MAN, ENVIRONMENT AND WATER - The *Moringa oleifera (Zogale)* Intervention

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SUMMARY OF PRESENTER'S BIODATA

Engr. Professor Mustapha Hassan Bichi was born in Bichi, Kano State on 23rd September, 1962. He attended Hagagawa Primary School, Bichi and thereafter, gained admission into Government Secondary School, Dawakin Kudu. After very competitive examinations, he was then transferred, as part of the first set of students, to the prestigious Science Secondary School, Dawakin Tofa where he obtained his WASC with Division One. After graduating in the pioneering batch of Civil Engineering students with First Class Honours B.Eng. (Civil) degree in 1985, he began his career in the Department of Civil Engineering, Bayero University Kano as a Graduate Assistant in 1986, and rose to become a professor of Water Resources and Environmental Engineering in October 2013.

He obtained his M.Eng. (Water Resources and Environmental Engineering) degree from University of Benin in Benin-City, and was the first recipient of PhD in Civil Engineering from the prestigious Bayero University Kano. He is a COREN-registered Engineer; a Fellow of the Nigerian Society of Engineers (FNSE); Member, Nigerian Institution of Civil Engineers (MNICE); Member, Nigerian Environmental Society (MNES); Member, Nigerian Water Supply Association (MNWSA); Member, Nigerian Association of Hydrological Sciences (MNAHS); Member, Waste Management Society of Nigeria (MWAMASON), and Member, International Association of Small Hydro-power Schemes (MIASHPS).

In the course of his academic career in the University, he has served on over 60 committees and task forces, and held several academic and administrative responsibilities, including:

- Member, Bayero University Governing Council
- Dean, Faculty of Technology (Now Engineering)
- Head, Department of Civil Engineering
- Chairman, University Transport Management Committee, and
- Chairman, University Staff Housing Allocation and Maintenance Committee

Professor Bichi has supervised over one hundred and seventy (170) students at both undergraduate and postgraduate levels including 30 M. Eng. dissertations, 15 MDS dissertations, 35 PGDCE projects, 30 PDDS projects, and over 60 B. Eng. projects in diverse areas of Water Resources and Environmental Engineering. He has to his credit over ninety (90) publications in journals, conference proceedings, and technical reports, comprising 4 book chapters, 21 articles in local and international journals, 23 conference/seminar papers, and over 32 technical reports. He has attended over 40 national and international seminars and conferences, including 5 international short courses.

He has served as external examiner in 7 universities and polytechnics at both undergraduate and postgraduate levels, including 3 PhD Theses and 13 Master's degree dissertations. He has also served as an external assessor for the promotion of 5 professors and 4 associate professors across 5 universities, including Ahmadu Bello University, Zaria; Abubakar Tafawa Balewa University, Bauchi; Federal University of Technology, Owerri; Federal University of Technology, Minna; and University of Benin, Benin-City.

In terms of community service, Professor Bichi has served on over 40 non-university committees and boards of various organizations, including the Federal Government of Nigeria, Kano State Government, Council for the Regulation of Engineering in Nigeria (COREN), National Universities Commission (NUC), Academic Staff Union of Universities (ASUU), and the Nigerian Society of Engineers (NSE). Some of these include:

- Commonwealth Scholarship Interview Panel
- Kano State Polytechnic Governing Council
- COREN Visitation Panels to various universities
- COREN Engineering Regulation Monitoring (ERM) Team
- NUC Accreditation Panels to various universities
- ASUU Tender's Board
- Chief Examiner of NSE Kano Centre, and
- Currently, Vice-Chairman, NSE Kabuga Branch

Professionally, Engr. Professor Bichi has over 60 projects to his credit in investigation, design, and construction supervision in various areas of civil engineering, including:

- Design of Medium Earth Dam across Duddurun River in Kano State
- Design and Construction of Complete Water Supply Schemes at Jalomi, Galadimawa, and Gakori Small Towns in Kaugama L.G.A., Jigawa State
- Design and Construction of Complete Water Supply Scheme at Rosso Small Town in Gwaram L.G.A., Jigawa State
- Complete EIA for Zobe Water Supply Project in Katsina State
- Complete EIA for Kwankwasiyya Village in Kano State
- Hydrogeological Investigation at the Mine Site of Obajana Cement Plc for Dangote Cement in Kogi State

- ☞ Design of Water Supply Extensions to Wamba, Andaha, and Nasarawa-Eggon Towns in Nasarawa State, and
- ☞ Design and Construction Supervision of the 10,000 litre Capacity Twin Underground Tanks at the New Campus of Bayero University Kano

Professor Bichi is a recipient of over 25 distinguished awards, fellowships, prices, and certificates of honour, and professional training, among which are:

- ☞ Best graduating student in Civil Engineering at Bayero University in 1984/85 session
- ☞ British Council fellowship to Hydraulic Research Institute, Wallingford, UK in 1987
- ☞ Federal Government Scholarship in 1988
- ☞ Best M.Eng Student in Engineering Hydrology, University of Benin, 1994
- ☞ Bayero University fellowships at various times, and
- ☞ MacArthur Foundation fellowships to Malaysia and Israel in 2011 and 2013 respectively
- ☞ Civil & Mechanical Engineering Training Programme, Robert H. Smith School of Business, University of Maryland, USA; September 2013.
- ☞ Water and Crop Management Training; Galilee International Management Institute, Israel; 24th April – 9th May 2013.
- ☞ Planning and Management of Water Supply System for Small Communities; Moteging Foundation and NES Kaduna State Branch, Nov. 1993.
- ☞ Geotechnics and Construction Technology Course; Laing Technology Group; Mill Hill, London, Feb-March, 1987

Professor Bichi is happily married with children.

MAN, ENVIRONMENT AND WATER - The *Moringa oleifera (Zogale)* Intervention

PREAMBLE

It is with humility and elation that I stand before you this morning to deliver this Inaugural Lecture titled: **Man, Environment and Water – The *Moringa oleifera (Zogale)* Intervention**. It is an opportunity for me to inform colleagues and the general public about my research career so far, my journey to professorship, and my future research directions. I would like to take you on a journey through the interactions of man with the environment and water, and how *Moringa Oleifera (Zogale)* intervenes in this regard.

INTRODUCTION

Man, Who is He?

The French philosopher, Pascal, exclaims *"What a chimera is man but a bundle of contradiction"!* He is great but at the same time weak and miserable, with insatiable desires. Man is the greatest being in the universe, yet he is so fragile that a little thing, just one bullet, for example, can destroy him. Man's whole life and activities are aimed at fulfilling his desires. This has led into man's quest for improving his standard of living with spectacular upsurge in the developments in science and technology, resulting into an intractable interaction with his environment.

Man and Environment

Even in the absence of man, the environment has been undergoing changes naturally. This has been effected by natural phenomenon including flooding, wild fires, volcanic eruption, earth quake, drought, desertification, wind erosion, and deposition. Man's effort at improving his standard of living has led to spectacular developments in science and technology. Although these efforts have resulted in the improvement of standard of living, on the other hand, they have also led to devastation and degradation of the environment. Bichi (1997) documented some of these consequences, including:

i) Solids leading to reduction of Dissolved Oxygen (DO) levels in water bodies.
ii) Oil spills restricting re-oxygenation of water and eventual loss of aquatic life.
iii) Wild life extinction and translocation.
iv) Solid wastes resulting in blockage of drains and floods.
v) Thermal pollution leading to loss of aquatic life.
vi) Photochemical smog impairing visibility and breaking down of rubber products.

vii) Physiological problems in plants and animals
viii) Acid rains leading to degradation of metal surfaces
ix) Chemical toxins being transferred into plant and animals
x) Radiation effects on plants and animals
xi) Eutrophication in water bodies, and
xii) Pathogenic organisms resulting in various diseases in man and animals

Bichi (2004a) also documented some of the losses due to solid wastes and floods in some major towns in Jigawa state, and in 2013 in Kano state (Bichi and Amatobi, 2013a).

Domestic and industrial effluents have led to the degradation of the environment and water resources. The major culprits include tanneries, abattoirs, and various industries that eject heavy metals along with their wastes. These create large dissolved oxygen (DO) deficits in water bodies resulting in the death and extinction of aquatic life and as well, cause various ailments in man and animals resulting from ingestion of heavy metals through the food chain. Bichi and Anyata (1999) and Bichi (2000) documented industrial pollution in the Jakara and Kano River basins, while Bichi (2013a) investigated the consequences of such practices in Kano. Bichi (1998) also documented the public health impacts of the industrial waste discharges from the industrial areas of Kano resulting in increased cases of bilharzia, dysentery, cholera, typhoid fever, and skin infections.

Vice-Chancellor, Sir, in Kano, the discharge of heavy metals in industrial effluents from Sharada and Challawa Industrial Estates into the environment has also attracted our attention (Figure 1). Dan'azumi and Bichi (2010a) documented the heavy metal profile in the Kano River which is the main source of drinking water for metropolitan Kano. The study found that the levels of chromium (Cr^{6+}), lead (Pb), copper (Cu), iron (Fe^{3+}), zinc (Zn), and manganese (Mn) have all exceeded the National Environmental Standard Regulation and Enforcement Agency (NESREA) and World Health Organization (WHO) maximum limits. Dan'azumi and Bichi (2010b) also traced the transfer of these heavy metals into the drinking water from the Taburawa Water Treatment Plant in Kano. This subsequently led to the relocation of the intake point of the treatment plant to a safer location upstream.

Heavy metals in soils and water for irrigation can also interfere with growth uptake of nutrients by plants (Aikman, 1983) and can also be transferred into humans through the crops grown as such. Bichi and Farouk (2013a) documented the heavy metals profile in surface and ground waters used for the irrigation of vegetable crops along the River Tatsawarki in the Kano River basin. They found these heavy metals in the soils used for irrigation along the river (Bichi and Faouk, 2013b). These heavy metals have also been seen in the vegetable crops irrigated with the waste water and grown on the contaminated soils along the river (Bichi and Farouk, 2013c).

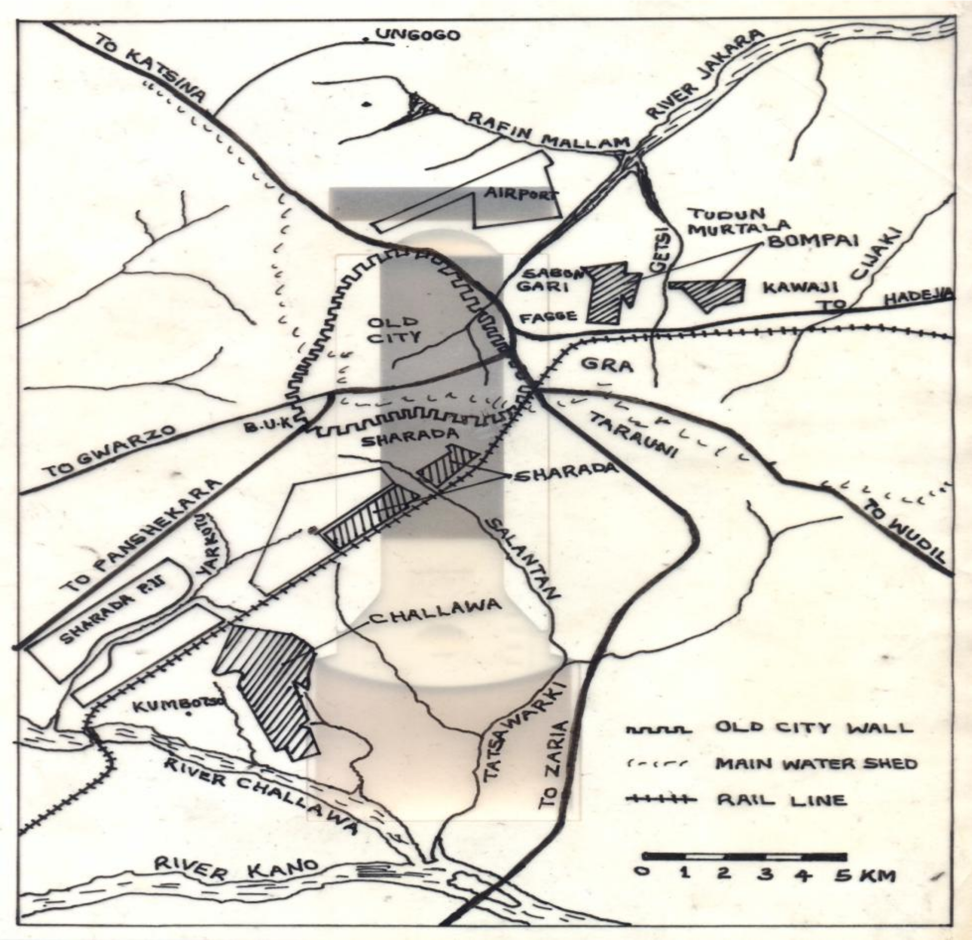

Figure 1: *Kano Industrial Areas and River Basins*

Of course, whereas deficiencies of reasonable quantities of these elements in humans give rise to malnutrition problems, excessive quantities of these, whether eaten in vegetable matter or animal food, can seriously affect health (Murry, 1976). Excessive quantity of chromium is known to cause lung problems; Arsenic leads to skin, liver, and intestinal disorders; hydrocarbons lead to bladder problems; lead destroys haemoglobin and causes neurological disorders; and hydrogen sulphide affects the central nervous system and cuts off breathing (Muir, 1976). Excessive amounts of copper damages the liver and central nervous system; cadmium causes renal and heart disease, vomiting, and diarrhoea (Butler, 1979). Cobolt leads to dermatitis and skin sensitivity (Irving San, 1978). Some cases of diarrhoea have also been attributed to excessive cadmium discharges.

These diseases are most likely to flourish in the industrial areas since these metals are not readily removed nor detoxified by any metabolic activities. Furthermore, these substances stay in the environment and are transferred, directly or indirectly, into the human body (Higgens et al., 1979). In order to address some of these problems, domestic and industrial wastes need to be treated in order to reduce their pollution loads before being discharged into the natural water courses. The treatment requires the use of chemicals which also further lead to new environmental problems. *Moringa oleifera* has been found to help in this regard, and we have investigated some its uses in this.

Man and Water

Man has been known to survive without food for months. But without water, the life expectancy of man is just a matter of days. The National Academy of Sciences, Engineering, and Medicine determined that an adequate daily fluid intake is about 15.5 cups (3.7 litres) of fluids for men and about 11.5 cups (2.7 litres) of fluids a day for women (NASEM, 2017). However, man requires not just water, but water of potable quality. Certain impurities in water can be as deadly to man as no water at all. Thus, all waters for drinking must satisfy a minimum quality requirement. This is achieved through water treatment. In addition, the water must also be readily available and affordable (Bichi, 2003; Bichi, 2010; Bichi, 2013b; Bichi and Amatobi, 2013b).

River water employed for human consumption and general household and industrial usage can be highly turbid particularly in the rainy season. This carries river silt, solid materials, bacteria and other micro-organisms. It is thus paramount to remove as much of this suspended matter as possible prior to disinfection and subsequent consumption. This is generally achieved by the addition of coagulants to the raw water, within a controlled treatment sequence. In many developing countries, these chemical coagulants such as alum, synthetic polyelectrolytes as coagulant aids, lime for softening and p^H correction, are either not available locally or are imported using scarce foreign exchange. A viable alternative for these is the use of *M. oleifera* seed extract as a natural coagulant and softening agent.

Perhaps the gravest of all dangers to which water supplies can be exposed is contamination by pathogenic organisms. These result in the cause of various water-borne and water related diseases with devastating consequence on health. Disinfection is a chemical process for eliminating pathogenic microbes from an environment. Chemical agents that have been used as disinfectants include halogens, phenols, alcohols, heavy metals, dyes, soap and detergents, ammonia compounds, hydrogen peroxide, and various alkalis and acids (Metcalf and Eddy, 1991). The most common of these are the oxidizing chemicals, and chlorine is the most universally used. However, chlorine has problem of decay and reduced concentration as the water flows through the distribution network (Devarakonda et al., 2010). It also has the potential for forming carcinogenic and mutagenic disinfection by-products (DBPs) (Goveas et al., 2010).

Disinfectants and their by-products may also be associated with increased risks of cardiovascular diseases, cancers, and birth defects. Although such risks are low, Arbuckle et al., (2002) noted that associations with such diseases could not be ruled out. These, and the high cost of chlorine, especially in developing countries where it needs to be imported, makes it imperative to look for cheaper alternatives that are also environmentally friendly. Studies by Eilert et al (1981), Thilza, et al (2010), and Bukar et al (2010) identified the presence of an active antimicrobial agent in *Moringa oleifera* seeds.

The *Moringa Oleifera (oleifera)* Tree

"… Zogale gandi mataimaki
Ana zagar ka, kana tsaye
Kana kallon jama'ar gari……"

Moringa oleifera, commonly referred to as Moringa, is the most widely cultivated variety of the genus *Moringa*. A native of the sub-Himalayan regions of North-West India, *Moringa oleifera* (*M. oleifera*) is now indigenous to many countries in Africa, Arabia, South East Asia, the Pacific and Caribbean Islands; and South America (NRC, 2006). The tree itself is rather slender with drooping branches that grows to approximately 10m in height. However, it normally is cut back annually to one meter or less, and allowed to regrow, so that pods and leaves remain within reach. *Moringaceae* is a single genus family with 14 known species. Of these, *Moringa* *oleifera* Lam (syns. *Moringa pterygosperma* Gaertn.) is the most widely known and utilized species. Commonly known as the 'horse-radish' tree (arising from the taste of a condiment prepared from the roots) or 'drumstick' tree (arising from the shape of the pods), *M. oleifera* has a host of other country-specific vernacular names (*Zogale* in Northern Nigeria), an indication of the significance of the tree around the world.

Rajangam (2001) reported that India is the largest producer of Moringa with an annual production of 1.1 to 1.3 million tonnes of tender fruits from an area of 380 km^2. Among the states, Andhra Pradesh leads in both area and production (156.65 km^2) followed by Karnataka (102.8 km^2) and Tamil Nadu (74.08 km^2). In other states, it occupies an area of 46.13 km^2. Tamil Nadu is the pioneering state insomuch as it has varied genotypes from diversified geographical areas, as well as introductions from Sri Lanka.

Description of M. oleifera

National Research Council (NRC, 2006) reported that Moringa has a tuberous tap root, whose presence helps explain the species' tolerance to drought conditions. Normally umbrella shaped, the tree comes with a lax crown of graceful, airy foliage, whose feathery effect is due to the finely trip innate division of the leaves. The leaves are densely crowded at the tops of the branchlets (Figure 2). Depending on climate, the foliage is evergreen or deciduous and, from a distance, reminiscent of a legume like leucaena or calliandra. In season, the tree is enshrouded in creamy white, honey-scented flowers arranged in drooping panicles 10-30 cm long. Flowers are insect pollinated and "require a large number of insect visitations," with carpenter bees being the most common guests (Bhattacharya, et al 2004). Flowers and fruits (pods) can be produced twice a year; though in many places, flowering and fruiting occur all year-round. The fruits are initially light green, slim and tender, eventually turning dark green and firm. Depending on genotype, they are up to 120 cm long. While most are straight, a few are wavy and some curly. In cross-section, most are rectangular but a number are triangular and some are round. Fully mature, the dried seeds are surrounded by a lightly wooded shell with three papery wings.

Figure 2: *Leaves of M. Oleifera.* (Source: NRC (2006)

Species Information
***Botanical Name*:** *Moringa oleifera* Lamarck
***Synonyms*:** *Moringa pterygosperma* Gaertner; *Moringa zeylanica* Pers.; *Guilandina moringa* L.
***Family*:** Moringaceae

Because of its wide distribution nature, Moringa has various common names in various localities. Some of these, according to National Research Council (2006) are:

English:	moringa, horse radish tree, drumstick tree, sujuna, ben tree, ben oil tree
French:	ben ailé, ben oléifère, benzolive, arbre radis du cheval
Spanish:	ben, árbol del ben, paraiso, morango, Moringa;
Portuguese:	acácia branca, marungo, muringa, moringuiero; cedro (Brazil)
Arabic:	ruwag, alim, halim, shagara al ruwag (Sudan)
Swahili:	mzunze, mlonge, mjungu moto, mboga chungu, shingo
Yoruba & Nago:	ewè igbale, èwè ile, èwè oyibo, agun oyibo, ayun manyieninu, ayèrè oyibo;
Fulfulde:	gawara, konamarade, rini maka, habiwal hausa;
Hausa:	zogale, zogale-gandi, bagaruwar maka, bagaruwar masar, shipka hali, shuka halinka, barambo, koraukin zaila, rimin turawa; and
Ibo:	Ikwe oyibo

MORINGA OLEIFERA INTERVENTIONS

Mr. Vice-Chancellor, distinguished ladies and gentlemen, I now want to explore the general interventions of *Moringa* in the life of man, and why, for instance, Hausa man refer to the plant as '*Zogale-gandi mataimaki".*

Nutritional Uses of *Moringa oleifera*

A large number of reports on the nutritional qualities of *Moringa* now exist in both scientific and popular literature (NRC, 2006). *Moringa* leaves contain more Vitamin A than carrots, more calcium than milk, more iron than spinach, more Vitamin C than oranges, and more potassium than bananas, and that the protein quality of *Moringa* leaves rivals that of milk and eggs. Fuglie (1999, 2000) for instance, has recorded oral histories in Senegal and throughout West Africa, and reported countless instances of lifesaving nutritional rescue that are attributed to *Moringa.* Lockett et al (2000) reported that the nutritional properties of *Moringa* are now so well known that there seems to be little doubt of the substantial health benefit to be realized by consumption of *Moringa* leaf powder in situations where starvation is imminent. In many cultures throughout the tropics, differentiation between food and medicinal uses of plants (e.g. bark, fruit, leaves, nuts, seeds, tubers, roots, flowers), is very difficult since plant uses span both categories and this is deeply ingrained in the traditions and the fabric of the community.

Gram for gram, fresh Moringa leaves out-perform these well-known nutritional champions (Figure 2), and they taste well too (treesForLife.org, 2008). Most parts of this plant are more than just edible; they are nutritious (Fagulie, 1999; 2000). Methionine and cystine are arguably the most critical dietary ingredients for people lacking regular access to meat, milk, cheese, eggs, or fish.

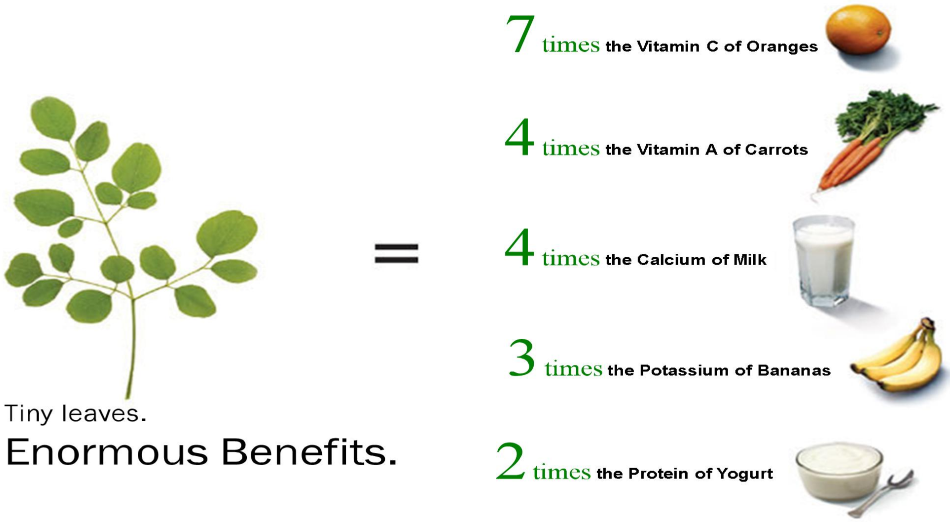

Figure 3: Nutritional Values of Fresh *Moringa* Leaves

(Source: TreeForLife.Org, 2008)

The various parts of *Moringa* have the following nutritional uses:

1. Leaves: In addition to being boiled like spinach, they are dried, crushed, and sprinkled on food.
The leaves are eaten fresh or dried as a storable powder (in which process they can lose much of their vitamin C).

2. Seeds: The soft seeds extracted from immature drumsticks are boiled and eaten like fresh peas.
Fried, they taste like peanuts. Only immature white seeds are eaten (either boiled or fried). Once they ripen, the taste turns bitter.

3. Pods: On a dry-weight basis the protein content of *Moringa* pods ranges from 20 to 30 percent—an amount well above average for a vegetable. Vitamin C content is so high that a 50 g serving (or less) provides an adult's daily needs. Iron—often deficient in African diets—is as high or higher in the pods than in the leaves. (NRC, 2006). There is even an international trade in both fresh and canned pods. India, Sri Lanka, Taiwan, and Kenya for instance export them to Asia, Europe, and the United States.
Immature Pods: have the general characteristics of a succulent string bean.

They may be eaten whole but for ease of use most are sliced and diced before cooking
Mature Pods: are well-known ingredients in pickles and in Madras they are common also in the famous drumstick curries.

4. Seed Oil: In one analysis of the fatty acids, the seed oil contained about 66 percent oleic, 9 percent palmitic and behenic, and 7 percent stearic. The nutritional contribution of the oil itself to meagre diets could be significant. Interest in the oil extracted from *M. oleifera*, known commercially as 'Ben' or 'Behen' oil, has existed for well over a century.

5. Roots: The pungent fleshy root is pulverized into a flaky condiment with a horseradish bite. The thick, soft roots are also pickled. For this, they are peeled, dried, ground, and steeped in vinegar.

6. Seedlings: Young seedlings are pulled up, boiled, and eaten whole.

7. Flowers: The flowers are cooked as a vegetable and are sometimes steeped in boiling water to yield a fragrant tea. In Kenya's Kibwezi region, farmers fry the flowers and liken the taste to that of fried egg. In Oaxaca, Mexico, poor people have adopted the tree solely as a source of white flowers for decorating churches and houses on religious festival days.

8. Honey: A good bee tree, *Moringa* begins flowering at a young age. The resulting honey is tasty, clear, and often consumed as a medicine

Medicinal Use of *Moringa oleifera*

The history of the medicinal uses of Moringa has been documented by www.moringacapsules.com (2009). According to this source, historical proofs reveal that ancient kings and queens used Moringa leaves and fruit in their diet to maintain mental alertness and healthy skin. Ancient Maurian warriors of India were fed with Moringa Leaf Extract in the war front. The Elixir drink was believed to add them extra energy and relieve them of the stress and pain incurred during war. These brave soldiers were the ones who defeated "Alexander" the Great.

Fahey (2005) and Fagulie (1999; 2000) also documented a plethora of traditional medicine references attesting to its curative power, and scientific validation of these popular uses is developing to support at least some of the claims. These various researches have indicated the therapeutic and prophylactic uses of *Moringa oleifera* in the following areas:

Bacterial	Dental caries, Syphilis, Typhoid, Urinary tract Infection
Viral	Common cold, Herpes, HIV-AIDS, Warts
Fungal	Thrush
Parasites	Guinea worm, Helminths, Schistosomes, Tryphanosomes
Endocrine Disorders	Thyroid, Anti-anemic, Anti-hypertensive, Tonic, Hepatorenal, Diuretic, Cardiotonic
Detoxification	Antipyretic, Purgative, Snakebite, Scorpion-bite
Digestive	Colitis, Diarrhoea, Dysentery, Ulcer, Flatulence
Inflammation	Rheumatism, Joint pain, Oedema, Arthritis
Immunity	Immune –stimulant, Lumpus
Nervous Disorders	Anti-spasmodic, Epilepsy, Hysteria, Headache
Nutritional deficiency	Antioxidant, Carotenoids, Energy, Protein, Iron
Reproductive Health	Abortifacient, Aphrodisiac, Birth Control, Lactation Enhancer
Skin Disorders	Antiseptic, Pyodermia, Astringent, Vesicant, Rubefacient
General Disorders	Bladder, Catarrh, Gout, Scurvy, Hepatamegaly
Others	Bronchitis, Ulcers, Fever, Throat infection, Cancer therapy, Prostate, Anti-tumor, Skin, Radio protective

Environmental Management and Socio-Economic Uses of *Moringa Oleifera*

Whether or not it has direct African root, Moringa could certainly prove beneficial to Africa. Taken all round, it shows a remarkable capacity to help solve problems such as:

Deforestation: This species is not a foresters' tree but its ability to thrive in wastelands and provide rapid shade cover could make it the choice for many tree-planting projects. Likely, too, it is a good nurse crop for slower-growing species that eventually will dominate the site.

Agroforestry: The tree is good in agroforestry and mixed cropping. The thin shade helps protect vegetables in the hot tropical sun. Because of its downward rooting pattern, there is little competition with associated crops. This makes it an ideal agroforestry component.

Shelter, Shade, and Privacy Screens: Though never showy, this tree is not unattractive. People sometimes plant it to ornament gardens as well as highway verges.

Its airy foliage casts only light shade. Planting a line of seedlings produces a living fence that can become a seamless line in as little as a year. Also, the branches are set upright in the ground to form an "instant hedge."

Wood: Although soft and spongy and not a great fuel, the wood burns cleanly and gives off little smoke or smell. White and tasteless, it also makes good chopsticks, and provides a pulp suitable for newsprint as well as wrapping, printing, and writing papers, not to mention the viscose rayon used in textiles and cellophane.

Rural Poverty: Potentially there is profit in Moringa. First, this is a fast-growing, high-yielding oilseed. Second, the trunk is gaining importance as a raw material for paper-making. And third, pods can be produced for the fresh market or for processing.

Visual Blight: Moringa is an excellent candidate for fast-track beautification of streets, slums, and squatter settlements. The average specimen looks like an arborist's nightmare, but a little care can endow it a pleasing rounded appearance. Interestingly, it might help de-uglify the mega cities that are projected to dominate the future of the tropics, and make them more liveable.

Public Health: With its mother lode of vitamins and minerals, Moringa is virtually a nutritional supplement for farm or village. Exceptional levels of iron and calcium make it particularly valuable for women young and old. Adding to its public-health benefits is that its seeds can help purify water. There are also indications that seed extracts are useful treatments against skin complaints.

Hunger: An ability to provide so many different foods makes this tree potentially valuable for the needy and destitute. It yields up its bounty at little cost to, or effort from, the growers.

Malnutrition: The pods and leaves are among the most nutritious foods to be found in the plant kingdom. In West Africa the leaves appear at the end of the dry season, when there are few other sources of leafy green vegetables. Several programmes already promote production of Moringa leaf powder for use in sauces or as a general food additive.

Fertilizer: The pressed cake obtained following oil extraction may be utilized as a fertilizer. Its use as a potential animal feed has, in the past, not been recommended as it contains an alkaloid and a saponin. Work is currently being carried out to verify this and, if necessary, to determine suitable methods for detoxification.

Fodder: Livestock relish the foliage so much that in some regions Moringa is an important fodder. In India, for example, water buffaloes are fed the chopped up leaves and branches, which are said to boost milk production. Trials conducted in Nicaragua found that range-fed cows gave a 30% increase in milk and meat production when their diet was supplemented with 45% Moringa forage.

Cosmetics: The oil has also been reported to have been used extensively in the 'enfleurage' process whereby delicate fragrances are extracted from flower petals. There are also references to the current use of the oil in the cosmetic industry.

Oil: Pressing the seeds produces pale-yellow oil. Alternately, seed can be boiled in water, in which case the oil floats to the surface where it can be skimmed off. Oil makes up 20-40 percent of the seed—a reasonable quantity. It is a valued base for ointments since it lacks colour, smell, and taste, and turns rancid only slowly. These same properties make this non-drying oil useful for effleurage, the process by which perfume companies extract flower fragrance. Because it absorbs and retains delicate scents, it is also valued in products like hair oil. It was once traded internationally ("ben oil") for lubricating the wheels of clocks as well as making oil paints for artists. More recently, it has shown particular value for making quality soap.

Fuel: Moringa oil is said to equal the best lamp fuel, burning with little scent or smoke and emitting a light both bright and clear. The leaves are now used in making "polvoron" candy and as bio-fuel.

Gum: When wounded, the bark exudes a polysaccharide used like glue.

Sexual Libido in men: The fruit is said to increase sexual libido in men. This belief is so common in the state of Tamil Nadu (India) that there have been passive references to this in its legislations.

BIO-ACTIVE INGREDIENTS IN *MORINGA OLEIFERA* SEED

Mr. Vice-Chancellor, Sir, I have so far dwelt on the interventions of the 'raw' Moringa in the life of man. In particular, I now want to look at the applications of the seeds in water and wastewater treatment. For these, the seeds have to be 'processed' in order to extract the bio-active ingredients responsible for its actions in this regard.

Processing of *Moringa oleifera* Seeds Powder

During our studies, the dry *M. oleifera* seeds used were obtained locally from the villages surrounding Bayero University. The seeds were air freighted to the Biotechnology

Engineering Research Unit (BERU) of the Department of Biotechnology Engineering, International Islamic University Malaysia (IIUM), Kuala Lumpur, Malaysia where the laboratory investigation was carried out. The flow chart for the production of the Moringa seeds powder is shown in Figure 4.

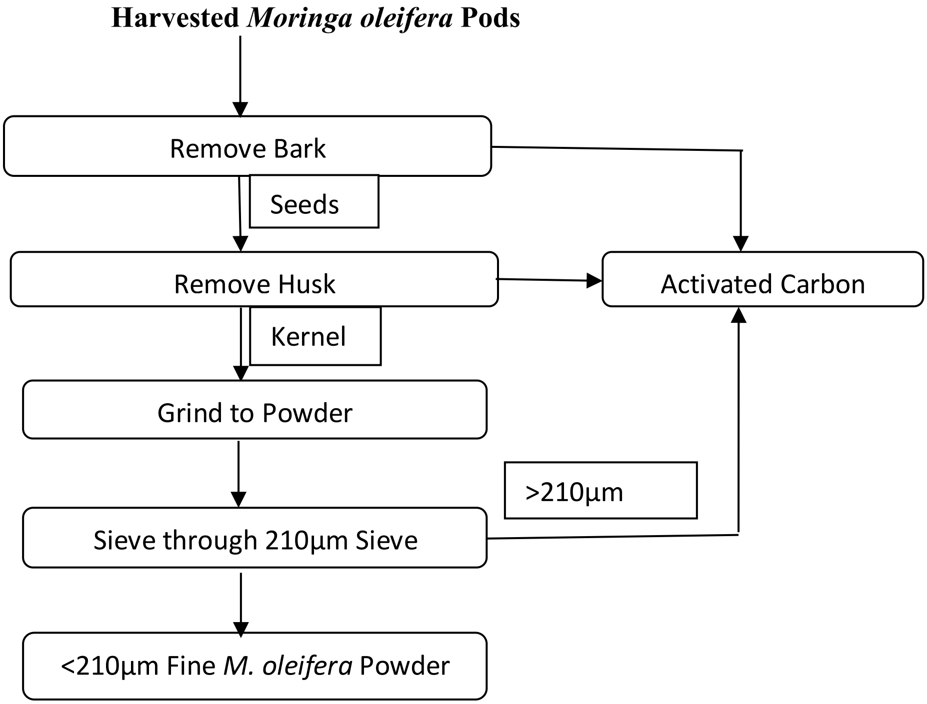

Figure 4: *Flow Chart for Production of Moringa oleifera Seeds Powder*

Extraction of Bio-active Constituents of Moringa Oleifera Seeds Powder

Six different methods of extracting the bioactive constituents from the <210µm Moringa seeds powder were investigated (Figure 5). Two methods involved the use of 'raw' seed powder, while four methods involved the use of the seed cake after extracting the oil (Figures 5 and 6). The yield of the extracted oil from the seed powder averaged 28.75±1.68%. Figure 7 shows (a) Moringa Seed, (b) Moringa Seed Kernel, (c) De-fatted Moringa Cake Powder, and (d) Extracted Moringa Seed Oil.

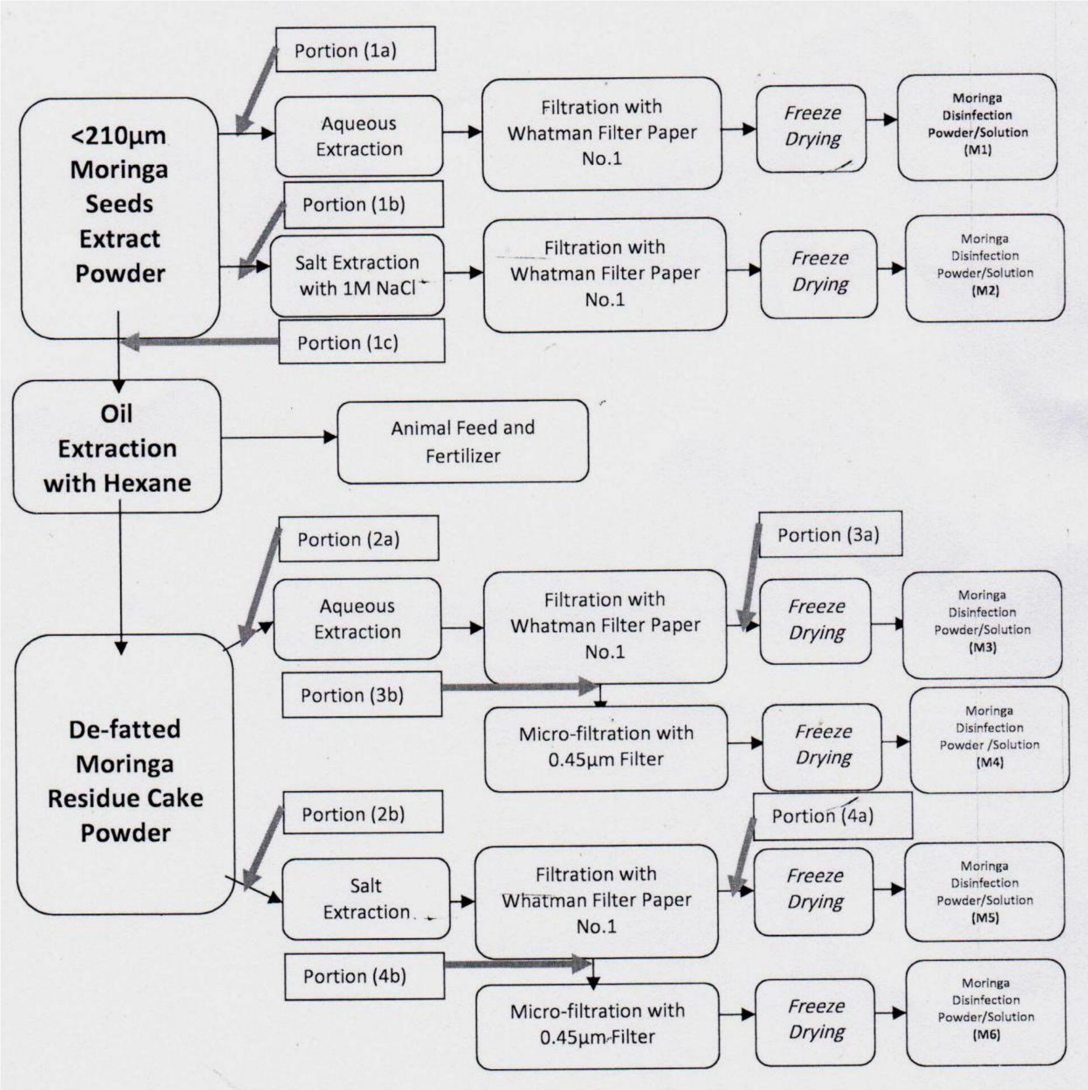

Figure 5: *Flow Chart for Moringa oleifera Seeds Extraction Methods*

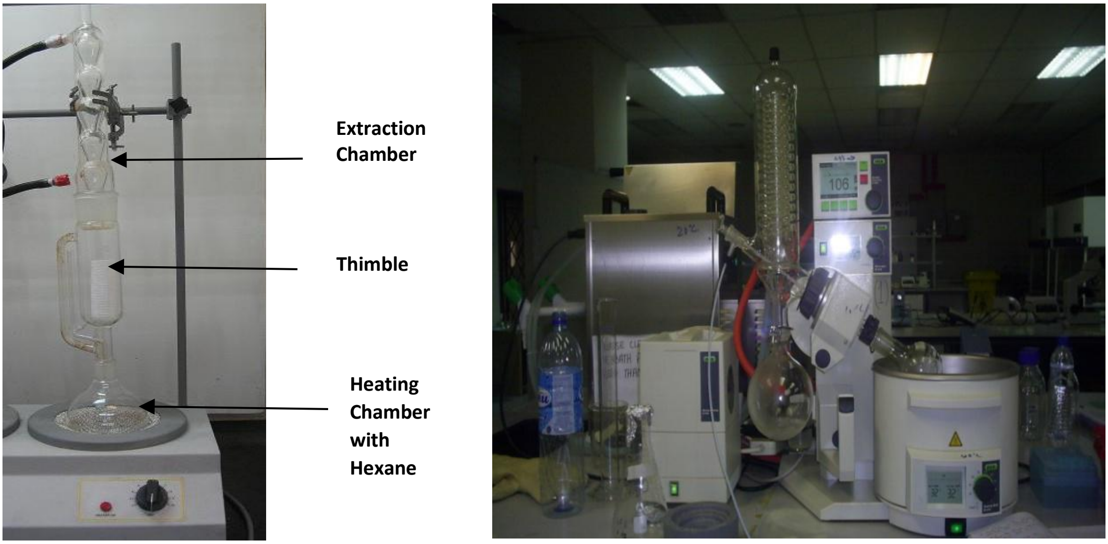

Figure 6: *Electro Thermal Soxhlet for Oil Extraction (Left) and Rotary Evaporator (BUCHI Rotavapour R-210/215) for Oil Separation*

(a) **(b)** **(c)** **(d)**

Figure 7: *(a) Moringa Seed, (b) Moringa Seed Kernel, (c) De-fatted Moringa Cake Powder, and (d) Extracted Moringa seed Oil*

The results indicated that its highest disinfection action was achieved with the use of de-fatted seed cake and extracting the active ingredients by aqueous extraction (Bichi at al., 2012a). This was therefore the best method of seed preparation for the application of Moringa seeds extract in water disinfection. The Minimum Inhibitory Concentration (MIC) for the Moringa disinfection was determined to be 200µL/mL which was equivalent to 4mg/mL. Bukar et al (2010) also found that the MIC for

Moringa Seed Chloroform (MSC) extract and Moringa Seed Ethanol extract were >4mg/ml. Earlier, Suarez, et al (2003) reported that 1 – 6mg/mL of flo were found to decrease viable cell counts by several orders of magnitude. This finding thus agreed with the earlier results. The Minimum Bacterial Concentration (MBC) was determined to be 210µL/mL which was equivalent to 4.2mg/mL.

We also determined the optimal conditions for the extraction of the bio-active compounds to be 31 minutes mixing time, 85 rpm mixing speed and 3.25 mg/mL Moringa dosage (Bichi et al., 2012b). This research further developed a Quadratic model that can be used to optimize the process of antimicrobial bio-active compound extraction from de-fatted *Moringa oleifera* seeds. The fitted cubic model in coded variable is given in equation (1).

E.Coli Removal (%) $= +99.42 +91.93 *A -111.31* B +72.92* C +34.62 *A^2 -50.20 *B^2 - 10.17* C^2 -5.99*A*B +3.72*A*C -3.46*B*C -52.97*A^3 +68.84*B^3 -31.22*C^3 -67.99*A^2 *B +61.55 *A^2*C +152.17*A*B^2 -190.44*A*C^2 -123.00*B^2 *C +106.59*B*C^2 -5.04*A*B*C$ …….(**1**)

Where: A=Mixing Time (min); B=Mixing Speed (rpm); and C=Moringa Dosage (mg/mL)

The analysis indicated that the standard deviation for the cubic model was 0.56, R^2=0.9999 and adjusted R^2=0.9994 which was the highest value of adjusted R^2 and thus adequate. The centre point for the optimized design solution at a mixing time of 31.0 minutes, mixing speed at 85.0 rpm, and *Moringa* dosage of 3.25mg/mL all fall within the range of values of the variables considered. All the six design points yielding E. Coli removal of around 99.42% and 98.83% at 95% Confidence Interval fall within this centre point.

The Bio-active Ingredients in *Moringa oleifera* Seed

Ndabigengesere et al (1995) found that the shelled *Moringa oleifera* contains 36.7% proteins, 34.6% lipids, and 5% carbohydrates. The un-shelled *Moringa oleifera* contains 27.1% proteins, 21.1% lipids, and 5.5 carbohydrates. Folkard et al (1989) identified the active ingredient in the M. o*liefera* seed to be a Polyelectrolyte. According to Jahn (1988), the Moringa flocculants are basic polypeptides with molecular weights ranging from 6,000 to 16,000 daltons. Six polypeptides were identified with their amino acids being mainly glutamic acid, proline, methionine, and arginine. Bina (1991) identified the active ingredient as a polypeptide acting as cationic polymers; and Ndabigengesere et al (1995; 1998) reported that the active ingredients in an aqueous *Moringa* extract are dimeric cationic proteins with molecular weights of about 13 000 daltons and iso-electric point of between 10 and 11.

Preliminary studies by Gassenchmidt et al. (1995), on the active ingredients of *Moringa oleifera* as a coagulant, have suggested that the active components are cationic peptides of molecular weight between 6.5 – 7.0 kDa. The extract of *Moringa oleifera* was described by Ndabigengesere et al. 1995 as dimeric cationic proteins with molecular mass of 12-14 kDa. Tauscher, (1994) mentioned that the sequence of one of the *Moringa oleifera* proteins is appositively charged 6 kDa polypeptide. *Moringa oleifera* seed extract was described as water-soluble protein with a net positive charge (Nkhata, 2001). Broin et al (2002) mentioned that the molecular weight is 6 kDa and that *Moringa oleifera* contains eight (13.1% positively charged amino acids, 7 arginines and 1 histidine) and only one (1.6%) negatively charged residue (aspartic acid). As a consequence, the protein in the solution is highly positively charged. Broin et al (2002) also proposed that the coagulation mechanism mainly relies on patch charge mechanism. Interestingly, according to the same study, this protein is also very rich in glutamine (14- residues, 23%). The high density of glutamine residues could favour floc formation through H-bonding among proteins coating the particles. Kebreab et al. (2005) mentioned that there were no characteristic differences (molecular weight and pI) between the proteins extracted by different methods. In all cases the coagulants were proteins, as determined by the dye binding method and absorbance at 595 nm. Kebreab et al (2005), additionally mentioned that the protein fraction obtained during the research does not consist of a single, homogeneous protein, but is a mixture of proteins with similar physical characteristics; and using mass spectrometry analysis of the protein also indicated a dominant protein with molecular weight of 4.75 kDa.

Eilert *et al* (1981) also identified an active anti-microbial agent in the seeds. When isolated, it was found to be *4α-4-rhamnosylox.y-benzyl-isothiocynate,* the only known glycosidic mustard oil at present. The compound is readily soluble in water at 1.3μmol/L and is non-volatile.

MORINGA OLEIFERA IN WASTEWATER TREATMENT

In wastewater treatment, the main aim is to reduce the pollution load so that the effluent can be sent back to the natural water course with minimum harm to the aquatic life and the environment. The use of natural coagulants (*M. oleifera* in particular) ensures sustainable, appropriate, effective enhancement of a particular wastewater treatment process, decreased reliance on the importation and distribution of treatment chemicals, creation of new cash crop for farmers, and employment opportunities.

In this, Folkard et al (1999) found that *M. oleifera* dosed at 150mg/l gave additional removals of 40% for Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) and excess of 80% of suspended solids (SS) compared to plain sedimentation. Kalogo et al (2000) also reported that a laboratory work on an upward flow anaerobic sludge blanket (UASB) reactor at the University of Ghent yielded more biogas and gave 71% removal of total COD at 2 hours hydraulic retention time (HRT) compared with 54% removal when ferric chloride (Fe_2Cl_3) is used. Subsequent studies later (Kalogo, et al, 2001) also indicated enhanced start-up of the reactor treating raw domestic waste water when 2 mL of a 2.5% (w/v) *M. oleifera* stock solution per litre of influent wastewater was used.

In 2010 in BUK, we investigated the use of the *M. oleifera* extract in the treatment of abattoir waste water (Lagasi, 2010). The *Moringa* extract was found to compare favourably with the use of the traditional Aluminium Sulphate ($Al_2(SO)_4$) in this regard. Later in 2016 (Tanko, 2016) found 87% - 99% removals of heavy metals – cadmium, chromium, copper, cobalt, lead, manganese, and zinc – from tannery wastewater discharged from Challawa Industrial Estate in Kano. Thus *M. oleifera* has been found to be easy, environmentally friendly and safe for the removal of heavy metals from industrial wastewaters, thereby protecting the lives of aquatic animals and humans.

MORINGA OLEIFERA IN WATER TREATMENT

The use of natural materials of plant origin to clarify turbid surface waters is not a new idea. Many believe the Biblical book of *Exodus* (15:23-27) is the earliest written reference to what is most likely *Moringa* being used to purify water (probably *Moringa peregrina*,):

> *"And the people murmured against Moses, saying, What shall we drink? And he cried unto the Lord; and the Lord showed him a tree, which when he had cast into the waters, the waters were made sweet…."*
>
> (Exodus, 15:23-27).

The traditional use of the *M. oleifera* seeds for domestic household water treatment has been limited to certain rural areas in the Sudan. Village women collecting their water from the River Nile would place powdered seeds in a small cloth bag to which a thread is attached. Many researchers (Muyibi et al 1995a, b; Bichi 2013b) have reported its use in surface water treatment using the extracted bioactive compounds.

Interventions in Coagulation

Coagulation is by far the most widely used process to remove the substances producing turbidity in water. These substances normally consist largely of clay minerals and microscopic organisms and occur in widely varying sizes ranging from those large enough to settle readily to those small enough to remain in suspension for a very long time. Colloidal and fine impurities in water possess a certain anticoagulation stability which is due to the presence of hydrate shells or a double electric field around particles. This anti-coagulation stability of impurities can be disturbed by heating, freezing, addition of electrolytes to water or by the application of a magnetic field.

This problem is most often solved by coagulating hydrophilic and hydrophobic impurities. The use of *M. oleifera* for coagulation, co-coagulation, or coagulant aid has been a subject of investigation in many parts of the world. Most of these works have been documented by Jahn (1986), Jahn (1988), Folkard *et al* (1989), Bina (1991), Ndabigengesere *et al* (1995), and Muyibi and Okuofu (1995).

Most works on the use of *M. oleifera* in coagulation employ the parameters used in conventional jar tests to evaluate the coagulating efficiency of the seed extract. However, Muyibi and Evison (1995) investigated among others, the multiple effects of physical parameters of rapid and slow mixing rates and times on coagulation of turbid water with *M. oleifera.* Using the single factor method of optimization and optimum dosage, it was observed that at initial turbidity of 50 NTU (low turbidity), the rapid mix velocity gradient and time was 432/s and 1 min respectively. Also for initial turbidity of 225-750 NTU (moderate to high), the optimum rapid mix velocity gradient and time was *443/s* and 4 min respectively. The residual turbidity recorded was < 10 NTU in all cases. Similarly, the optimum slow mix velocity gradient and time recorded were 149.9/5 and 20 min for low turbidity water; and 208.3/5 and 25min for medium and high turbidity water.

Moringa oleifera as a Primary Coagulant

Many researchers like Folkerd et al (1989) and Muyibi and Okuofu (1995) have reported the potential use of *M. oleifera* seed extracts as a primary coagulant. Madsen *at al,* (1987) in a study carried out in Sudan using the Nile River water found that there was a fall in turbidity, within 1 hour, from 2000 FTU to 1- 2FTU for the Blue Nile water; from 50FTU to 10FTU for the White Nile water and from 300FTU to 10FTU for the irrigation canal water. Folkard *et al* (1989), working in Malawi, evaluated the performance of M. o*leifera* and *M. Stenopetola* in the flocculation of turbid water with alum. They found that both M. o*leifera* and M. *Stenopetola* gave equivalent performance to alum in the clarification of highly turbid waters. There was, however, a limit to the effectiveness of the seeds on low turbidity waters, the limit varying depending on the source.

In another study carried out in Kano, Nigeria, Muyibi and Okuofu (1995a) reported a 92.99% reduction in turbidity within 2 hours settling period for initial turbidities ranging 205-986NTU using M. o*leifera* dosages of 40 - 400mg/l depending on initial turbidities. In another study, they used three water samples from Challawa Water Works, Thomas Reservoir and Rimin Gado Reservoir. They found that turbidity removal varied from 26.5% to 45% for Challawa water, 32.5% to 83.3% for Thomas Reservoir water, and 27.8% to 49.1% for the Rimin Gado Reservoir water. They also noted that for Thomas Reservoir water, for example, at initial turbidity of 90 NTU, the turbidity removal was 83% while at 60NTU initial turbidity, removal dropped to 63%. It was then concluded that, in general, turbidity removal increase with increase in initial turbidity of the raw water sample. These results corroborate the earlier findings by Jahn (1988) and Folkard et al (1992).

Muyibi and Evison (1996) also worked in Kano and used water samples from Challawa and Dambatta Water Works, and Rimin Gado (Guzu-guzu) reservoir. The report showed that for Challawa and Dambatta water works water samples, turbidity removals were 36-98.2% and 14.3-99.4% respectively, with the dosage varying from 100 to 450mg/l and 100 to 250mg/l, respectively. The optimum dose of *M. Oleifera* for the two samples was 250mg/1.

For the Rimin Gado (Guzu-guzu) Reservoir water samples, turbidity removal varied from 17.1-95.7% with the M. *Oleifera* dose varying from 100 to *450mg/l.* It was however, observed that in this case, turbidity removal was probably inhibited by the humic substances and high natural colour of the water samples. Muyibi and Okuofu (1995) noted that since *M. Oleifera* is a polyelectrolyte, it may not be effective as a primary coagulant for low turbidity water because such waters contain low concentration of colloidal particles, with a low rate of inter particle contact in such systems. This was later corroborated by Muyibi and Evison (1995a).

Folkark and Sutherland (2001) designed and constructed a pilot water treatment plant within the premises of Thyolo Water Treatment Works in Malawi. The system was commissioned during the rainy season with the source river exhibiting turbidity levels in excess of 44 NTU throughout the study period. They found that at a dose of 100mg/l, the raw water turbidity was reduced from 400 NTU to approximately 30 NTU in the outflow from the sedimentation tank, and ultimately to around 1 NTU as the sand filter 'worked in'.

During the following wet season, the main Thyolo works was operated using *M. oleifera* as the sole coagulant. They found comparable treatment performance with alum, and at M. oleifera dose of 57mg/l, the initial turbidity of over 325 NTU was consistently reduced to below 2 NTU.

Co-coagulation of M. Oleifera with Alum

Investigations were carried out on the use of *M. oleifera* in conjunction with alum. Felkard *et al* (1989) reported dramatic improvements in floc characteristics and significant savings in imported alum usage of the order of 50 to 80%. Muyibi and Okuofu (1995) also observed that the floes formed in conjunctive use were bigger, denser and settled faster after slow mixing, than when alum *or M. oleifera* alone were used. Furthermore, rates of floc formation and settling were reported to be comparable to alum in the range of raw water turbidities (26-40 NTU) considered. Savings in alum use in the range of 40-80% was similarly reported, depending on the raw water and the quality of the product water desired. In the same study, it was noted that as optimum dose of alum was reduced by 80%, 60%, and 40% and the *M. oleifera* seed dose increased by 10mg/l from *20mg/l* to *50mg/l,* respectively the residual turbidity of the water decreased. In another study, Muyibi and Evison (1996) reported a saving of up to 40% in alum use when *M. oleifera* was used as a co-coagulant. The lowest residual turbidity was recorded at a combination of *30mg/l* alum + *40mg/l M. oleifera.*

M. oleifera as a Coagulant Aid

Since *M. oleifera* seed extract is a polyelectrolyte, it may be able to function as a coagulant aid, using alum as the primary coagulant (Jahn, 1982). Muyibi and Okuofu (1995) reported that in one investigation, the optimum dose of alum without *M. oleifera* was *40mg/l.* When *M. oleifera* was used as a coagulant aid, the optimum dose of *M. oleifera* was found to be *10mg/l* while alum was 20mg/l. The optimum time of application of *M. oleifera* was found to be 50 seconds' after slow mixing. It was further noted that the flocs formed were dense and settled faster than with alum alone. The residual turbidity was also found to be much lower than that of alum alone.

Interventions in Water Softening

Softening is the removal of ions which cause hardness in water. Hardness is caused mainly by calcium and magnesium ions, or at times, by iron, manganese, strontium, and aluminum ions. Hardness causes excessive soap consumption and scale formation in hot water pumps, boilers and pipes. Public water supplies should not exceed 300 to *500mg/l* of hardness; although, aesthetically, a hardness greater than 150mg/l is unacceptable (Corbitt, 1990). Because the cost of chemicals for softening is high, local materials are being considered as substitutes. *M*. o*leifera* seed extract has been identified as a potential softening agent (Muyibi and Evison, 1995a; Muyibi and Evison, 1996; Muyibi and Okuofu, 1996).

Barth *et al* (1982) reported that initial hardness *of* water varying from 80300mg/l $CaCO_3$ was found to have been reduced to between 50-70% after coagulation and softening with *M. oleifera.* Sani (1990), using water samples from Watari and Challawa Rivers, and from Yarimawa and Kofar Kabuga wells, reported total hardness reduction from 54mg/l to 25mg/l $CaCO_3$ for River Watari water while using 40-200mg/l *M. oleifera* dosage. This reduction was from 95 to 30mg/l $CaCO_3$ for Challawa water using *50-250mg/l* M. o*leifera* dosage. For Yarimawa well water, the reduction was from *11.2mg/l* at *100mg/l M. oleifera* to 9.8mg/l at *400* mg/l *M. oleifera* dose; whereas for Kabuga well water sample, the hardness reduced from 21 mg/l to 17mg/l $CaCO_3$ as M. o*leifera* dosage increased from 0 - 250mg/l, but at 150mg/I, the hardness went up to *20*mg/l and leveled off to 15mg/l $CaCO_3$ at 250mg/l *M. oleifera* dosage.

Muyibi and Okuofu (1995) studied the softening of water samples from 17 hand-dug wells in Kano Nigeria, and found that the residual hardness decreased with increased dosage of *M. oleifera.* It was also observed that for the same initial hardness, water samples containing both calcium and magnesium hardness required higher doses of M. o*leifera* than those containing only calcium hardness. Muyibi and Evison (1995a) using water samples from 4 sources of varying hardness in England also observed that hardness reduction increased with increasing dosage of *M. oeifera.* This was later corroborated in another study by Muyibi and Evison (1996). It was further reported that for water samples with hardness values of 50 to 600mg/l $CaCO_3$, softening with *M.* o*leifera* was found to be dependent on the initial hardness of the water and the seed extract dosage. Muyibi and Okuofu (1995) also found that the absorption isotherm for softening with *M. oleifera* was linear and of approximately the Langmuir type. This was later corroborated in another study by Muyibi and Evison (1996).

Softening of water with *M. oleifera* has a potential advantage since it is accompanied by very low reduction in alkalinity, which is required to provide the necessary buffering capacity to achieve required treatment objectives (Muyibi and Okuofu (1996), Muyibi and Evison (1995a); Muyibi and Evison (1996).

Interventions in Disinfection

Chemical agents that have been used as disinfectants include halogens, phenols, alcohols, heavy metals, dyes, soap and detergents, ammonia compounds, hydrogen peroxide, and various alkalis and acids (Metcalf and Eddy, 1991). The most common of these are the oxidizing chemicals, and chlorine is the most universally used. However, chlorine has problem of decay and reduced concentration as the water flows through the distribution network (Devarakonda et al, 2010). It also has the potential for forming carcinogenic and mutagenic disinfection by-products (DBPs) (Goveas et al, 2010). Disinfectants and their by-products may also be associated with increased risks of cardiovascular diseases, cancers, and birth defects (Arbuckle et al., 2002). These and the high cost of chlorine, make it imperative to look for cheaper alternatives that are also environmentally friendly. This brought us to look into the interventions of *Moringa oleifera* in disinfection of water (Bichi et al, 2012c).

Moringa Oleifera Inactivation Mechanism

We first investigated the disinfection properties of Moringa seed extract using synthetic water, and derived the log-inactivation plot of the *E. coli* and the microbial consortium exposed to Moringa seeds extract for synthetic water. The regression equation obtained was

$$\text{In}\ (N_0/N_t) = 0.0746 - 0.00423\ Ct \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The correlation coefficient was 99.2% and the Adj R^2 was 98.9%, indicating goodness of fit. The analysis of variance indicated no significant lack of fit ($P > 0.1$). The slope of line gives the Chicks-Watson coefficient of specific lethality. The coefficient of specific lethality (Λ_{cw}) was 3.77 L mg^{-1} min^{-1} for an *E. coli* in synthetic water.

We went further to examine this disinfection action using surface water obtained from Rimin Gado (Guzu-guzu) Dam Reservoir, and obtained the log-inactivation plot of the *E. coli* and the microbial consortium exposed to Moringa seeds extract. The regression equation was

$$\text{In}\ (N_t/N_0) = 0.080 - 0.00418\ Ct\ (\text{mg/min mL}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

The correlation coefficient is 95.2% and the Adj R^2 was 93.7%, indicating goodness of fit. The analysis of variance also indicated no significant lack of fit with $P=0.57$ ($P > 0.1$). The slope of line gives the Chicks-Watson coefficient of specific lethality. The coefficient of specific lethality (Λ_{cw}) was 3.75 L mg^{-1} min^{-1} for an *E. coli* in surface water. Thus the average Coefficient of lethality for Moringa disinfection (Λ_{cw}) was 3.76 L mg^{-1} min^{-1}.

These results were found to be consistent with those determined by earlier researchers using chlorine. Butterfield et al (1943) reported a coefficient of specific lethality (Λ_{cw}) of 3.75 L mg^{-1} min^{-1} for an *E. coli* exposed to chlorine while Cunningham et al (2008) reported a Λ_{cw} value of 4.71 L mg^{-1} min^{-1} for an *E. coli* exposed to chlorine.

Mode of Attack of Moringa Disinfection Extract on E. coli

The antimicrobial activity of Moringa extracts was previously attributed to plant-produced benzyl isothiocynate derivatives (Eilert et al, 1981). Suarez et al (2003) showed that at least part of the antimicrobial activity of Moringa seeds extract may stem from Flo-like polypeptides. Antimicrobial peptides have attracted increasing attention recently because they can efficiently kill fungi and bacteria that are otherwise resistant to many commonly used antibiotics. According to Zasloff (2002), they act by forming essential enzymes, leading to cell deaths. Suarez et al (2003) reported that the antimicrobial action of Flo might results from similar activities or from its bacterial flocculation effect. The report further noted that the former is more likely because for example, Flo concentration required to obtain half-mixed effect on *E. coli* are 0.1 mg/L for bacteriostatic action, 1.0mg/L for bacterial activity, and 6.0mg/L for cell flocculation. The study concluded that visual inspection of Flo-incubated *E. coli* revealed that the peptide aggregated the bacteria, as indicated by defined particles or flocs.

The results of our investigations are shown in Figures 8a – 8d. The Figures show the changes in the *E. coli* cell morphology from the active cell (Figure 8a) to the cell condition after the Moringa extract application for 1 hour (Figure 8b), then cell rupture after Moringa application for $1\frac{1}{2}$ hours (Figure 8c), and finally the destroyed cells after Moringa extract was applied for 2 hours (Figure 8d). The result of the study on the mode of attack showed that the cytoplasmic membrane of the *E. coli* bacterial cell was ruptured and the intercellular components were seriously damaged after treatment with *M. Oleifera* seed crude extract (Bichi et al, 2012c). However, the inter-cellular components did not leak out. Based on previous studies of cell lysis pathways of antimicrobial peptides on bacteria (Cham et al, 1998; Chen et al, 2003), this indicated that extracted compounds interacted with the lipid bi-layers in membranes leading to the separation of the two membranes (outer and inner). Subsequently, water dips into the cell, which causes cell to swell more and leads to death. Thus the results obtained agreed with the explanations given by earlier researchers.

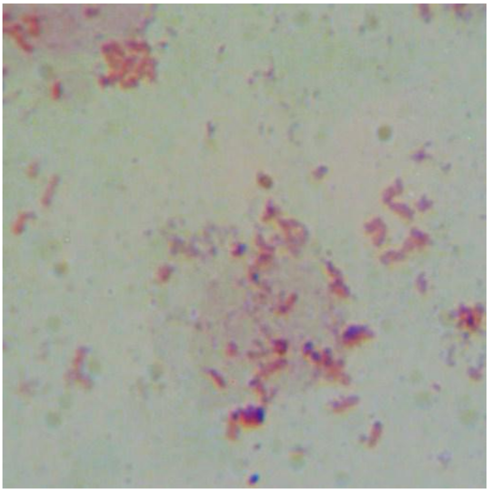

Figure 8a: *E. coli without Extract*

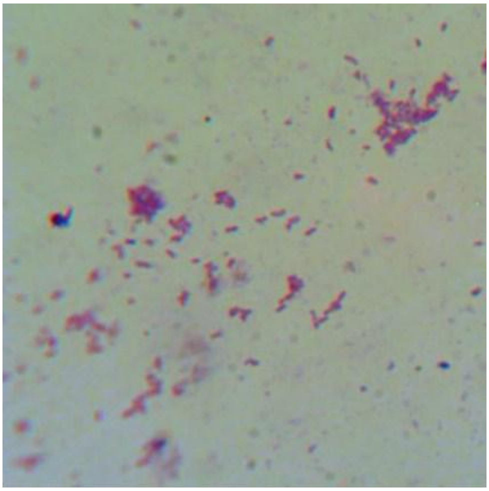

Figure 8b: *E. coli with Extract after 1 hour*

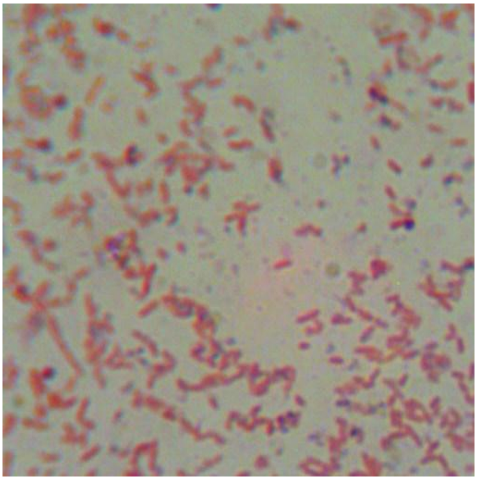

Figure 8c: *E. coli with Extract after* $1\frac{1}{2}$ *hour*

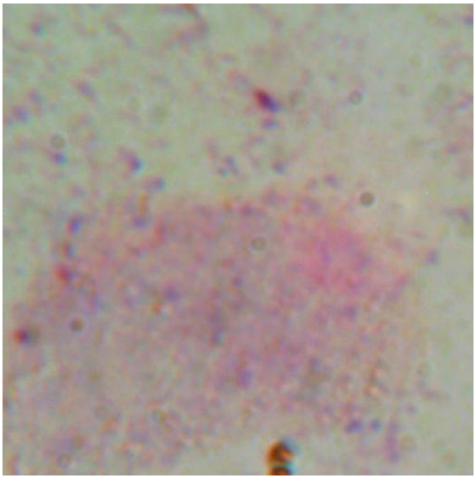

Figure 8d: *E. coli with Extract after 2 hours*

Effect of Shelf-Life on the Action of *Moringa* Extract

One problem with the application of Moringa seed extract in water treatment is that it needs to be prepared fresh for application. In 2015, we investigated the effect of storage of the extract on its actions (Ali and Bichi, 2015). The findings with respect to its actions in coagulation and disinfection are indicated in Figure 9.

AGE OF EXTRACT (DAYS)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
DISINFECTION TEST	**No Growth**										
CONGULATION	**Coagulation took place**										
CONTORL [N/M]	**Microbes Growth**										
AGE OF EXTRACT (DAYS)	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**2 2**
DISINFECTION	***No Growth***							***Microbes Growth***				
COAGULATION TEST	***Coagulation***							***Microbes Growth***				
CONTROL[N/M]												

(**Source:** *Ali and Bichi (2015)*)

Figure 9: *Variation of Action of Moringa oleifera Seed Extract with Age*

This revealed that *Moringa oleifera* seed extract deteriorate with age in respect of the following:

i) The disinfection properties of the *Moringa oleifera* extract decreases with age growth and this efficiency dropped steadily within 18days.

ii) The turbidity removal efficiencies decrease with the age of the coagulant with respect to initial turbidities of 50NTU to 52.8NTU, and this also dropped after 18 days at the temperature of 27.5°C.

iii) The p^H for the extract varies with age. It rises initially from 7.8 to a maximum of 9.8 on the third day and thereafter steadily decreases to 6.4 on the 18th day.

Moringa oleifera Seed Oil

Many seed oils have been shown to possess antimicrobial activity (Ugbogu and Akukwe, 2009). Although Moringa seed oil has been found to possess some antimicrobial properties (Bukar et al, 2010; Thilza et al, 2010), it may not be suitable for application in water disinfection because of its insolubility. Thus it has to be removed when applying to water disinfection.

However, we also investigated the application of Moringa seed oil in other areas (Bichi and Shehu, 2018). We found that even though *Moringa* seed oil is not as effective as gentamycin against *E. coli*, it has achieved up to 78% of its antimicrobial action. Thus it can be used as mild disinfectant such as skin ointment, hand spray, and sanitizers. It is, however, recommended that more work be done to determine its shelf life as the oil used was fresh and the antimicrobial action may deteriorate with time. Its action against other common microbes also needs to be investigated in order to establish its general effectiveness.

SUMMARY OF MAJOR CONTRIBUTIONS

The major contributions made in my journey to professorship can be summarized as follows:

1. Profiled the effects of heavy metals from the Kano industrial areas into the environment.
2. Traced these heavy metals into our drinking water supplies. This led to the relocation of the water intake of Tamburawa water treatment plant (No. 1) to a safer upstream location.
3. Traced the heavy metals from the Kano industrial effluents into the vegetables grown along the polluted water courses.
4. Determined that the aqueous extraction from the de-fatted *M. oleifera* seed cake is the best method of seed processing for its application in water disinfection, and the Minimum Inhibitory Concentration (MIC) as 200µL/mL with the Minimum Bacterial Concentration (MBC) as 210µL/mL.
5. Determined the optimal conditions for the extraction of the active ingredients of *M. oleifera* seed for application in water treatment as 31 minutes mixing time, 85 rpm mixing speed and 3.25 mg/mL de-fatted Moringa seed powder.
6. Developed a quadratic model for the extraction of the bioactive ingredients in *M. oleifera* seed.
7. Demonstrated that *M. oleifera* can be employed in the treatment of wastewater and particularly in the removal of heavy metals from the wastewater.
8. Demonstrated that *M. oleifera* can be used as a friendly natural material in coagulation, softening and disinfection in water treatment.
9. Developed the log-inactivation equation for the application of *M. oleifera* in water disinfection and determined its coefficient of specific lethality (Λ_{cw}) as 3.76 L mg^{-1} min^{-1} for *E. coli* inactivation.
10. Determined the mode of attack of *M. oleifera* seed extract on E. coli as by rupturing the cell wall and damaging the inter-cellular components leading to death.
11. Determined that the shelf-life of the freshly prepared *M. oleifera* extract is only

18 days as effective coagulant and disinfectant.

12. Found that *M. oleifera* seed oil can be used as a mild disinfectant such as skin ointment, hand spray and sanitizers.

AREAS OF FURTHER RESEARCH

Mr. Vice-Chancellor, Sir, in spite of these modest contributions, a lot of work still needs to be done in order to fully exploit the potential of *Moringa* in the service of man. Particularly, more research needs to be carried out in the following areas:

1. **In coagulation, further works needs to be carried out on:**

- ☞ Ease of preparation of dosing solutions for treatment applications.
- ☞ Quality control and acceptable levels of impurities.
- ☞ Stability of protein products in storage.

2. **In disinfection, further works need to be done to ensure effective application of Moringa seeds extract by:**

- ☞ Checking the problem of bacterial re-growth after disinfection.
- ☞ Investigating the residual for bacteria quality maintenance during storage of the treated water.

3. **Moringa Seed Oil**

- ☞ Determine its shelf life as its antimicrobial action may deteriorate with time.
- ☞ Investigate its action against other common microbes in order to establish its general effectiveness.

4. **Further works also need to be done on the cost of production and overall economics from cultivation, harvesting, processing and applications.**

My immediate research direction is aimed at finding answers to some of these questions and we are currently working with MSc and PhD students in this regard.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, *Moringa (Zogale)* has great potential for use in the service of man, and can make meaningful interventions in the intractable relationship between man, environment and water. It is a cheap and effective food supplement, can be used in environmental protection, can be employed in removing heavy metals from waste water, and has great potential as a cheap and environmentally-friendly substitute for expensive and imported chemicals used in water treatment. In order to fully exploit and promote these enormous benefits to humanity, the following steps are recommended:

- ☞ It is highly recommended that the cultivation of the *Moringa Oleifera* tree should extensively and intensively be promoted in Nigeria and other developing countries.

- ☞ The country can be producer of the seeds and the natural disinfectant at the same time. *Moringa Oleifera* can become a cash product for the country.

- ☞ The use of *Moringa Oleifera* for other purposes such as food supplementation, medicine, economic applications, etc should be promoted in order to reduce cases of diseases, alleviate poverty, and promote family health among the populace.

- ☞ It is strongly recommended to implement the present results to a pilot plant, and to do a feasibility study for the project as a first step for industrial implementation.

- ☞ Encourage the development of research results such as ointment, coagulants, disinfectants, food supplements, medicines, and refreshment/beverages.

- ☞ The government, through the RMRDC should encourage networking and linkages with international markets.

- ☞ Community outreach should be facilitated by organizing workshops and visits to villages and local community centres.

- ☞ Research and other related activities, such as promoting the use of the tree, require financial resources. Grant proposals should be developed and potential contributors invited to partner this innovative exercise.

ACKNOWLEDGEMENTS

Mr. Vice-Chancellor Sir, I am indeed very happy and fulfilled today. I thank Allah (SWT) for His grace and continuous guidance to achieve this feat. I am indebted to my parents, late Malam Hassan Mohammed (Bagudu) and Hajia Aisha Mohammed for their upbringing, love and care. I also thank my uncle, Alhaji Lawan Mohammed Tsanyawa who took over my care after the demise of my father in 1981. I also thank my other uncles, brothers and friends for their love, care and encouragement.

I would like to pay tribute to my late wife, Hajiya Hauwa Musa Yakasai who could not live to see this day. May her soul rest in peace, ameen. I thank my wife Hajiya Binta Buba Musa and other members of my family for their love, care and support.

When I started this academic journey, I came across so many committed and dedicated teachers at the primary, secondary and tertiary levels. I remain eternally grateful to all of them. I would like to mention just a few of them: Malams Mukhtari Marway and Sani Mohammed Maikaratu - my teachers at Hagagawa Primary School, Bichi; Malam Tajuddeen Gambo and Dr. Mike Dowse at Science School, Dawakin Tofa; Professor B. W. Young, Professor S. K. Spholia (my B.Eng. supervisor in 1985), Professor Salihu Mustafa (at ABU), Professor B. U. Anyata (my M.Eng. supervisor at University of Benin), late Professor S. A. Muyibi (at UIA, Malaysia) and Professor J. C. Agunwamba (of University of Nigeria, Nsukka) who supervised my PhD here in BUK.

I would like to thank my colleagues, both academic, technical and administrative, in the Department of Civil Engineering and in the Faculty of Engineering for being wonderful allies. My students at both undergraduate and postgraduate levels have also been willing contributors to my various research efforts.

I want to thank my numerous academic and non-academic colleagues in Bayero University for making the university a home for me. I want to thank the former Vice-Chancellor, Professor Abubakar Adamu Rasheed for consistently being on my neck to finish my PhD and get elevated to professor. The current Vice-Chancellor, Professor Muhammed Yahuza Bello (who was DVC Academic then) personally paid for the production of my PhD thesis after my successful viva-voce. I pray to Allah to reward all of you abundantly for this love and brotherhood. Alhamdulillah, when the BUK Senate awarded the first PhD. in Civil Engineering to me in March 2013, I became a professor in October 2013, having being an associate professor since 2005.

Finally, I wish to express my gratitude to the Bayero University Kano for giving me the opportunity to realize my potential, and the MacArthur Foundation for sponsoring my PhD research work in Malaysia. Also, the members of the Inaugural Lecture Committee, for successfully organizing this lecture. I thank all of you members of this audience and wish everybody safe journey back. May Allah bless you all.

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LIST OF PROFESSORIAL INAUGURAL LECTURE TO DATE

S/N	NAME	DEPT	DATE	TOPIC
1st	Emmanuel Ajayi Olofin	Geography	4th March, 1992	The Gains and Pains of Putting a Water Lock on the Face of the Drylands of Nigeria
2nd	Garba Dahuwa Azare	Education	24th June, 2000	BASIC CONCERNS: Revitalizing Nigeria's Primary Education in the New Millennium
3rd	Dajuma Abubakar Maiwada	Education	29th July, 2000	Improving Teaching and Learning in University Education with Particular Reference to Bayero University, Kano
4th	Majekodunmi Oladeji Fatope	Chemistry	7th July, 2001	NATURAL PRODUCTS SCIENCE: Looking Back and Looking Forward
5th	Muazu Alhaji Zaria Sani	Nigerian Languages	13th October, 2001	A focus on Some Segmental and Suprasegmental Features in Hausa Phonology
6th	Isa Hashim	Political Sciences	20th March, 2004	Planning and Budget Implementation in the Health Sector
7th	Abdulla Uba Adamu	Education	24th April, 2004	SUNSET AT DAWN, DARKNESS AT NOON: Reconstructing the Mechanisms of Literacy in indigenous Communities
8th	Auwalu Hamisu Yadudu	Private and Commercial Law	5th June, 2004	LAW AS INTERPRETATION: An Exploratory inquiry from Islamic Law Jurisprudence

S/N	NAME	DEPT	DATE	TOPIC
9th	Mohammed Sanni Abdulkadir	History	31st July, 2004	STRUCTURING, STRUGGLING AND SURVIVING ECONOMIC DEPRESSION IN NORTHERN NIGERIA: The 1930s As Preview of the present
10th	Muhammad Sani Sule	Bio-chemistry	23rd March, 2013	Enzymology and Radiation Biology in the Understanding of Biochemistry
11th	Essiet Unanaowo Essiet	Agriculture	22nd May, 2013	AGRICULTURE SUSTAINABILITY IN THE DRYLAND OF NIGERIA: Realities and Prospects
12th	Aliyu Kamal	English Studies	5th March, 2014	The Islamic Novel Style and Structure
13th	Abdu Ahmed Manga	Agriculture	9th April, 2014	Horticulture as a Panacea for Food Insecurity and Unemployment
14th	Sa'idu Muhammad Gusau	Nigerian Languages	26th May, 2014	Wakar Baka Bahaushiya (The Hausa Oral Songs)
15th	Abdulla Uba Adamu	Mass Comm-unication	9th July, 2014	IMPERIALISM FROM BELOW: Media Contra-Flows and Emergence of Metro-Sexual Hausa Visual Culture

S/N	NAME	DEPT	DATE	TOPIC
16th	Ghaji Abubakar Badawi	Library and Information Sciences	29th July, 2015	THE ROLE OF PUBLIC LIBRARIES AS CENTERS OF INFORMATION TO DISADVANTAGED GROUPS: A 2004 - 2014 Study of the Information Needs of Gada Prostitutes in Dawakin Kudu Local Government Area of Kano State, Nigeria.
17th	Mohammed Kabir	Community Medicine	16th September, 2015	Public Health Concern for Chronic Non-Communicable Diseases Surpasses Anxiety Over Most Infections
18th	T.I. Oyeyi	Biological Sciences	30th March 2017	Linking Schistosomiasis and Water Resources Development in Kano State Nigeria: Public Health Impact and Mitigation
19th	Abdulrazaq G. Habib	Medicine	27th April, 2017	Medicine, Science and Society – The Global Health Imperative
20th	S. Y. Mudi	Chemistry	6th July, 2017	Natural Products: Plants as Potential Sources of Drugs
21st	Sani Ibrahim	Biological Sciences	27th July, 2017	BETWEEN LIFE AND DEATH: Water Quality and Resource Evaluation - The Place of Hydrobiologists
22nd	J. Afolabi Falola	Geography	26th October, 2017	The Poor We Have With Us Always

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23rd	Umar G. Danbatta	Electrical Engineering	2nd November, 2017	GETTING OUT OF THE WOODS: Diversifying Nigeria's Economy Through the Telecommunications Sector
24th	Adelani W. Tijani	Nursing	23rd November, 2017	Wholesome Alimentation: Path to Radiant Health
25th	Juwayriya Badamasiuy	Private and Commercial Law	21st December, 2017	Uncovering Patriarchy in the Law: Feminist Movement for Re-Interpretation of Islamic Law in Focus.
26 th	Isa Mukhtar	Nigerian Language	25th January, 2018	STYLISTIC THEORIES AND THE LINGUISTICS OF HAUSA PROSE TEXTS: the (SFL) approach.
27th	Ganiyu Sokunbi	Physiotherapy	29th March, 2018	TODAY IT HURTS, TOMORROW IT WORKS: Complimentary and Alternative Therapy for Failed Back Syndrome
28th	Aminu K. Kurfi	Business Administration and Entrepreneurship	19th April, 2018	Micro-finance as an Elixir for Poverty Alleviation and Wealth Creation in Nigeria
29th	Muhammad S. Khamisu	Arabic	17th May, 2018	Substitution in Arabic Languages Rules and Types
30th	Habu Nuhu Aliyu	Pure and Industrial Chemistry	21st June, 2018	SCHIFF BASES AND THEIR TRANSITION METAL COMPLEXES: The Drug for the Next Generation
31st	Hashim M. Alhassan	Civil Engineering	19th July, 2018	EASING THE BURDEN OF TRAVEL: Can Roadway Capacity Modeling Help?
32nd	Habu Mohammed	Political Science	13th September, 2018	TUG OF WAR OR ECHO IN THE DARK? Civil Society Organizations (CSOs) and the Fight Against Corruption in the Era of Change Mantra in Nigeria

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33rd	Bello Idrith Tijjani	Physics	20th September, 2018	NAVIGATING THE DATA LABYRINTH: Application of Some Advanced Statistical Analysis in Atmospheric Physics
34th	Mohammed Ajiya	Electrical Engineering	18th October, 2018	SEAMLESS GLOBAL CONNECTIVITY AT THE SPEED OF LIGHT: Converting Intrinsic Phenomena in Optical Fibers to Capacity Increase.
35th	Abdulrahman Abdul Audu	Pure and Industrial Chemistry	25th October, 2018	MY ACADEMIC VOYAGE IN WATER INTO THE WORLD OF HEAVY METALS
36th	Ibrahim Rakson Muhammad	Animal Science	21st February, 2019	FORAGE AND FODDER PRODUCTION IN NIGERIA: Its Sensitivity in Sustainable Ranching.
37th	Muhammad Bashir Ibrahim	Department of Pure and Industrial Chemistry	14th March, 2019	WATER POLLUTION AND THE QUEST FOR ITS REMEDIATION: The Natural Resource Option
38th	Oyerinde O. Oyesegun	Department of Physical and Health Education,	4th April, 2019	MAN DOES NOT DIE BUT KILLS HIMSELF: The Dilemma of the Health Educator and the Moderating Influence of Health Education
39th	Danladi Ibrahim Musa	Department of Physical and Health Education	25th April, 2019	WAGING WAR ON THE DEADLY QUARTET AND ITS CO-MORBIDITIES: A Physical Activity Panacea
40th	Kabiru Isa Dandago	Department of Accounting	2nd May, 2019	THE ACCOUNTING IN HUMANITY KNOWS NO BOUNDS
41st	Mustapha Hassan Bichi	Department of Civil Engineering	20th June, 2019	MAN, ENVIRONMENT AND WATER - The *Moringa oleifera (Zogale)* Intervention