in sealed containers on the bench top at room temperature.

3.3.3 Preparation of the extract of *Moringa oleifera* seed cake coagulant

About 4 kg of dry *Moringa oleifera* seeds was used for the preparation of the coagulants. It was obtained from Zaria, Kaduna State Nigeria. The seed wings and coat were removed from selected dry good quality *Moringa oleifera* seeds and the nuts ground to a fine powder with the domestic food blender and then it was extracted using soxhlet apparatus as shown in Figure 3.3.

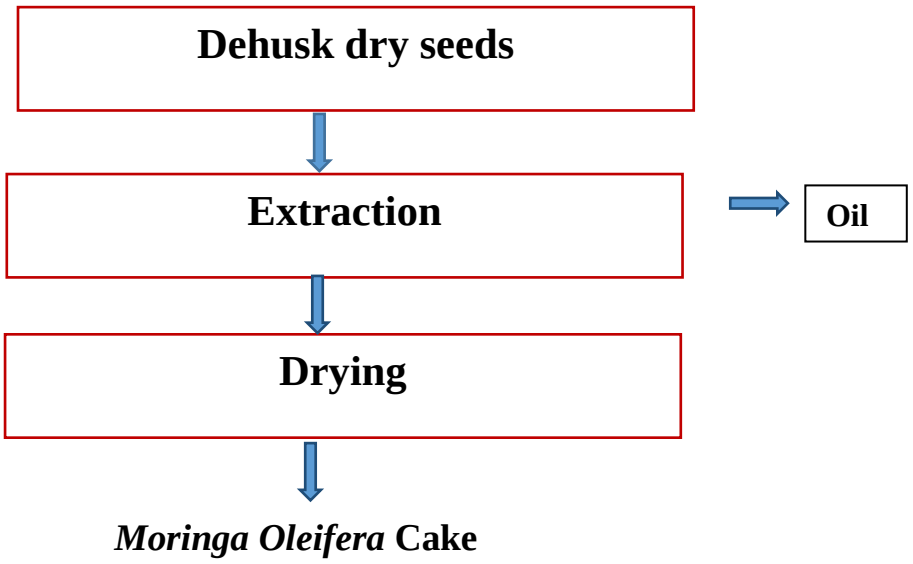


Figure 3.3: Extraction of *Moringa oleifera*

3.3.4 Jar Test Analysis

Standard Jar test procedures were employed for this purpose viz. rapid mix for 2 minutes at 200 rpm to distribute the coagulant, followed by slow mix for 20 minutes at 20 rpm to allow flocculation (Muyibi, 1995). The optimizations for cactus and *Moringa oleifera* were conducted using the jar test apparatus. The apparatus allowed six beakers to be agitated simultaneously. About 2 g of powder *Moringa oleifera* was weighed and put in a beaker and also 200mL of distilled water was added. The resulting solution was used for the jar test analysis. A six place jar test apparatus (Stuart Flocculator SW 6 model) was used. 10, 15, 20, 25, 30, and 35 mL of *Moringa oleifera* coagulum were measured into 6 beakers (10, 15, 20, 25, 30, and 35 mL into the first, second, third, fourth, fifth, and sixth beaker respectively.) containing 200 mL separately and another test was performed using 1,2,3,4,and 5mL of *Moringa*. The beakers were placed inside the jar test apparatus and the paddles (one per beaker) were inserted into the beakers. Rapid mix was set at 200 rpm for 2 minutes, then the apparatus was switched on. Immediate after 2 minutes, slow mix was set at 20 rpm for 20 minutes. The beakers were removed and the supernatants allowed to settle for 2 hours. The same procedure was repeated with cactus but 1, 2, 3, 4, 5,and 15mL of cactus were measured into 6 beakers (1, 2, 3, 4, 5, and 15 mL into the first, second, third, fourth, fifth, and sixth beaker respectively.) containing 200 mL separately and another test was performed using 20,25,30,and 35mL of cactus . The supernatants were then tested for tubidity using turbidimeter (Model 2100 Hach).

3.3.4.1 Dose blends of cactus to Moringa oleifera

Coagulant Dosage (mg/l), cactus to *Moringa* ratio: Jar 1 = 80:20, Jar 2 = 60:40, Jar 3 = 40:60, Jar 4= 20:80,

With a calibrated pipette, each stock solution dosages of cactus and *Moringa* solutions would be added onto the water samples in the beakers as rapidly as possible.

3.3.5 Turbidity measurement

The turbidity measurement of the sample water was done using a HACH 2100P direct reading potable turbidimeter at the Kaduna State Water Board, Zaria Dam, Nigeria. It is a multipurpose turbidimeter. It was configured to read turbidity at the wavelength of 750 nm specified for measuring turbidity.Distilled water was first poured into a 15 mL sample cell and inserted into the turbidimeter. The calibration button was pressed and the instrument was then calibrated. Initial calibration of the 2100P turbidimeter was based on formazin, the primary standard for turbidity (Lange, 2004). Each of the samples to be read was poured into a 15 ml sample and inserted into the turbidimeter. The turbidity of the samples were displayed on the LCD panel of the instrument in Nephelometric Turbidity Units (NTU). After each reading, the spectrophotometer was calibrated again with the distilled water before being used on the next sample.

3.3.6pH Measurement

The pH of the sample was measured using a calibrated Jenway 3505 pH meter. A volume of 200 mL of the supernatants obtained from the beakers containing the treatments was measured into a beaker. The pH meter probe was then inserted making sure it did not touch the beaker. The pH reading was then taken from the LCD display after it had stabilized.

3.3.7 Conductivity measurement

The samples used for the pH measurements were used for the conductivity test. A calibrated Jenway 4510 Conductivity meter was used. The conductivity meter probe was then inserted

making sure it did not touch the beaker. The reading was recorded from the LCD display after it had stabilized.

3.3.8 Total dissolved solid measurement

A calibrated Jenway 4510 total dissolved solid meter was used. The total dissolved solid meter probe was then inserted making sure it did not touch the beaker. The reading was recorded from the LCD display after it had stabilized.

3.3.9 Determination of chemical oxygen demand (COD)

About 0.4g of mercury tetraoxosulphate (vi) acid($HgSO_4$) was place in a reflux flask and 20ml sample of aliquot diluted to 20ml with distilled water was added and mixed. Then, 10ml of standard potassium dichromate was added and 3or 4 glass beads was also added and mixed well. 30ml of conc. H_2SO_4 was carefully added containing silver tetraoxosulphate (vi)acid (Ag_2SO_4). It was then reflux for 2hours cool and the condenser was wash down with distilled water. It was then diluted to about 100ml and cooled to room temperature. Excess dichromate was titrated with standard ferrous ammonium sulphate using 2-3 drops of indicator. The colour change was sharp, from blue-green to brown-green to reddish-brown. A blank containing 20ml distilled water was treated and reflux in the manner (ISO, 1990).

Then, the COD was calculated as follows:

$$\text{COD (mg/L)} = \frac{(a-b)C \times 8000}{sample\ (ml)} \quad \text{.....3.1}$$

Where,

a=titration for blank.

b=titration of sample.

c=normality of ferrous ammonium sulphate ($0.25N_A$)

3.3.10 Determination of biological oxygen demand (BOD)

Preparation of the seed dilution water was made and the dilution was calculated as required. For instance, raw water estimated BOD was 400mg/L and the dilutions were 1/100 and 1/200. The final effluent- estimated BOD was 20 mg/L and the dilutions were 1/5 and 1/2. The sample was diluted with seeded dilution water in 2 litre volumetric flasks. For instance, 1/100 dilution 20 ml sample in 2 litre. The diluted sample was transferred to a number of BOD bottles (4 bottles for each dilution). The bottles were incubated for 5 days (120 hours) at $20^{O}C$. The treated surface water dilution was prepared and shared into four bottles and then incubated for 3-5 days at $20^{O}C$. The residual dissolved oxygen was determined after incubation period.

3.3.11Fourier transform infrared (FTIR) spectroscopy

FTIR spectra were recorded on samples prepared in potassium bromide (KBr) disks using a Shimadzu Corporation, Model-1601 PC. Samples were prepared in KBr disks by means of a hydrostatic press at 6-8 tons pressure. The scanning range was 500 to 4000 cm^{-1}.

3.3.12 Bacteria analysis test (The tube method)

3.3.12.1 Presumption test

Three sets of 5 tubes each containing 10ml of lactose broth and inverted durham vials were inoculated with 0.1ml, 1ml and 10ml of water samples each. No air was trapped in theinverted durham vials prior to inoculation. The tubes were then incubated $37^{O}C$ for 48 hours. The tubes were then examined for cloudiness (evidence of growth) and gas production trapped in inverted durham vial (evidence of lactose fermentation). A tube is considered positive for coliform presence when it is cloudy and produced gas. The presumptive test is considered qualitative.

3.3.12.2 Confirmation test (qualitative test)

A loopful of a positive lactose broth culture was transferred from a tube inoculated with the smallest inoculum giving a positive presumptive test (0.1ml in above test) into 2% brilliant green bile broth. It was incubated at $37^{O}C$ overnight. It was then looked for cloudiness and gas production for a positive result.

3.3.12.3 Complete test (qualitative test)

A loopful of a positive brilliant green bile broth, 2%, culture was streak onto MacConkey agar plates. It was then incubated at $37^{O}C$ overnight. Coliform bacteria was detected which produce brick-red colonies with a surrounding zone of precipitate bile on MacConkey. Stain representative colonies by gram method was used to detect gram negative, non-sporulation rods microscopically.

3.4 Determination of Ca and Mg

About 0.5g of dried *Opuntia stricta* cactus and *Moringa oleifera* were weighed each and put into 100 ml glass beaker separately (previously washed with acid and dried). 30 ml of mixed acid (25 ml of nitric acid, 4 ml of perchloric acid and 2 ml of concentrated sulphuric acid) were added under a fume cupboard. The content and beaker were then place on a hot plate and heated gently and gradually increasing the heat to full. Heating continue till when the brown fumes have changed to white fumes (if digest did not change to white colour add about 5-10 ml of the mixed acid and continue to heat till it changes to white colour). The above process was repeated without *Opuntia stricta* cactus and *Moringa oleifera* samples. This served as a blank. The beaker and content were then allowed to cool and 10-20 ml of distilled water was added. It was then stir and filter into 50 ml volumetric flask and all the contents in the beaker were washed into the flask

and made to volume with distilled water. The digest was kept for the determination of Ca and Mg by Atomic Absorption Spectroscopy each for *Moringa oleifera* and *Opuntia stricta* cactus.

3.4.1 Potassium Standard

About0.2600g of potassium nitrate was dissolved in 100cm^3 volumetric flask and was made to the mark with distilled water to give 1000ppm of potassium standard from which the following series of working standard were prepared; 2.00ppm, 4.00ppm, 6.00ppm, 8.00ppm and 10.00ppm.

3.4.2 Sodium Standard

About 0.4g of sodium nitrate was placed in a 100cm^3 volumetric flask dissolved with distilled water and made to the mark, this gave 1000ppm of sodium standard from which these series were prepared; 5.00ppm, 10.00ppm, 15.00ppm and 20.00ppm.

3.4.2.1 Calibration of Flame Photometer for Potassium and Sodium Determination.

The gas outlet from the cylinder was connected to the gas inlet, at the rare panel of the instrument; the air outlet from the air compressor was equally connected to the air inlet at the rare panel of the instrument. The instrument was connected to the main and switched on automatically. It was allowed to warm for about 30 minutes to attain electronic working temperature. During the period of warming up, the standards of element to be determined were prepared. Distilled water was allowed to be aspirated into the machine and was zeroed using the blank adjustment knob. The element to be determined was selected using filter selection lever. The highest standard of the element to be determined was read on the instrument to obtain the corresponding intensity. The instrument was calibrated in such a way that 10.00ppm will read 10ppm (intensity). After reading the highest standard of that element, other series of the standard were then read. After calibration and standardization of the instrument, the digested sample was read and the corresponding intensity was recorded.

Calculation for potassium:

$$Concentration\ of\ K\ (ppm) = \frac{intensity\ \times dilution\ factor \times extraction\ volume}{sampl\ weight} \ldots\ldots..3.2$$

Calculation for sodium:

$$Concentration\ of\ Na\ (ppm) = \frac{intensity\ \times dilution\ factor \times extraction\ volume}{sampl\ weight} \ldots\ldots 3.3$$

3.5 Determination of the Elongation of the Coagulated Treated Surface Water.

Three sets of sterilized 200 ml sample bottles were filled with water sample. Each set consist of five sample bottles. A Sample was taken from each set every 24 hours for coliform count to determine the bacteria growth of water treated with Moringa, cactus mucilage and the blend of Moringa and cactus mucilage for a period of six days (Muhammad, 2011).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained during this research. The results on physicochemical properties of the coagulants, turbidity, conductivity, total dissolved solid, pH, COD, BOD, bacterial and the elongation of the coagulated treated surface water sample are presented and discussed.

Table 4.1: Trace metals (ash content) in*Moringa oleifera* and *Opuntia stricta*(cactus).

Parameters	Moringa	Cactus
Potassium (K) %	0.700	0.350
Sodium (Na) %	0.020	0.180
Calcium (Ca) %	0.114	1.522
Magnesium (Mg) %	0.074	0.083

From Table 4.1,*Moringa oleifera* contains 0.7% of K, 0.02% of Na, 0.114% of Ca and 0.074% of Mg while *Opuntia stricta*(cactus) contains 0.35% of K, 0.18% of Na, 1.522% of Ca and 0.083% of Mg. This is in support with thereport by Emmanuel *et al*, (2011), who worked on the application of processed *Moringa oleifera* seed cake.It was stated that the Moringa seed cake has great support for microbial growth as the surface water stay longer. The increased activities of the microorganism in the surface water may have resulted in the release of more of the nutrient in the surface water (Emmanuel *et al*, 2011).

4.2 Fourier Transform Infrared (FTIR) Spectroscopy Characterization of Coagulants

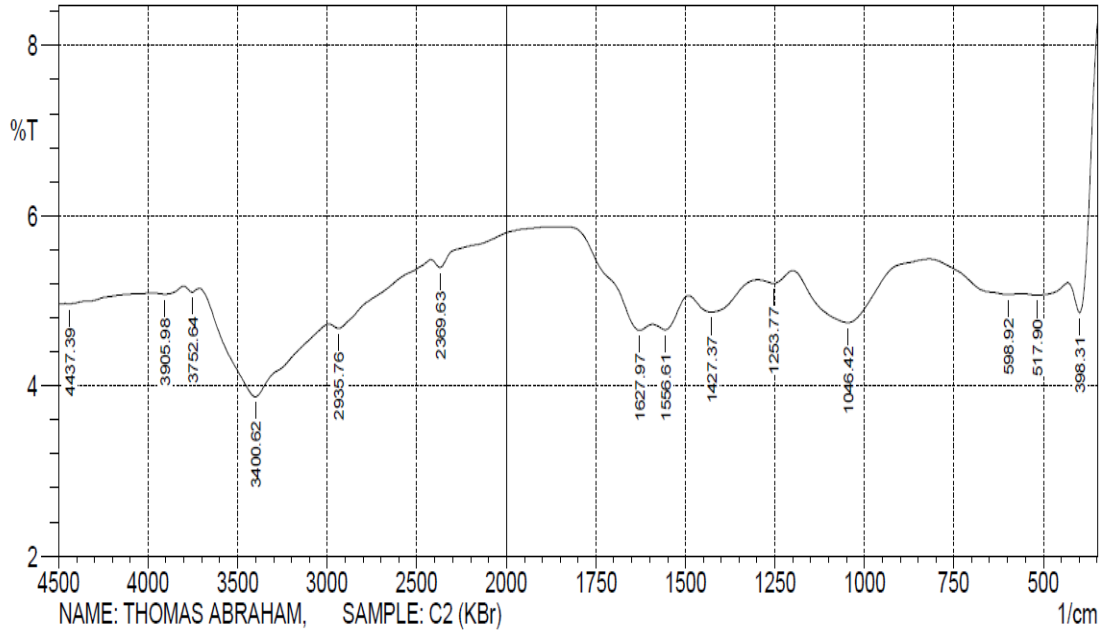


Figure 4.1: FTIR analysis of *Opuntia stricta*(cactus)

There are four main features in the mucilage of cactus: the first is the broad band at 3400 cm^{-1} which corresponds to OH stretching of alcohol and carboxylic acid -OH groups involved in intermolecular hydrogen bonding. The second is the band at 1627.97 cm^{-1} corresponding to the COO- stretch characteristic of carboxylic acid salts. Thirdly, the band at 1253.77 cm^{-1} correspond to C-O-C ether stretch. Two strong bands at 1253.77 cm^{-1} and 1046.42 cm^{-1} are due to C-O stretch of secondary alcohols and C-O-H stretch in cyclic alcohols, respectively. The FTIR spectra mucilage was corroborated with the findings of Alcantar. (2007), who worked on characterization of *Opuntia ficus indica* (cactus)mucilage. The hydroxyl (OH^-) functional group indicate the presence of galactose, xylose, rhamnose and arabinose while carboxylic (COOH) functional group indicate the presence of galactunic acid in the cactus mucilage.

The FTIR analysis in Figure 4.1, shows the characteristics of pectic polysaccharides in*Opuntia stricta*(cactus) mucilage. Pectins have a D-galacturonic acid backbone and various degrees of

branching composed of neutral sugars, and methylation of the carboxylic acid functional group(Davis, 2010). Their spectra show the functionalities associated with the carboxylic acid and carboxylate, ether and alcohol groups that comprise these compounds.

Table 4.2: Functional groups assigned to bands in spectra of *Opuntia stricta* (cactus) mucilage

Functional group	**Peak cm^{-1}**
C-H	2935.76
C-F	1253.77
OH	3400.62
COOH	3400.62
O=C-O-C	1627.97
R-NH2	1627.97
Aromatic compound	1427.37

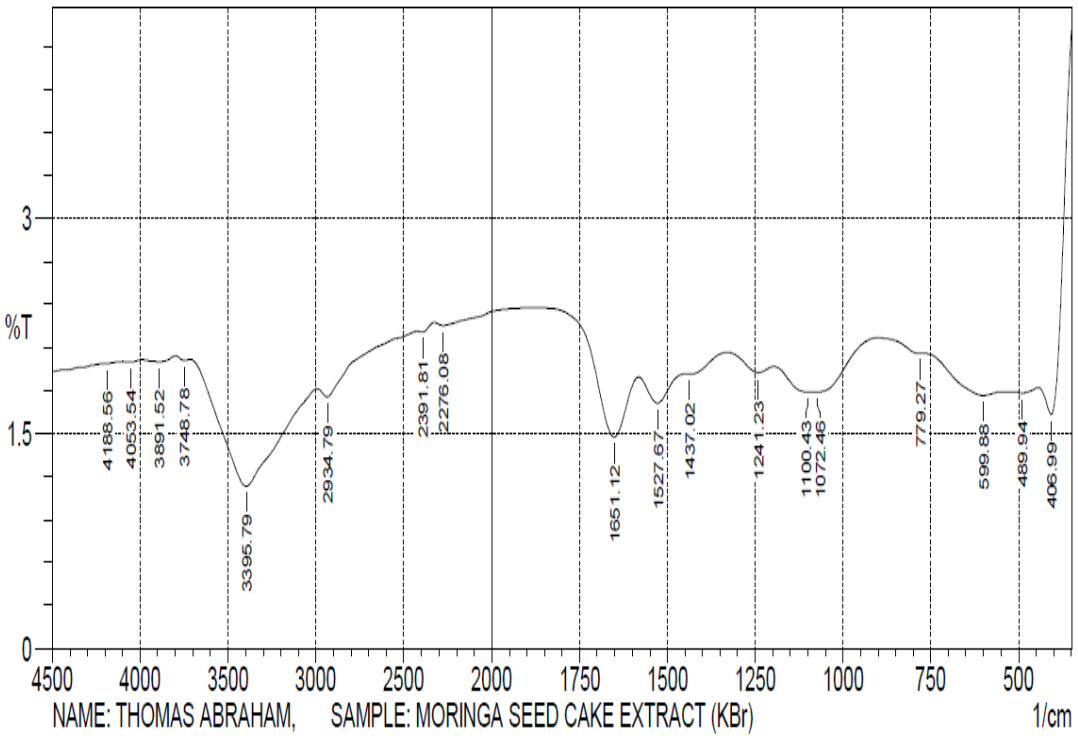


Figure 4.2: FTIR analysis of *Moringa oleifera*

Table 4.3: Functional groups assigned to bands in spectra of *Moringa oleifera*seed cake extract.

Functional group	**Peak cm^{-1}**
C-H	2934.79
C-F	1072.46
OH	3395.79
R-Cl	779.27
O=C-O-C	1627.97
R-CO-NH2	3395.79
RR-N-H	3748.78
C=O	1651.12
=C-H	1651.12

Figure 4.2 shows the FTIR analysis for *Moringa oleifera*.The four main features in the extract of *Moringa oleifera* are: the first is the broad band at 3395.79 cm^{-1} which corresponds to OH stretching of alcohol and carboxylic acid -OH groups involved in intermolecular hydrogen bonding. The second is the band at 1241.23 cm^{-1} correspond to C-O-C ether stretch. Thirdly, two strong bands at 1100.43 cm^{-1} and 1072.46 cm^{-1} are due to C-O stretch of secondary alcohols and C-O-H stretch in cyclic alcohols, respectively. Fourthly, the bands at 3748.78cm^{-1}, 3891.52cm^{-1}, 4053.54cm^{-1} and 4188.56cm^{-1} correspond to amines stretch which indicate the present of cationic peptides. This is in support with the findings of Ndabigengesere and Narasiah, (1998), reported that the action of *Moringa oleifera* as a coagulant in water treatment lies in the presence of cationic peptides in its seed.

In FTIR absorbance spectroscopy, peak shifts and intensity changes are important for inferring chemical interaction. Peak shifts signify a change in the chemical environment of a functional group. The coupled appearance and disappearance of absorption bands indicate a reaction involving the corresponding functional group.

4.3 Effect of Moringa and Cactus dosage on % Turbidity Reduction

The effect of *Moringa oleifera* and cactus mucilage on percentage turbidity reduction is shown in Figure 4.3.

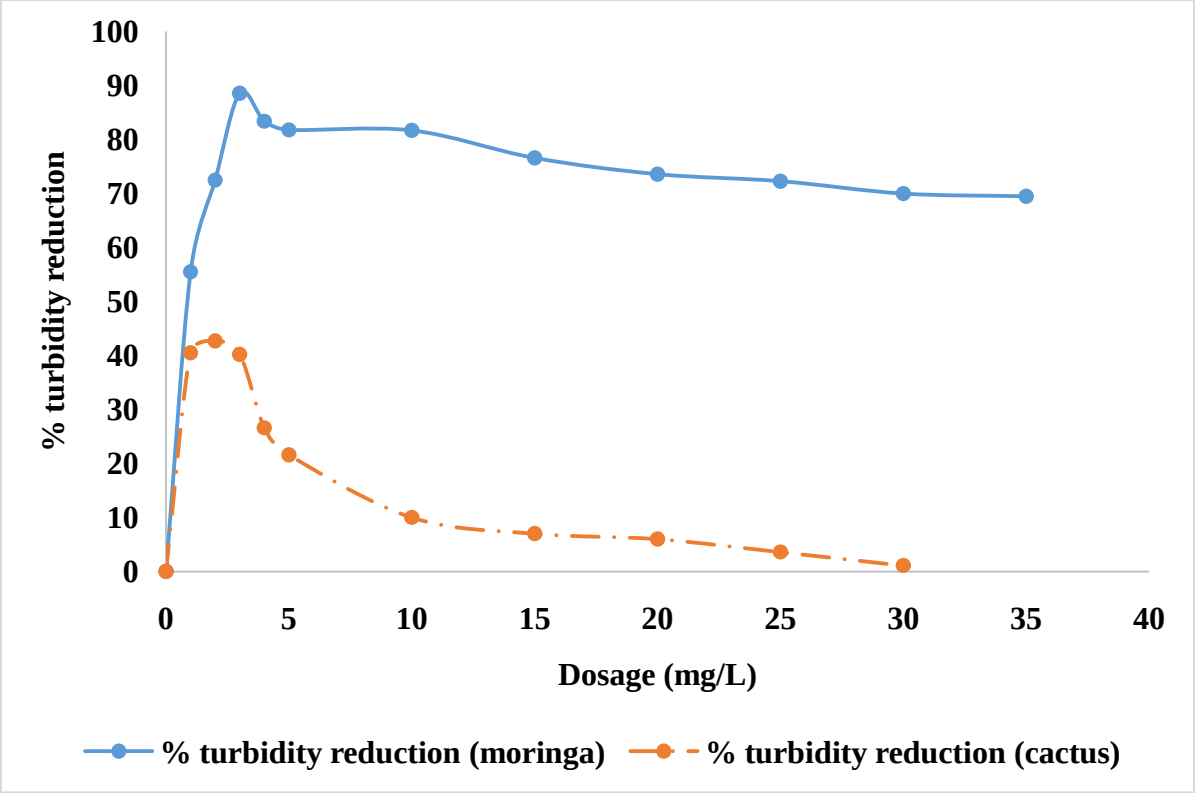


Figure 4.3: Effect of *Moringa* and cactus dosage on % turbidity reduction.

At a *Moringa* dosages of 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, and 35 mg/L, the % reduction in turbidity of the sample water was 55.5, 72.5, 88.6, 83.4, 81.8, 81.7, 76.6, 73.6, 72.3, 70, and 69.5% respectively (Appendix I: Table BI). This shows that the optimum dosage was 3 mg/L. This confirmed the findings of Muyibi, (1995) that shows *Moringa* is less efficient in low turbid water. At cactus mucilage dosage of 1, 2, 3, 4, 5, 15, 20, 25 and 30 mg/L, the % reduction in turbidity of the sample water was 40.5, 42.7, 40.2,26.6, 21.7, 7, 6, 3.6 and 1.1% respectively. This shows that the optimum dosage was 2 mg/L. The optimum dosage was used to set the dosage of *Moringa* and cactus mucilage at different blending ratio treatment. The maximum

allowable turbidity value for safe drinking water as declared by WHO and SON guideline is 5 NTU (WHO, 2011; SON 2007).The treatment at 3 mg/L of *Moringa* gave turbidity value within WHO and SON guideline whereas the treatment of cactus mucilage at 2 mg/L did not. In many water quality, impurity particles are dominated by negatively charge ions and cationic polyelectrolytes are the coagulating agent for *Moringa*(Gassenschmidt *et al*., 1995) while the coagulating agent for cactus mucilage is dominated by negatively charge uronic acid(Fox*et al*., 2012) Therefore, there would be more interaction between the water and *Moringa* than the interaction between the water and cactus mucilage. Thus, the settling rate of floc from water coagulated with *Moringa oleifera* seed extract was observed to settle faster than that of *Opuntia stricta* (cactus) on the initial turbidity. The faster the settling rate, the higher the turbidity reduction. This could explain why*Moringa oleifera* has higher percentage turbidity reduction than *Opuntia stricta* (cactus).

Studies show that the dominant mechanism in turbidity reduction by *Moringa oleifera* seed extract is adsorption and charge neutralization and inter particular bridging(Ndabigengesere *el al*., 1995; Gassenschmidt *et al*., 1995; Muyibi and Evison., 1995). The mechanism in *Opuntia stricta* cactus operates predominantly through a bridging-coagulation mechanism where solution particulates do not directly contact one another but are bound to a polymer-like material that originates from the cactus species.

4.4 Effect of *Moringa* dosage on Conductivity and Total Dissolved Solid

The conductivity and TDS of *Moringa oleifera* increased from 80.6 to 154.3 µS/cm and from 42.6 to 92.8 mg/L respectively as shown in Figure 4.4.

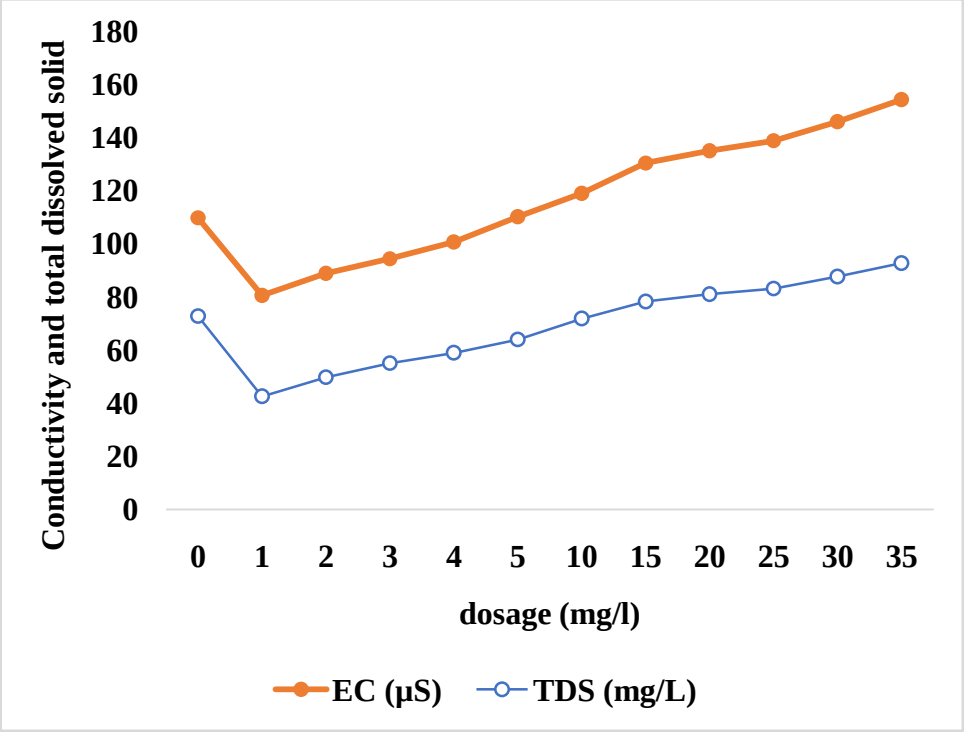


Figure4.4: Effect of *Moringa* dosage on conductivity and total dissolved solid.

Increase in*Moringa* coagulant dosage increased the conductivity and TDS of the treated water because more dissolve particles and ions are formed, this is in consonance with findings of Muhammad, (2011) who reported that increased in *Moringa oleifera* dosage lead to increase in conductivity and TDS. The percentage turbidity reduction of the treated surface water with *Moringa oleifera* coagulant increases, reaches the maximum and then decreases as the dosage of *Moringa oleifera* coagulant increases (Figure 4.3). As the dosage of *Moringa oleifera* coagulantincreases, the electrical conductivity and TDS increases (Figure 4.4; Appendix II: Figure I), resulting in the decreased of the percentage reduction in turbidity as shown in Figure

4.3. All though, all the treated water sample gave conductivity and TDS values below the WHO (2011) benchmarks of 1000µS/cm and 500 mg/L respectively. This was because the untreated surface water has conductivity and TDS values of 109.8µS/cm and 72.8mg/L which is lower than the WHO (2011)and SON (2007) benchmarks of 1000µS/cm and 500 mg/L. This is also in consonance with the findings of Muhammad(2011), who reported that the TDS of A.B.U dam river water is less than 200 mg/L.

4.5 Effect of Cactus mucilage Dosage on Conductivity and Total Dissolved Solid

The conductivity and TDS of cactus mucilage increased from 115.2 to 171.1 µS/cm and from 69.4 to 113 mg/L respectively as shown Figure 4.5.

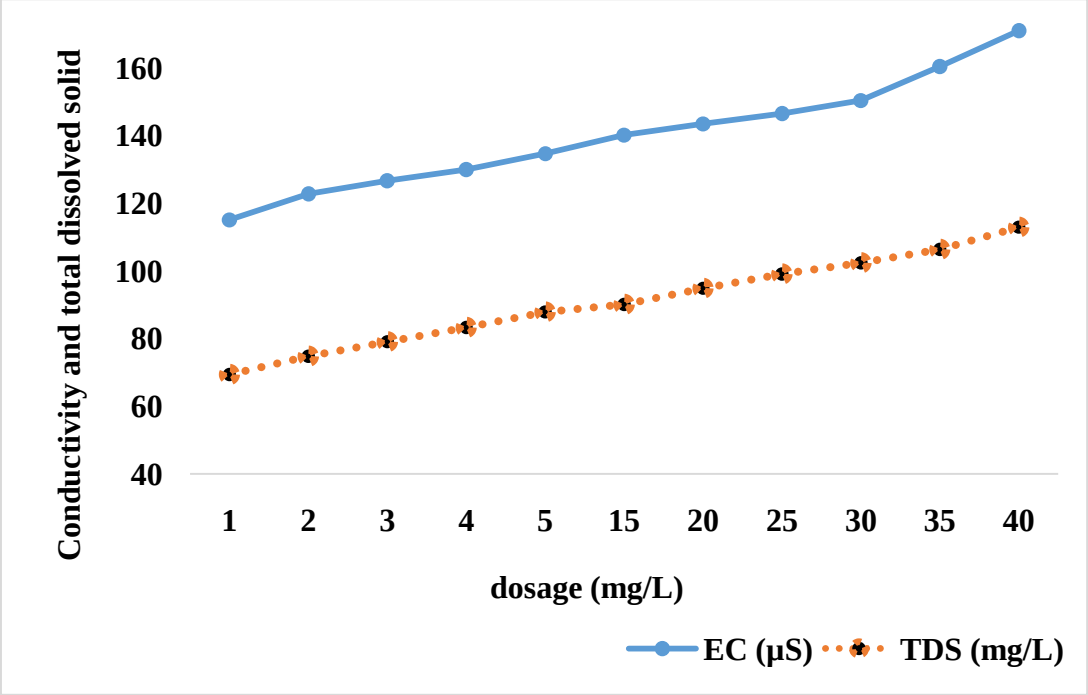


Figure4.5: Effect of cactus dosage on conductivity and TDS.

Increase in cactus mucilage coagulant dosage increased the conductivity and TDS of the treated surface water because more dissolve particles and ions are formed, this is in consonance with the

findings of Muhammad,(2011) who reported that increased in *Moringa oleifera* dosage lead to increase in conductivity and TDS. The percentage turbidity reduction of the water treated with cactus mucilage coagulant increases, reaches the maximum and then decreases as the dosage of cactus mucilage coagulant increases (Figure 4.3). As the dosage of cactus mucilage coagulant increases, the electrical conductivity and TDS increases (Figure 4.5; Appendix II: Figure II), resulting in the decreased of the percentage reduction as shown in Figure 4.3. All though, all the treated water sample gave conductivity and TDS values below the WHO (2011) and SON (2007) benchmarks of 1000µS/cm and 500 mg/L respectively. This was because the untreated surface water has conductivity and TDS values of 109.8µS/cm and 72.8mg/L which is lower than the WHO (2011) and SON (2007) benchmarks of 1000µS/cm and 500 mg/L. This is also in consonance with the findings of Department of national health and welfare (1993) and Muhammad (2011), who reported that the TDS ofriver water is less than 200 mg/L.

4.6Effect of *Moringa oleifera* and Cactus Mucilage Dosage on pH

The effect of pH on *Moringa oleifera* and cactus mucilage dosage is shown in Figure 4.6. The recommended acceptable range of pH for drinking water as specified by WHO, (2011) and SON (2007) is between 6.5 and 8.5.

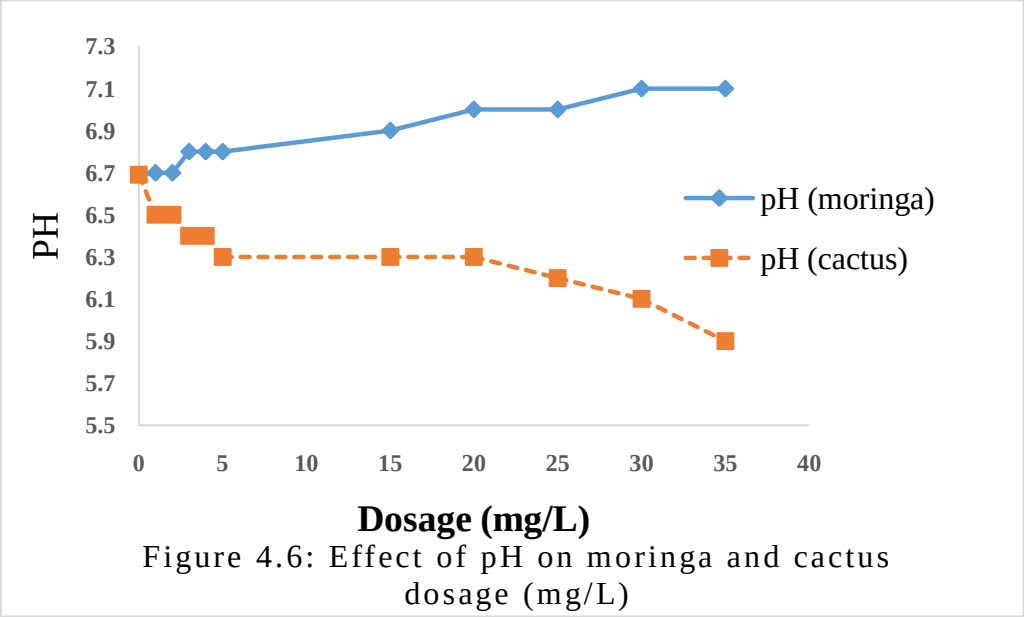


Figure 4.6: Effect of pH on moringa and cactus dosage (mg/L)

The pH increase slightly from 6.69 to 7.1 after *Moringa* extract sedimentation. Ndabigengesere *et. al*., (1995), reported that the action of *Moringa oleifera* as a coagulant lies in the presence of water soluble cationic proteins in its seeds. This suggests that in water, the basic amino acids present in the protein of *Moringa* would accept a proton from water resulting in the release of a hydroxyl group making the solution basic. This accounted for the basic pH values observed for *Moringa* treatments compared with cactus mucilage treatments.

Cactus mucilage dosage shows that all the treatments gave a pH range from 5.9 to 6.69.The pH values were decreasing as the concentration of the cactus mucilage increased. This was attributed to the fact that cactus mucilage contains galactunic acid which lowered the pH levels, reported by Buttice *et al*.,(2010).There was no significant effect in pH when cactus and *Moringa* were combined as shown in Table 4.4.

Table4.4: Physicochemical properties of *Moringa* and cactus treated surface water.

Dose C+M (mg/l)	Turb. (NTU)	% reduction Turb.	pH	Cond. (µS)	TDS (mg/l)	T (^{0}C)	COD (mg/l)	BOD (mg/l)
Untreated	44	0	6.69	109.8	67.5	24.5	140	7.7
80:20	13.1	70.2	6.57	112.5	68.1	25.5	80	3.6
60:40	12.4	71.8	6.58	112.2	67.7	25.5	63	3.0
40:60	5.1	86.1	6.61	110.5	67.1	25.0	48	2.8
20:80	8.9	79.7	6.65	110.3	66.7	25.1	32	2.7

Key: C=cactus, M=Moringa

2 mg/L dosage was used to set the ratio of cactus mucilage to Moringa combination ratio at 80:20, 60:40, 40:60, and 20:80 as presented in Table 4.4, resulting in turbidity of 13.1, 12.4, 5.1 and 8.9 NTU respectively. It could be noticed that the total dissolved solids, conductivity and pH were not affected by the combination ratio of cactus to Moringa. This could be as a result of the homogeneous mixture of the coagulants. The TDS level (ranged between 66.7 to 68.1 mg/L) was almost similar to that of the untreated water sample that possessed 67.5 mg/L. Similar, findings were also observed in case of electric conductivity (EC). All values ranged between 109.8-112.5 µS/cm being similar to untreated water sample (109.8 µS/cm). The pH level (ranged between 6.57 to 6.69) was almost similar to that of the untreated water sample possessed 6.69. This is in agreement with the findings of Mohamed (2014), who reported no significant change in TDS, EC and pH for water samples treated with *Moringa oleifera* and calcium hypochlorite combined.

Cactus mucilage to *Moringa* combination ratio at 80:20, 60:40, 40:60 and 20:80, recorded COD values of 80, 63, 48 and 32 mg/L respectively. The COD values decreases with increase in Moringa and decrease in cactus mucilage dosage. The untreated water had COD value of 140 mg/L which showed that there was a reduction in organic and inorganic matter in the treated water. Cactus mucilage to Moringa combination ratio at 80:20, 60:40, 40:60 and 20:80, recorded

BOD values of 3.6, 3.0, 2.8 and 2.7 mg/L respectively. The untreated water has BOD value of 7.7 mg/L which shows that there is a reduction in organic matter in the treated water. The COD result is not in support of the previous findings Ghebremichael, (2005); Ndabigengesere and Narasiah, (1998) that the use of *Moringa oleifera* leads generally to an increase in COD levels in the treated water. This could be due to the combination of cactus mucilage and*Moringa* which lead to blending of the active agents in cactus mucilage and *Moringa*. Biochemical oxygen demand is a chemical procedure for determining how fast biological organisms use up oxygen in a body of water. The mucilage from the cactus either engulf the bacteria and starves them to death, or it binds to the bacteria and causes them to settle out of the water. The combination of arabinose, xylose, galactose, rhamnose, galacturonic acids, fluorine, chlorine, 4-(4'-O-acetyl- -L rhamnopyranosyloxy) benzyl isothiocy-anate (Abram *et al*., 1993), 4-(-L rhamnopyranosyloxy) benzyl isothiocy-anate (Abuye *et al*., 1999), niazimicin (Akhtar *et al*., 1995), pterygospermin (Anderson *et al*., 1986), benzyl isothiocyanate (Anwar *et al*., 2003) and 4-(-L-rhamnopyranosyloxy) benzyl glucosinolate (Asres, 1995) are responsible for the reduction in BOD and COD activity for the blend of *Moringa* and *Opuntia stricta*(cactus) coagulant. Decrease in COD is an indicator of reduction in organic and inorganic pollutants. Also, increase in coagulation lead to decrease in BOD and COD activity.

Table 4.5: *Moringa oleifera* bacteria analysis for treatedsurface water sample

Dosage (mg/L)	No. of Coliform	Confirmed test	Complete test	% reduction in coliform
0	82	+	+(E.coli was detected)	
1	46	+	+	43.9
2	32	+	+	60.9
3	7	+	-	91.4
4	14	+	-	82.9
5	20	+	+	75.6

Keys: + means presence of E. coli; - means absence of E. coli.

From Table 4.5, at *Moringa* dosages of 1, 2, 3, 4, and 5 mg/L, the % reduction in coliform was 43.9, 60.9, 91.4, 82.9 and 75.6% respectively. This shows that the optimum dosage is at 3 mg/L. This is in agreement with Madsen *et al.* (1987) who reported a 90% reduction in the bacterial load of water treated with *Moringa* seed paste. The active ingredients in *Moringa* seeds are water soluble cationic peptide as seen from their coagulation and antimicrobial activities(Ndabigengesere *et al*., 1995).

The mode of *Moringa* seed extract action on E. coli cells was explained as rupturing of cells and damaging the intercellular components, when water dips into the cell which causes it to swell more and burst leading to death. The *Moringa oleifera* protocol can produce potable water of higher quality than that of the original source, but is unable to guaranteebacteria-free water immediately after 3 days of treatment. Finally, it could be concluded that treated water with *Moringa oleifera*seed extract at varying concentrations lead to significantly drastic reduction in water microbial counts. The antimicrobial activity of *Moringa oleifera* is dependent on the dosage. The active agents in *Moringa* that possesses antimicrobial activity have been reported to include: 4-(4'-O-acetyl- -L rhamnopyranosyloxy) benzyl isothiocy-anate (Abram *et al*., 1993), 4-(-L rhamnopyranosyloxy) benzyl isothiocy-anate (Abuye *et al*., 1999), niazimicin (Akhtar *et al*., 1995), pterygospermin (Anderson *et al*., 1986), benzyl isothiocyanate (Anwar *et al*., 2003) and 4-(-L-rhamnopyranosyloxy) benzyl glucosinolate (Asres, 1995)

Table 4.6: Cactus Mucilage bacteria analysis for treated surface water sample.

Dosage (mg/L)	No. of Coliform	Confirmed test	Complete test	% reduction in coliform
0	82	+	+	
1	6	+	-	92.7
2	4	+	-	95.1

3	8	+	-	90.2
4	20	+	+	75.6
5	30	+	+	63.4

Keys: + means presence of E. coli; - means absence of E. coli.

From Table 4.6: at cactus mucilage dosage of 1, 2, 3, 4 and 5 mg/L, the % reduction in coliform were 92.7, 95.1, 90.2, 88 and 79% respectively. This shows that the optimum dosage is at 2 mg/L, which was used to set the dosage of the ratio of cactus to *Moringa* at 80:20, 60:40, 40:60 and 20:80.Previous studies have shown cactus mucilage contains carbohydrates such as arabinose, xylose, galactose, rhamnose and galacturonic acids (Butticee*t al*., 2010). The FTIR anlysis of cactus mucilage also indicate the presence of fluorine. Galacturonic acid could possibly be the active ingredient that affords the coagulation capability of *Opuntia* specie whereas the combination of arabinose, xylose, galactose, rhamnose,galacturonic acids and fluorine is responsible for the antibacterial activity. This is in consonance with the findings of Alcantar, (2007)who observed 98% reduction of bacteria from water when treated with cactus mucilage. Alcantar, (2007) recorded that cactus mucilage engulf around the bacteria in the water, depriving them of their food and starving them to death. The cactus mucilage also inhibit the growth of the bacteria.

Table 4.7: Bacteria analysis of the treated surface water sample for the blending of cactus mucilage (C) and *Moringa oleifera* (M)

Dosage (mg/L) C+M	No. of Coliform	Confirmed test	Complete test	% reduction in coliform
0:0	82	+	+	
80:20	6	+	-	92.7
60:40	5	+	-	94.0
40:60	2	+	-	97.5
20:80	3	+	-	96.3

Keys: + means presence of E. coli; - means absence of E. coli. C=cactus, M=Moringa

From Table 4.7: at cactus to *Moringa* ratio of 80:20, 60:40, 40:60 and 20:80, the % reduction in coliform was 92.7, 94, 96.3 and 97.5% respectively. This means that the synergistic effect of cactus mucilage and *Moringa* coagulant could be used as natural disinfectant. This is in consonance with the findings of Mohamed, (2014) that shows 97% reduction of coliform when the combination of*Moringa* and calcium hypochlorite was used. The antibacterial activity could be due to the present of chlorine and fluorine in *Moringa* and fluorine in cactus mucilage as confirmed in the FTIR analysis (Figure 4.1 and 4.2). The active agents *Moringa* seeds solution are water soluble materials as seen from their coagulation and antimicrobial activities of the raw turbid water. Thus, one can easily recover turbid water with low microbial concentration consumption.

4.7 Determination of the Elongation of the Coagulated Treated Surface Water

The determination of the elongation of the coagulated treated surface water is shown in Figure 4.7.

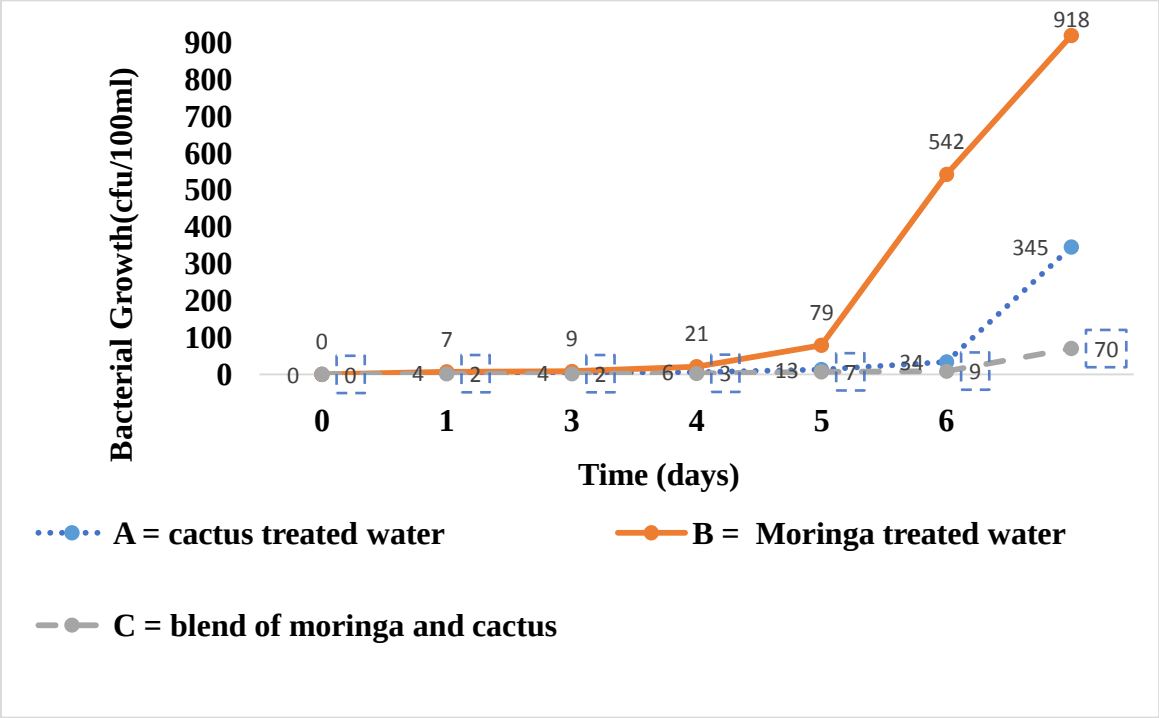


Figure4.7: Determination of the Elongation of the Coagulated Treated Surface Water

The determination of the elongation of the coagulated treated surface water is shown in Figure 4.7.

The treated water samples were found to be contaminated above WHO standards of 10cfu at day 3 for both *Moringa* and cactus coagulant while the blend of the coagulants lasted for 5 days (Appendix I: Table B2). The bacteria re-growth rate is faster in *Moringa* than in cactus while cactus and Moringa coagulant blend gave the least bacteria re-growth rate. The bacteria re-growth rate is the rate at which bacteria grow in the treated water sample.The surface water treated was not safe after 48 hours as a result of bacterial re-growth, this confirms earlier works of Eilert *et al*., (1981), Jahn (1986), Madsen *et al*., (1987), Folkard *et al*., (1989), Bina. (1991), Schwartz. (2000) and Doerr. (2005). This bacteria regrowth is ascribed to two causes; the increase in the nutrients in the settled solids/sludge after coagulation from which the bacteria feed and multiply rapidly, and the mechanism of bacteria removal is that the bacteria being

carried down with the flocs and settling with the solids/sludge during the coagulation and settling process. The bacteria re-growthrate is faster in Moringa than *Opuntia stricta* (cactus)treated waterbecause the dissolved Moringa seed cake has higher solubility rate of dissolved nutrients than the dissolve nutrients in *Opuntia stricta*(cactus)(Oluduro *et al*.,2007). The concentration of the nutrients increases as the water stay longer because more nutrients are dissolved in the water. This condition provides a good ground for bacteria to feed and multiply rapidly.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1Conclusion

Based on the turbidity, conductivity, TDS, pH, COD, BOD, bacteria (E.coli) and the determination of the elongation of the coagulated treated water analysis obtained in this work, the following conclusions are made:

1. For raw surface water with turbidity of 44 NTU, the optimum doses of *Moringa oleifera* and *Opuntia stricta* (cactus)were found to be, 3 mL and 2 mL respectively. Using *Moringa oleifera and Opuntia stricta* (cactus) 88.6%, and 42.7% reduction in turbidity was achieved, respectively after coagulation. Also, 86.1% turbidity reduction was recorded for the blend of cactus mucilage and *Moringa oleifera* at blending ratio of 40:60.
2. The percentage increased in conductivity and TDS of *Moringa oleifera* treatedsurface water were 91.4% and 54.1% respectively. The percentage increased inconductivity and TDS of *Opuntia stricta* (cactus) mucilagetreated surface water were 48.5% and 62.8% respectively. The blend of *Moringa oleifera* andcactus mucilage treated surface water gave the percentage increased in conductivity and TDS of 2.7% and 3.0% respectively.
3. *Moringa oleifera*coagulant increased the pH of the surface water from 6.69 to 7.1 while *Opuntia stricta* (cactus) mucilage coagulant reduced the pH from 6.69 to 5.9. The pH for the blend of *Moringa oleifera* and cactus mucilage was from 6.57 to 6.65. There was no significant effect on the pH when blending *Moringa oleifera* seed cake extract and *opuntia stricta* (cactus) mucilage to the surface water.
4. The highest percentage removal of COD and BOD were 77.1% and 64.9% respectively for the blend of *Moringa oleifera* and *Opuntia stricta* (cactus) mucilage. Bacterial count was reduced from 82 cells per 100 ml to 7 cells per 100 ml for *Moringa,* to 4 cells per

100 ml for cactus and to 2 cells per 100 ml for the blend. On the other hand, the elongation of the coagulated treated surface water with *Moringa oleifera*, *Opuntia stricta* (cactus) and the blend *Moringa oleifera* and *Opuntia stricta* (cactus) were 3 days, 3 days and 5 days, respectively.

5.2Recommendations

1. Study on the efficacy of *Moringa oleifera* and *Opuntia stricta*(cactus) on heavy metal separation.
2. Study on the efficacy of *Moringa oleifera* and *Opuntia stricta* (cactus) on waste water should be done.
3. *Moringa oliefera* seed extracts and cactus mucilage should be used hence forth as primary coagulants for the treatment of surface raw water.
4. Research should be performed in order to improve on the elongation of the coagulated treated surface water.
5. The economic analysis on the study of blending *Moringa oleifera* and Opuntia stricta (cactus) mucilage on surface water should be carried out.

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APPENDIX I

Table B1: Percentage turbidity reduction of *Moringa* and cactus treated surface water.

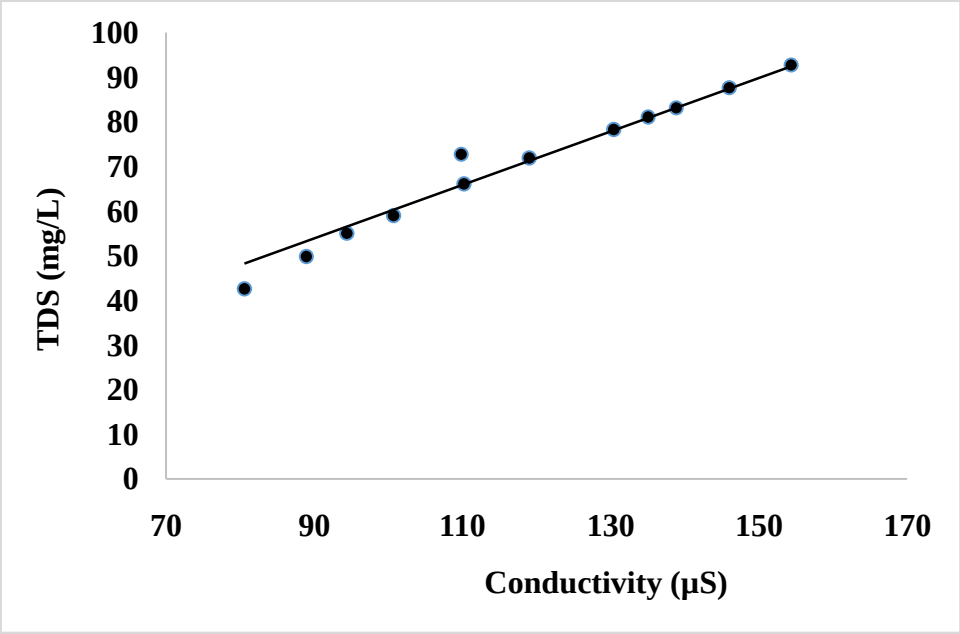
Dosage (mg/L)	Moringa turbidity (NTU)	Cactus mucilage turbidity (NTU)	% Moringa turbidity reduction	% cactus turbidity reduction
0	44	44	0	0
1	19.6	26.2	55.5	40.5
2	12.1	25.2	72.5	42.7
3	5.03	26.3	88.6	40.2
4	7.3	32.3	83.4	26.6
5	8.02	34.5	81.8	21.6
10	8.06	39.6	81.7	10
15	10.3	40.92	76.6	7
20	11.6	41.36	73.6	6
25	12.2	42.42	72.3	3.6
30	13.2	43.52	70	1.1

Table B2: Elongation of the coagulated treated surface water.

Time (days)	A	B	C
1	4	7	2
2	4	9	2
3	6	21	3
4	13	79	7
5	34	542	9
6	345	918	70

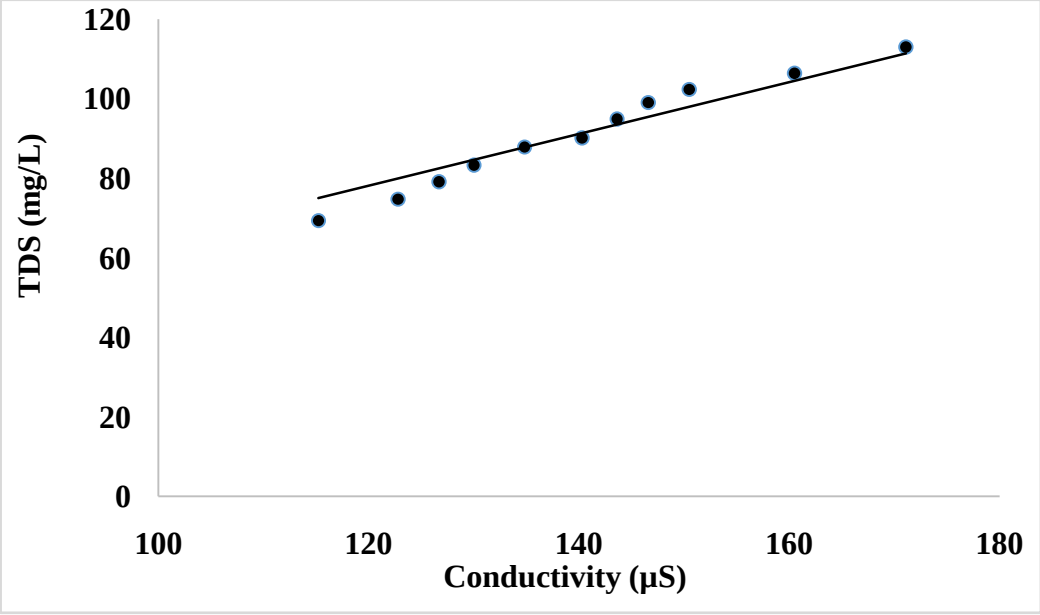
A=cactus treated water, B=Moringa treated water, C= Moringa and cactus treated water.

APPENDIX II



y=0.5989x; R^2 = 0.964. Keys: y=TDS, x=Conductivity

Figure I: Effect of conductivity on TDS of Moringa treated surface water.



y=0.6508x; R^2 = 0.9392. Keys: y=TDS, x=Conductivity

Figure II: Effect of conductivity on TDS of cactus treated surface water.