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Biocoagulants for Water and Waste Water Purification: a Review

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Abstract – *A survey and inventory of indigenous knowledge and plants used by rural Africans to purify water was carned out vis-à-vis the inherent local water crisis cum challenges in the existing water purification technologies. The findings indicated that from time immemorial indigenous people have had to use rich knowledge base to treat their water. Plants identified were Moringa oleifera, Jatropha curcas, Pleurotus tuberregium, Citruss aurontifolia, Strynos potatorium.A review of the of the potentials of these plants coagulants with respect to turbidity removal and disinfection of water borne diseases vis-a vis the pitfalls of chemical coagulants and disinfectants such as Alum and Chlorine have been presented.Studies conclusively demonstrates that biocoagulants especially Moringa oleifera seeds are as efficient as Alum is purifying water and wastewater at low cost.The need to further develop biocoagulants as green treatment alternative for global water management admist growing global water crises is emphasized.*

Keywords: *Biocoagulants,Water ,Wastewater, Calum, Chlorine Moringa Oleifera*

I. Introduction

Water is essential for human survival. It has been reported that the total amount of water in the world is about 1400 million cubic km (= 10^{18} tonnes) and remains constant (ref. water cycle 207) Apparently, more than 97% of this total volume is seawater of the rest 22% is ground water and 97% is ice locked away in the glaciers and the polar ice cap. This obviously leaves less than 1% of the supply of fresh water, which takes in the water hydrological cycle, but half of this is found in rivers, lakes, and swamps. Most of the fresh water is polluted. In Northern Nigeria, for instance, 95% of the surface water, and this remains true for sub-Saharan Africa, is considerably polluted (Adegbola, 1987)

Reports according to Cofie et al (2003) also indicate that 90% of water in India is polluted, it may not be an overstatement that most surface water in developing countries remain suspicious in terms of quality. The ever-increasing prevalence of endemic diseases like diarhoea, dysentery, amoebiassis aepatitis, typhoid, Jaundice etc may be suggestive of the severe exposure to harmful effects of water pollution in developing countries. Even in the highly industrialized countries, several children still die of water borne diseases. Water quality in the developed nations despite advanced technologies for treatment still leaves a lot to be desired. Thurman et al (1998) reported poor water quality in rural areas in Australia. In the United States, Hegart et al 91999) reported high occurrence of Helicobacter pylori in surface water while in Chile and Peru a similar observation has been reported (Medall et all, 1992) and Hopkins et al, (1993); and Hulten et al, (1996). The disposal of garbage, sewage and industrial effluents into rivers is mainly responsible for their pollution and is one of the main concerns of environmentalists today, particularly in less developed nations.

Besides, toxic substances like aldelyde, ketones, amines Carboxylic acids etc present in water even in very small amounts deplete the dissolved oxygen, altering the survival pattern for aquatic life. The toxin even find their way in the neonates / newborn babies indirectly through lactating mothers causing immense harm to them. It is no Joke to Mention here that, the tests of nuclear weapons and disposal from nuclear research centres is discharged in the sea and it becomes radioactive. It is no gain saying that the level of fishes and vegetations has drastically reduced. The precise quantity of damage in the developing countries is not really available but huge billions of gallons of sewage and detergent-based wastes are disposed off daily.

Water, which is safe for drinking must be free of pathogenic organisms, toxic substances and an excess of minerals and organic debris. It must be colourless, tasteless and odourless in order to be attractive to consumers and preferably cool.

Water is the basis of life. About 75% of the body weight is made up of water. WHO estimates that about 85% of the rural populace lack potable drinking water. In developing countries 15 million infants die every year due to contaminated drinking water, poor hygiene and malnutrition. About 80% of illnesses in developing countries are directly connected with contaminated drinking water (WHO). The provision of water supply near by for consumers and sufficient for their daily needs will help greatly in decreasing the incidence of skin diseases, eye infections and also reduce diarrhoea diseases as well as most worm infections, particularly if the water is of good quality bacteriologically. However, major improvements in health conditions through provision of sufficient safe water can only be achieved through domestic hygiene practice and proper methods of water purification.

Ground water, surface water and rainwater are often the major sources of water in a community. Ground Water: is often the most appropriate source of water for drinking as long as it does not contain high mineral content. Ground water could be extracted through wells or bore holes. Surface Water: requires treatment to make it safe for human consumption. Surface water is almost always contaminated by people and animals who defecate in or near the water. The water is obtained from streams, lakes, ponds etc, while Rain Water: Rain water is itself is pure. It can be collected in large storage basin or smaller containers. However rain water collected in dirty or unclean containers have to be treated to make it safe for drinking.

Water gets contaminated in so many ways particularly through anthropogenic factors thereby making it unsafe for consumption. It is incumbent to curb pollution, treat and recapture water bearing in mind that the total water volume on earth cannot be increased as shown in the water cycle bellow.

Waste is a very turbid liquid with an offensive smell in most cases. Its composition varies from large floating or suspended solids to smaller suspended solids, very small solids in colloidal form (microbial and chemical) pollutants (Send and Demirer, 2003) The quantity of organic matter present in waste water determines the strength of waste wate (Rosa et al, 1989) The orgabubc natter cibcebtratuib us exoressed in terms of the amount of Oxygen required by micro-organisms to oxidize the organic matter. It is termed Biochemial Oxygen Deman (BOD) (Mara, 1978). The different components of waste water are of primary importance as it plays a crucial role in the design of the treatment plant. Waste water generally contains biological components like (faeces and urine), pathogenic organisms mostly of faecal origin and non-biological substances as shown in the sketch below:

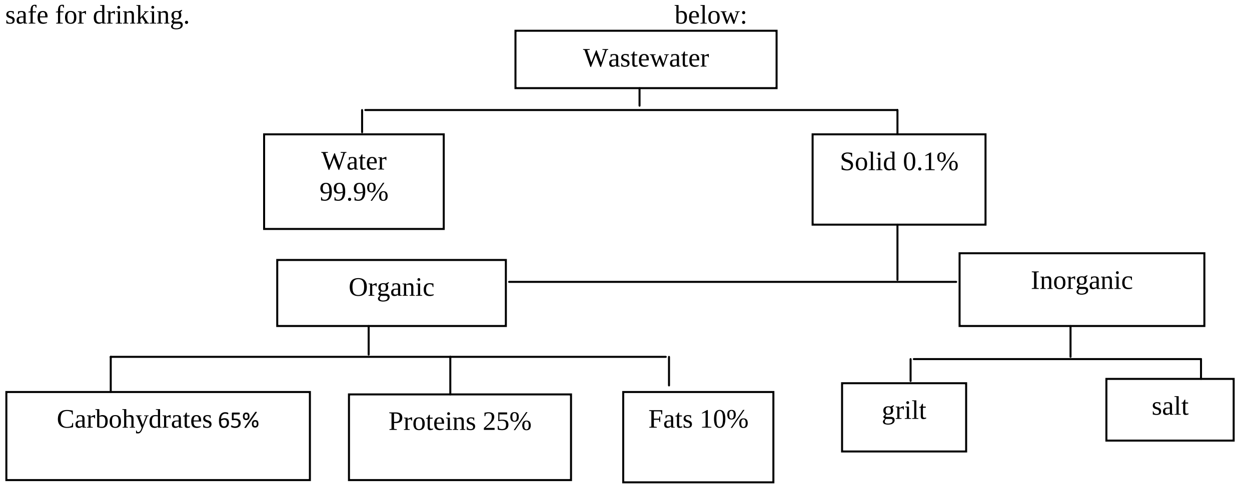

Fig. 1. Physicochemical content of wastewater

Wastewater in most cases may be discharged into other water sources contaminating and polluting it. This wastewater could contain pathogenic organisms responsible for enteric diseases in man according to Cheesbrough (1984). Some of the diseases and their causative organisms are cholera caused by *vibrio cholerae*, typhoid fever caused by *Salmonella typhi*, bacillary dysentery caused by *Shigella species* amongst others.

The microbiological risk of wastewater can be assessed in terms of seriousness of the risk and the frequency of the risk (WHO, 1982. This seriousness depends on:

(i) The nature of microorganisms present in wastewater in question.

(ii) The minimum infective dose that is, a certain concentration of bug is likely to cause an epidemic than that same concentration of *Escherichia coli* in the wastewater.

(iii) The survival and reproductive capacity of the microorganism in the wastewater. Apparently, Details contaloguing of the Pathogenic/Microbial spectrum of wastewater in the Suu Saharan Africa is lacking.

Studies on Microbial content of wastewater have been limited on the detection of fuecal indicators organisms in streams, ponds and water catchments but literature on the content of pathogens in wastewater from hospitals, hair dressing saloon and abbatoirs in Subsaharan Africa is lacking let alone treatment. Yet, disposal of wastewater from these units are potential ground water of contaminants. Bacterial analysis have been the main focus on diseases transmitter by water (Satory et al, 1998; Smith, 2000) but fungi and viruses are equally of utmost importance and the traditional coliform/faecal indicator tests does not simulate/ or correlate well with the presence of water and fungi and other microbial groups in water and waste water according to Rosa et al, (1998). While Aspergillus flavus have been isolated from water bodies where faecal coloforms are not detected (Peterson et al. 1997)

Pathogenic organisms from waste can be broadly classified as bacteria, fungi, viruses, protozoa and helminthes. A number of disease, and disease causing agents have been isolated from poultry wastes and these include; New Castle disease virus, *Chalmydia*, psittacosis (conjunctivitis and pneumonia in humans), *Erysipelothrix rhusiopathia* (causes erysipelas), *listeria monocytogenes* (listeriosis), Mycobacterium *avium*, *Candida albicans*, *Aspergillus fumigatus* (rhinitis, athsma, and chronic pulmonary disorder)

Clostridium (food poisoning and botulinum), Salmonella spp, Bacillus anthracis (anthrax), Brucella abortus (Brucellosis) leptospirosis, Escherichia coli and bovine tuberculosis Skirrow (1994) and satory (1998).

The authors also noted that several toxigenic fungi exist in poultry waste and with a remote possibility of transmission under certain changing conditions. Animals are asymptomatic carriers of organisms that can cause disease in other species.

Wastewater treatment is carried out to remove turbidity, chemicals and microbiological pollutants that may constitute health hazards by series of unique processes. The most important stage of wastewater treatment is disinfection. Most other processes serve to condition the wastewater for final disinfection (Tang, et al 1994). Conventional method of wastewater treatment occurs in stages – pre-treatment, primary stage, secondary stage and tertiary stage. Disinfectants such as chlorine are used for disinfection and coagulants such as alum are used for coagulation in wastewater treatment.

The spread of water-borne diseases through consumption of feacally-contaminated water is a major concern for many communities in developing countries. Water is of considerable importance as a vehicle of transmission of so many diseases worldwide. Bacteriological testing for quality of drinking water is determined by enumeration of coliform bacteria and more specifically faecal coliforms (Escherichia coli) (WHO 1982). The standard values for both water and wastewater varies and generally signifies the presence of diverse Pathogens. For example Campylbacter species have been reported from cattle faeces (Atabay et al, 1997) Campylobacters cause gastroenteritis, abortion and secondary infections (e.g bacteraemia and arthritis) in humans, animals birds and live as commensals of the intestinal tract of many animals and birds. The studies of Atabay and colleagues suggests that cattle faeces is rich in Pathogenic organisms. They isolated forty-four strains of phenotypically unique campylobaecter from faeces of 26 out of 45 cow in a single herd. Many campylobacter species and related genera, including *Campylobacter jejuni*, *Campylobacter coli*, *Campylobacter lari*, Acrobacter, wolinealla, and Helicobacter have been reported to cause gastroenteritis in human (Skirrow, 1994). A high prevalence of campylobacter and a wide diversity have been reported in pig (Weijtens et al, 1997).

These organisms are potential contaminants in water bodies and inadequate studies exist to highlight their role in wastewater ecology and appropriate intervention strategies especially in Subsaharan Africa. Yet many locals keep animals and use the faeces as fertilizer.

From the isolation of Catalase negative urease positive compylobacters (CNUPC), there appears to be a wide differential gap in the ecology, biochemistry and nutritional requirements of Microorganisms, thus posing enormous challenges in isolation and identification. As such there are viable bacteria that remain unculturable in various media thus rendering a lot of suspicion on the hugh data available on the specific identities of various organisms Rosa et al, 1998). For instance, Atabay et al (1997) used enrichment and membrane filtration onto blood agar or plating onto cefoperazone amphotericin teicoplanin agar in the case of CNUPC whereas this strain did not grow on modified cefoperazone charcoal deoxcholate agar (MCCDA).

In a similar line, Hegarty *et al* (1999) in their study observed no correlation between the presence of *Helicobacter pylori* and the traditional indicator organisms in water supplies. Epidemiological association between water sources and the prevalence of *H pylori* infection has also reported by several researchers (Klein et al 1991; Remirez-Ramos et al 1994; Mendal et al 1992; Mitchell et al 1996; Goodwin 1993. Hopkins et al, 1993).

Water and sanitation facilities in sub-Saharan Africa and Africa in general are appauling and for the most part absent. Poor waste disposal facilities, open field defecation, untreated cum poorly treated wastewater from factories constantly contaminate ground water resource. An average of 125 litres of clean water is needed per person yet, in Africa in general most people can not boost of 25 litres of clean free water.

The situation is grave in most villages, this has heavy consequences on the entire nation or continent in that 70% of Africans live in the rural areas and practice subsistence agriculture. Apparently water borne diseases constitute 80 – 90% of the disease burden on the continent, with sharp rise in the morbidity and mortality rates. In an attempt to treat these infections, lack of adequate finances to purchase the necessary antibiotics has led to abuse and poor compliance to treatment, thus the increasing prevalence of antibiotic resistance strains of organisms such as salmonellosis, amoebiasis, helicobacter pylori infections and many others has rather compounded the pathogenicity and epidemiological pattern, water purification technologies in Africa are quite cumbersome while commenting vehemently that most of the technologies are imported from western countries at exorbitant cost makes the final treated water products expensive to a highly impoverished population. Water is a decisive resource for economic, social and environmental integration as well as inevitable tool for sustainable development. More than 70% of the world's inhabitants lack potable water with more than 80% of diseases in the low income earning countries being waterborne. In high-income earning countries either 90%

of potable water is treated using unecological means.

In the same vein, Hulten et al (1996); and Forrest et al, (1998) used *H.pylori* specific nucleic acid sequence to detect *H. pylori* in water in Columbia, Peru, Sweden and as well as in Sewage in the United States. Other techniques such as PCR and combined fluorescent antibody cyanoditoyl tetrazolium chloride (CTC) staining had been used in addition to enumerate *H.pylori* in attempt to overcome the phenomenon of viable but non culturable (VBNC *H.pylori)*.

The studies of hegarty et al (1999) strongly indicated that *E Coli* was not detected in 50% of the samples in which *H.pylori* was detected, this lack of significant association between the presences of *E.Coli* for the determination of the potability of water may fail to protect people from *H.pylori* and other specific infection. Such a lack of association may possibly indicate that *H.pylori* may survive longer in freshwater habitat than E coli or possibility that *H.pylori* is part of a normal flora of many fresh water bodies and can survive in limited nutrients. While total coliforms were found in 85% of the samples containing *H.pylori*, however, there should be a careful interpretation of their association. A somehow conclusive report on the limitations of Indicator organisms as a reflection of the ultimate pollution picture of water has been done by Efstratiou et al (1998). In their studies on the Correlation of bacterial indicator organisms with salmonella spp., Staphylococcus aureus and Candida albicans in sea water, total coliforms correlated better with Salmonellas and staphylococcus aureus than did faecal coliforms and faecal streptococci, faecal coliforms correlated better with the presence of Candida albicans.

Their studies show strong conclusion that total coliforms is sufficient to predict the presence of Salmonella and Staph spp in sea water that is moderately polluted.

The works of leclerc et al (2000) also strongly acknowledge the limitation of indicator organism (*E.Coli* and coliform) to confirm the presence of enteric viruses in human faeces, water and sewage. While acknowledging the overall advantages of the use of traditional indicator organisms, bacterio phages detection has been recommended to indirectly tract the presence of enteric viruses.

Reports exist to show the continuous isolation of Pathogenic micro organism especially antibiotic resistant strains from polluted water and wastewater. Sisti (1998) and Sidhu (1999), reported a high incidence of Aeromonas species from influent and effluent of urban waste and Water purification plants. Motile Aeromonas spp are ubiquitous in aquatic environments and have also been isolated from sewage, polluted and unpolluted fresh water, drinking water even after Chlorination as well as mineral water. Aeromonas have been implicated in gastrointestinal infection, disseminating infections in immuno compromised as well as wound pathogens with Aeromonas veronii biotype sobria noted as most virulent.

The potential therefore exists for large numbers of oocysts to enter the sewage treatment works from both domestic sewage and from sources such as Cattle Markets and abattoirs in the west (Madore et al 1987) and this probably would be worse in developing countries. Livestock animals are probably more likely to be at risk of infection. Cryptosporidium is widespread and second to rota virus as the most prevalent pathogen in outbreaks of diarrhoea in calves. It has been reported that infected lambs and calves shed approximately 10^{10} oocyst daily between 4 to 14 days post infection while levels of oocysts as high as approximately $4000l^{-l}$ in some effluent and 137001^{-l} in a raw sewage containing slaughter house waste (Madore et al, 1987).

As it has been observed that indicator organisms may not correlate well with the presence of some pathogens in sewage (Jones et al, 1990a), special Isolation and Identification techniques for some specific groups of organisms like cryptosporidium is necessary. The use of discontinous sucrose and isopyenic percoll gradients has been employed for cryptosporidium isolation (Arrowood and strerling (1987).

One of the known multiple benefits of anaerobic digestion is the fact that it distinfects sewage. The effects of anaerobic digestion on parasitic protozoans in general and cryptosporidium oocyst in particular has been described as rewarding Tappouni, 1984), Pike, 1990 and whitemore, 1995, Yongabi et al, 2004). A number of related sound technologies to treat Sewage/wastewater exists; the use of wetland, folkewalls, water harvesting and recycling, (but have not been applied in Africa as they require some high initial cost.

Solar irradiation has been proposed as a means of disinfecting contaminated water in areas that experience hot and sunny climates Mcguigan et al, 1998). Smith et al (2000) further reported that bacteria suspended in water were exposed to UVA irridiation for up to 8 hrs. Culturability, determined by Colony forming unit and most probable number counts, fell by six log 10 units, while cellular activity determined by the kogure cell elongation test was retained by at least 5% of the cells present after 8 hours. They further noticed that Nonculturable cells and Active But non-culturable cell (ABNC) of Salmonella typhimurium produced by UVA irradiation did not retain infectivity for mice.

(Evans, 1992; and Wallace et al, 1997) The potential of transmission of pathogenic organisms from chicken waste and wastewater could be high as researches abound to support the transmission and incidence of compylobacter enteritis (Deming et al, 1987) Annan-prah and Janc, 1998 and Jones et al, 1990).

In his study, Fulya Turantas (2002) observed a better correlation with faecal streptococci as an indicator of sanitation in ice cream and frozen vegetables than with faecal coliforms. Generally, however, indicator organisms still remain useful in giving valuable information about levels of contamination of evironmental samples. Josephson *et al* (1997) reported high total heterotrophic bacterial counts, Staphylococci, Pseudomonas, total and faecal coliform counts in household kitchen wastewater.

Smith et al (2000) reported the beneficial effect of solar disinfection of water on infectivity of Salmonella – typhimurium. The study also observed that some cell remains active but non-culturable but are of no potential hazard in mice.

Studies on the inactivation of foot and mouth disease, Aujeszky's diseases and classical swine fever viruses in pig slurry using thermal treatment has been found beneficial in decontaminating pig wastes (Turner et al, 2000) The study further opined the danger of using untreated pig slurry for manure and identified further risks such as African swine fever virus, and Swine vesicular diseases virus.

Methods for effective decontamination of these wastes have been reported; physical method through application of heat (Monteith et al, 1986) and lonizing radiation (Faroog et al, 1993): chemical methods using chlorine, ozone, acids and alkalis (Herniman et al, 1973) and finally biological methods such as the action of bacteria or proteases (Deng and Cliver, 1995), or the use of aerobic or anaerobic treatment (monteith et al, 1986).

There are other techniques involving physically removing the virus or organism from the liquid medium using sand column filtration. Although nearly all of the these methods are suitable for use in water or aqueous solution with low dry matter (DM) content, only a limited number may be suitable for use with large quantities of a liquid containing substantial levels of dry matter such as animal slurry. Ozonation of U.V irridiation could have benefit if the slurry is pre-clarrified. Similarly, the use of gamma irradiation is somehow limited to certain viruses-that are resistant to this method unless high doses are used. Besides the health risks at large scale would be considerable. This concern holds true for ozonation and other chemical treatments such as the use of formalin. Considering the aspect of efficacy / reliability as well as relative costs, ease of scale-up and slurry disposal after treatment, Turner and Williams (1999) observed that heat treatment of pig slurry and dosing with alkaline (NaoH and (CaoH) are fairly in expensive and easy to scale up, and disposed easily by land spreading.

Apparently, all these methods may not adapt well in low income earning countries as they still remain expensive and above all not environmentally sound technologies. The need to treat animal waste stands exigent.

The distribution of specific antibodies of Ersipelothrix rhusiopathiae has been identified in abattoir workers (Molin et al, 1989).

Hospital waste management has been accorded little attention, yet, Many health facilities spring up by the day, the world over (Shehab Ullah, 2003) The works of Shehab Ullah observed that Hospital solid waste is being disposed of like other wastes; collection, dumping in landfills as well as incineration. Apparently, no effective management of hospital wastewater has been reported, more so, with biocoagulants.

Shehab Ullah (2003) reported with dismay that hazardous wastes disposed without proper treatment could play a strong role in the epidemiology of infectious diseases like HIV/AIDS, hepatitis B and C. Generally, inadequate and inefficient management of septic slugde is one of the most pressing environmental problems faced by cities of the developing world. In Nigeria, as well as inmost developing countries, attention seems to be focussed on solid wastes and hazardous industrial Wastes without realising that septic sludge is just detrimental to human health (Sridhar, 1995).

The world health organisation has frequently decried that indiscriminate disposal of septic sludge is a major causative agents of communicable and water-borne diseases.

An overview of existing Management practices for septic sludge in developing countries are (1) disposal into water bodies (river and canals) and open drains (2) disposal on land (3) and Burial in Shallow trench.

A close loop system for wastewater management and sanitation has also been proposed (GTZ, 2000). The composition of biomedical wastes are I) human tissues, placenta, blood, body fluid, Catheter, Iv set, gloves, soiled plaster cut, linen, bedding, needles, syringes, scalpel, blades, and other items that may cause puncture. (Dutta and Gupta, 2003) The liquid waste is mainly waste water from all units. All these waste have potential to transmit infections disease causing agents. The most acceptable and widely practiced methods of Managing biomedical solid waste is incineration but little or no report exist on the management of biomedical wastewater. Such wastewater has been discharged into rivers, drains or in open fields. Report shows that in Ghana, mostly in the cities the increased urban agriculture mostly depend on the use of wastewater for irrigation (Cofie et al, 2003). The two most crucial steps in water purification are coagulation using alum and disinfection [Al_2 $(SO_4)_3$. $18H_2o$] is widely used, other polytectrolytes are ferric chloride ($fecl_3$) are used. During Coagulation, lime (cao or Ca(oH)2 is used for pH stabilization since Alum generates acide water

Coagulation must have a pH range within which it is effective Al_2 $(SO4)_3$. $18H_2O$ + 3Ca $(OH)_2$ – Al $(OH)_3$ Ca + SO_4 + $18H_2O$. The insoluble Aluminium hydroxide forms a gelatinous floc that settles slowly sweeping out suspended materials. These imported inorganic coagulants requires special handling and capital expenditure. As such the final treated water becomes expensive for the locals. K" = 1.6×10^2 sec for free residuals and 1.6×10^{-5} per second for combined residuals when applied to Coliforms. Chlorine is highly soluble and 700mg/l of water is used for disinfection. Chlorine like alum does generate some undesirable effects as it impacts some kind of odour, taste and ineffective against Shielded bacterial cells.

It is pH dependent chlrorine generate Cancer producing compounds such as Tetrahalomethane that disrupts endocrines system (Chemistry and Industry, 2000).

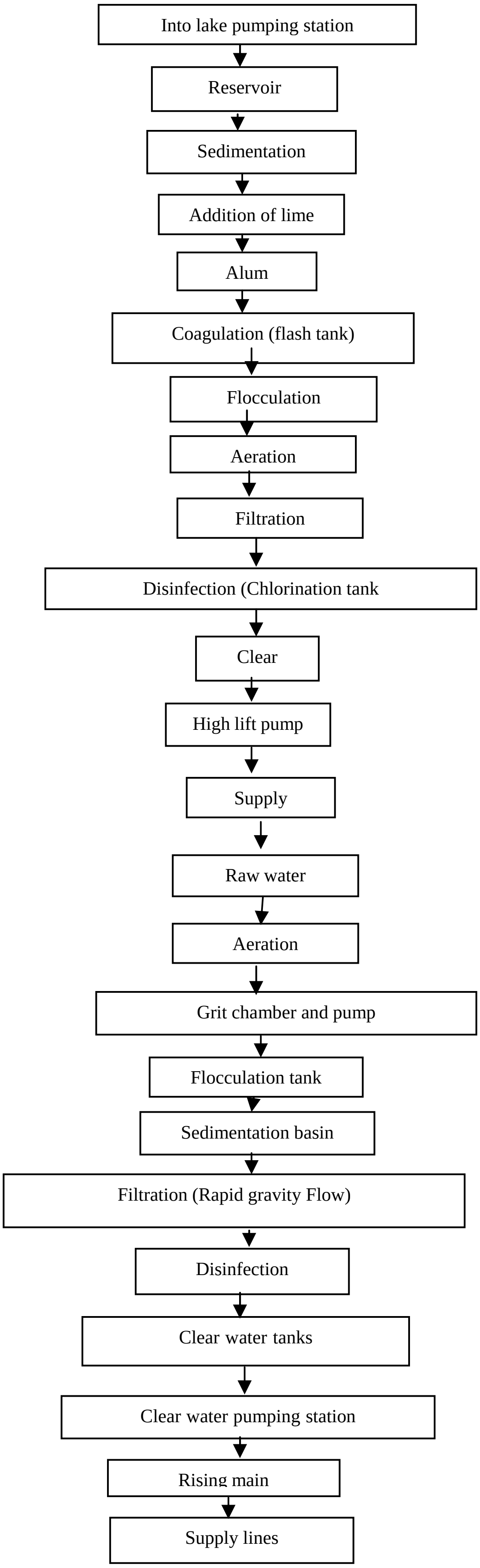

Fig. 2. Conventional steps in water purification

Water that contains diseases-causing organism is not fit for human consumption. As such it is necessary for water to be purified so as to be made safe for drinking. To achieve this, various methods have been employed. But each method has it own setbacks interms of efficiency, cost and ecological Suitability. There are seven major water purification technologies, some are more efficient in removing particular types of impurities that others. A combination of two or more technologies is better in a given situation. These Methods include; Distillation, Ion exchange, Carbon adsorption, filtration, ultra filtration, reverse osmosis, Electro deionization, ultraviolet (UV) radiation. Distillation is probably the oldest method employed in water treatment but it requires large amount of energy and water despite the fact that it removes a bread range of contaminants. It requires expert training, and careful maintenance to ensure efficiency. Ion exchange is very efficient in removing organic contaminant from water as well, the only set back is that Micro organisms can attach to the resins and can thus trigger regrowth couple high operating cost. The Carbon adsorption is 99.99% efficient in removing suspended solids, the pressure of a Millipore membranefilters of 0.22um track down all bacterial but cannot remove inorganics as well as cooloidal particles (Wegelin, 1987). Ultrafiltration acts as molecular sieve, effectively removed all types of particles, microbes, it produces high quality water with minimal energy input, still defective in removing inorganics while reversed Osmosis can effectively remove all types of contaminants to some extent (particles, pyrogens, microorganisms, colloids and desolves inorganics) through the flow rate is limited. Electrode ionization is a technology clone frome electrodialysis and ion exchange, its inexpensive to operate and absolutely efficient in removing inorganics but the set back is that the water requires pre-treatment for water. The adsorption of UV light by the DNA and proteins in the Microbial cells results in cell inactivation but the method cannot remove particles, colliods or ions

II. Coagulants

A coagulant is a chemical which in solution furnishes ionic charges opposite to those of the colloidal turbid particles in water. Coagulants neutralise repelling charges on the colloidal particles and produces a jelly-like spongy mass called a floc. Flocculation causes considerable increase in the size and density of coagulated particles resulting in a faster rate of settling of the particles in a solution or in the wastewater. (Ellis, 1988) Perhaps the use of Chemical in the definition may have exclusive of plant materials and of course limited.

Since 1867, it is known that lime and slate of ion were helpful in reducing the time required for solids to settle naturally (Folkard and Sutherland, 1986). Their use, however, produces high moisture sludge, which required expensive dewatering equipment. Alum a metallic coagulant has been a suitable coagulant in water and wastewater treatment for many years now. It has been in use and is still in use in the form of powder dispensed by one of the several forms of mechanical dry feeder units. This unit automatically controls the amount of alum fed and measures the time of coagulation as well. The early treatment plant added lime directly to water flow, this was inefficient as it did not assume mixing. Today, the dry alum bag is dropped into a solution which is then transported to the mixing and flocculation basin of the plant (Jahn, 1981).

There also exists the polymeric polyelectrolyte coagulant which is long chain high molecular weight molecules which bear a large number of charged molecules with their net charge either positive, negative and/or neutral. The chemical groups on the cationic polymer are thought to combine with active sides of colloids; such interaction of a single molecule with a large number of particles produces a bridging effect binding them together into a large particle which settles under the action of gravity. Polyelectrolytes have advantage over metallic coagulants in acting as coagulants; their role as coagulants is similar to that of activated silica. Activated silica is a preparation of colloidal sodium silicate that acts as a coagulant and a coagulant aid in association with alum as observed by Jahn (1984) Kaggwa et al (2001) and Kebreab (2004).

A disinfectant is a substance that destroys pathogenic organisms. They are neither toxic to man nor animal, neither are they unpalatable though in required concentration (Ellis, *et al* 1988). Disinfectants are applied in water and wastewater treatment to destroy water borne pathogens so as to prevent or reduce water-borne diseases. Chlorine is the most commonly used disinfectant in water and wastewater treatment. Very few disinfectants of plant origin are reported commercially.

Chlorine is used in water and wastewater treatment for disinfection, prevention and removal of odour, and irons, although principally as a disinfectant. Chlorine was first used for day-in-day-out disinfection of a municipal water supply in America when George and Pandalai (1949) added chlorine of lime to water supply in Jersey City.

Operation and maintenance of plant-based technologies operating a plant-based water clarifier system is very simple with no major Machinery nor specialized labour required as observed by Kebreab, (2004) and Yongabi, (2006) Maintenance involves removal of non-biodegradable materials, harvesting and disposal of plant materials. Disposal may either be in the form of composting, methane generation or use of fibre based handicrafts. Dredging of sediments may be required every 3 to 5 years in the cases of wetlands. For wastewater treatment using the water hyacinth system, gravity flows are generally used, while energy to operate the water hyacinth based systems is provided by sunlight.

The methodologies and/outfits for purification of water globally remains expensive especially for developing nations, as well as ecologically unsustainable Public taps in most African cities are often over crowded with long queues and scrambling for water with women and children often abused and vandalized, this is socially unacceptable as the dire consequences need not emphasis. Unfortunately, there are indications that a number of water borne pathogens are growing resistant to chlorine – Alum and Lime treatment. Chlorine or Halogen compounds used in disinfecting water has been tagged a precursor for cancer, as it forms tetrahalomethane compounds and lead to hormone mimics. Besides Aluminium Sulphate is generating dementia in young and elderly. Paradoxically, while these problems abound, there is a lot of indigenous knowledge and plants that has remained unexploited due to lack of adequate science and technology complimentarily. From time immemorial, indigenous people have relied on their indigenous knowledge and heritage for survival. Historically, there is evidence to suggest that communities in the developing world have used plant based materials as a strategy for purifying drinking water (Miller et al, 2008). Unfortunately, as it always turn out, adequate investigation into indigenous knowledge system in order to validate and improve upon such knowledge is really lacking. There is a need to probe into indigenous knowledge in water purification in order to use that as a springboard for appropriate technology. We present a review of medicinal plant biocoagulants used in water purification

II.1. Historical Development of Biocoagulants

Some previous studies have screened a number of plants as disinfectant for water treatment, Acrorus calamus linn (buch) (araceae) Roots, Anaphalis Cunefolia Hook (Compositae) Entireplant, Arnebial nobills Rachanger (Ratangot) (Boraginaceae) Root, Eclipta aibba (linn) Hassk (Bhgangra) Entireplant compositae, Hypericum spp (Gut ifera) wholeplant, Azadirachta Indica L juss leaf (meliaceae), Moringa oleifera Moringaceae fruits, roots, bark, wood stem (Jahn, 1981).

Native plants have traditionally been used to improve quality of water in many countries in Africa and Latin America viz. Seeds of Moringa used in Guatemala, peach and bean seeds are used in Bolivia as coagulant aids clarify water. It has been reported that dried beans (vicia fave) and peach seeds (percica vulgaris) have been used in Bolivia and other countries of water treatment. Similarly, Schoenoplectus tatora, an aquatic plant has been used in Bolivia and Peru for Water Quality treatment (Kebreab, 2004; Miller et al, 2008).

Schoenoplectus tatora like cattail is used to remove phosphorus and nitrogen before being discharged to natural drainage systems.

The use of aquaculture as a means of treating waste water took centre stage and this involves both natural and artificial wetlands as well as the production of algae, higher plants (submerged and emerse), vertebrates and fish to remove contaminants such as Manganese, Chromium, Copper, zinc and lead from water. Similarly, water hyacinth (Eichhornia crassipes) has been widely used for the treatment of wastewater, amongst other plants like duck weed, seaweed and alligator weed (Kranert and Hillebrecth, 2001; Shaban et al 2005 and Shuaibu and Yongabi, 2005). Progress continues in the area through invitro experiments employing hydroponics, cultivation of grasses using domestic wastewater is promising as, it removes organic matter and suspended solids through physical, adsorption and absorption and other mechanisms. But in Africa there technologies are yet to yield dividends and may not be possible in the foreseeable future.

A number of seed extracts have been known to flocculate particles esin water and the following procedure has been used according to Jahn (1981) and which if developed may yield divides. It include;

1)Extract the seeds from the plant fruit.

2)Dry seeds for up to three days.

3)Grind the seeds to a fine powder.

4)Prepare a mixture of water and ground seed material (the volume of water depend on the type of seed material used) in case of <u>*Moringa*</u> <u>*leifera*</u>, add 100cm^3 of water for each seed; for peach or bean seeds, add, l of water to each 0.3 to 0.5g of ground material.

5)Mix this solution for 5 to 10 minutes: the faster it is stirred, the less time is required.

6)Finally, after the sediments settle, decant the treated water, testing it for P^H, color and tubidity.But with wetland system, water hyacinth is the most popular plant used in phytoremediation.

The water hyacinth which is a native of South America is widespread in all the Continents. It thrives well in nitrogen rich environment, and consequently does extremely well in raw and partially treated wastewater. In this regard, wastewater is passed through a water-hyacinth-covered basin, where the plants remove nutrients, suspended solids heavy metals and other Contaminants. Equally, batch treatment and flow-through systems, using single and multiple lagoons, are used. Performance of four different wastewater effluence treatment systems using water hyacinth has been reported and Shaba et al, (2005) but this phytoremidation technology has not been widely utilised as it is difficult to practice at small scale, despite its bioremediation.

A number of Innovative wastewater treatment technologies abound. Wastewater treatment using natural and constructed wetlands, although it is largely in the developmental stage, is widely gaining attention in the west and Asia. Wetland treatment systems generally use spray or flood irrigation to distribute the wastewater into the wetland area. Another way is to flood the wastewater through a system of shallow ponds, lagoons, channels, basin or constructed areas where emersed aquatic vegetation has been planted and is actively growing.

There is a contrast in design criteria with this and the use of water hyacinth lagoons for wastewater treatment. The design criteria for wastewater hyacinth treatment include the depth of the lagoons which should be sufficient to maximize root growth and absorption of nutrients and heavy metals, retention time, flow rate and volume of effluents to be treated, desired water quality as well as the potential use of the water treated. (Foo, 2005,

Land requirements for pond construction are approximately 1m^2/ m^3/ day water to be treated. Phosphorous reduction as well as nitrogen is estimated between 10 – 75%

A number of these systems have been discussed and applied around the world such as in lake Victoria, in Kenya (Foo, 2005, Folkewalls in Sweden Wetland technology is in current use in quatemala and also rivers near la paz, Bolivia. Totora technology is being used in Bolivia and puno in, peru on the shores of lake Titicaca to treat small wastewater flows of 5 to 6 litres per second. The use of equatic plants appears to be effective only during the growing season, and is subject to a number of constraints indulging temperature. Wetland, system facilities may be suitable for seasonal use in treating wastewaters from recreational facilities, and has the potential application as a method for pre-treatment of surface water for domestic supply and storm water. The overall financial cost and skills inovle may be limiting for wide scale ex;loitation in Africa. There is a very little information available concerning the costs of plant-based technologies. It thus appear that labour and making the flocculent solution is the only cost involve andin the case of *Moring oleifera* as well (Kebreab, 2004). Generally, it's been hard to find cost estimates for water hyacinth / wetland based wastewater treatment as well. It thus appear, however, that the above system may be a bit more expensive than just the use of *Moringa Oleifera* system. Forinstance, the cost of the totora system in peru has been estimated at $65,000 (http.//www.oas.org/dsd/publications unit/oea5qelch.22htm). It has been reported that for most plant seeds, the lower the pH of the water, the more effective the treatment as suspended materials coagulate better at lower pH values. Peach beans seem to defy this rule. *Moringa oleifera* has been found to be more effective in reducing turbidity than aluminuin sulfate (Alum) but generates a neutral pH in contrast to alum (Jahn, 1981, Folkard et al, 1990; Folkard and Sutherland, 1996; Folkard et al, 2000). Generally, the higher the initial turbidity, the better the coagulation. In using plant materials for coagulation activity, Folkard et al (2000) reported that the particle size must be smaller, that means the plant materials must be well ground. The Smaller the particles, the more efficient the clarification process. This has played a crucial rule in color removal as observed with peach and bean seeds.

The concentration of the resultant coagulant solution has also an effect on the reduction of turbidity in the final water product. The effectiveness of a coagulation in turbidity and colour reduction is a function of its particles size and coagulant concentration (Jahn, 1984).

While it has been reported that *Moringa oleifera* seeds reduces bacterial count in wastewater by at least 99% Wetland treatment system using totora have been observed as efficient at removing nutrients and oxygen demanding substances from effluent. It has been seen to remove parasites, total and faecal coliforms from inflows by 88-99%. Equally, Silver lead and copper have been removed in less than 2 days. Operation and maintenance of plant-based technologies operating a plant-based water clarifier system is very simple with no major Machinery nor specialized labour required as observed by Kebreab, (2004) and Yongabi, (2004) Maintenance involves removal of non-biodegradable materials, harvesting and disposal of plant materials. Disposal may either be in the form of composting, methane generation or use of fibre based handicrafts. Dredging of sediments may be required every 3 to 5 years in the cases of wetlands. For wastewater treatment using the water hyacinth system, gravity flows are generally used, while energy to operate the water hyacinth based systems is provided by sunlight.

There are a number of virgin forests in Cameroon, especially in the South Western part of the country. Natives of Bakweri, Bakundo, Bangwas and others visit the forests to hunt for mushroom and bush rodents. In a survey, some elderly acclaimed that when they are thirsty and have no other option, they still don't just drink any kind of available water, they would rather have to watch bees hovering on a stream/brook. They settle for that water source. Commenting on this, it has been observed that bees do not generally hover on dirty water, and as such this is used as indicators of clean water. (Personal communication, 2004). Another indicator, some villagers used in the hunt for clean water is how much and what type of trees grows on the banks of the stream. It has been observed that in the forest, stream/brooks with palm trees (*Elais guineensis)*, raffia palm, date palm, coconut trees or India Bamboos) growing on the banks usually generate fairly clean water. Their belief is that the roots of palm trees or the afore-listed trees does purify water. Interestingly, the roots of palms, date palms, raffia palms and oil palms have been used as activated carbon to mop up heavy metals successfully in a sand-based water filtration system. Foo, (2004) further explained that plants in a water pool can ensure or improve water quality / clarity, and has been attributed to the process of absorption of nutrients by a larger root system. In the rainy seasons though, the people depend very much on rainwater harvest but feel that despite the sparkling appearance of rainwater it is still not wholesome. The general feeling is that the water is hard, waste their soap during washing and lacks the familiar potable water taste. (Personal Communication, kom elders, 2004). The elderly recommend that hot pellets of charcoal be placed in the water and allowed to stand for sometime. This to them solves the problem of hardness and does not waste soap and thus lathers well.

The conclusion can be drawn here that there is corroboration between the uses of charcoal/activated carbon to mop up metals/heavy metals from unwholesome water as observed by Lechevallier and Mafeters (1990). This practice is common in some tribes in Northern Nigeria. They used kept/soury corn fufu or pastry, and drop it in very turbid water. This attracts debris/particulate matter and aids coagulation. They allow it for some hours depending on the turbidity of the water. After this, they filter by decanting and is ready for drinking (information from the Research Department of Catholic Arch Diocesan Rural Development Project Jos, Plateau State, Nigerian (CARUDEP), 2005).

In reality cereal flours aid in coagulation of particulate matter and can generate some fair level of clean water, but would require further treatment. Actually, starch from maize flour can also aid in the coagulation of particulates from turbid water, the only big setback is that it can generate a lot of nutrients in the water and thus promote microbial proliferation if allowed for more than 24 hours. The following biomaterials do have a fair level of coagulation and would also be good for use in turbid water in fish ponds This would allow the fish to feed on the nutrients while generating some level of clarity as well according to Okafor and Ejiofor (1986). They are, Maize flour and starch, Broad beans, Cowpea beans. Necessity, they say is the mother of invention. It is absolutely unimaginable how some indigenouspeople cope with odds in Africa. Apart from relatively poor sanitary conditions in a number of communities in Southern Cameroon, pollution of streams with agrochemical residues is apparent. Gamaline 20, Nordoxsuper 75 (a copper-based fungicide imported from Oslo, Norway) is frequently used to control cocoa pod disease, the leaching effect into streams have been noticed as dead fish flood about in streams. This holds true in South Western Nigeria. First turbid/muddy water as the only source of water is fetched and kept in the sun all day long till sunset. It is then filtered by decantation into clean container containing, candle wax/paraffin wax; sometimes it is melted directly into the water, and allowed to float. This is then allowed a week retention, or sometimes more, then the candle wax or paraffin, which have attracted particles and appear brownish are now removed. The water is then boiled for an hour and stored for drinking, cooking, and sometimes for laundry purpose. (Personal Communication, a Bakweri elder, South west, Cameroon, 2004). Most of this indigenous biocoagulants are not validated scientific except Moringa.

The seed powder of *Moringa oleifera, Lam* has been used in many African societies for water clarification for a long time, tribes in Northern Nigeria, Northern Cameroon, Chad, Niger, Sudan, Malawi, Ethiopia, Eritrea, Mauritania etc. have a history of use in clarification of turbid water for domestic use. (Sutherland et al, 1990; Lowell, 2001 and Kebrea, 2004).

II.2. Seeds of Moringa Oleifera

The seeds of *Moringa oleifera* tree have been found to be of great importance and most widely studied. Oil extracted from the seed is used to treat goitre and acute rheumatism and also applied as remedy for hysteria scurvy (Burkill 1985a). The oil is also used in cosmetics production and as lubricants in delicate machines like watches (Ramachandra, *et al* 1980). The seed is, today, used in water treatment as a coagulant and disinfectant (Eilert, *et al* 1980, 1981). The seed contains fixed oils, fatty acids such as palmitic acids, oleic acids, behinic acids, stearic acids and pterygospermin, an unstable substance with low melting point which decomposes readily to benzylisothionate (Ramachandra, *et al* 1980).

The active ingredient responsible for coagulation, a polyelectrolyte was isolated in the laboratory and found to be in less concentration during wet season than in dry season (Kurup, 1954b and Saluja et al 1987). The seed has been found to have antibacterial activity against both gram positive and gram-negative bacteria (Kurup, *et al* 1954a). The seeds were found to have antimicrobial effect against all *Staphylococcus aucreus, Pseudomonas aeruginosa isolates* in vitro while on filter disc inhibited the growth of *Staphylococcus aucreus, Bacillus subtilis* but not *Psedomonas aeruginosa* and *Escherichia coli.* It also had activity against the following organisms at certain dilutions: *Bacillus subtilis* and *Staphylococcus aucreus* 1: 70,000. The antibacterial action of pterygospermin has been ascribed to one of its molecular components released when pterygospermin breaks down (Jahn, 1986). Pterygospermin has also been reported to have high activity against moulds and fungi. Since the early 1970s a number of studies have been carried out to determine the effectiveness of the seed in water treatment. Laboratory investigations confirm the seed to be highly effective in the removal of suspended solids. (Berger *et al* 1984). Today the seeds of *Moringa* are being used in Guatamela, the Nile region and generally in Africa to treat water and wastewater. Moringa pterygosperma, a synonym of *Moringa oleifera* lam, is a deciduous plant with smooth or cocky bark. It can grow up to 1238 metres in height and 60cm in girth. The leaves are imparipinnete compound leaves with up to six pairs of pinnae. Each pinna has opposite pairs of branched pinnules with different numbers and size of leaflets. Between each pair of pinnules is a rod-like gland on the upper surface which easily falls off.

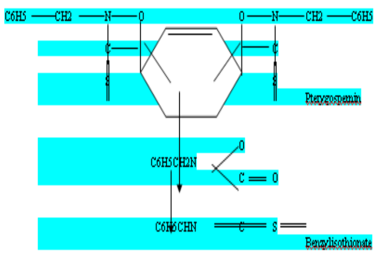

Fig. 3. Structure of pterygostermin from seeds of Moringa oleifera

The leaflets are oblong or obviate, the largest in about 2.5 x 1.2cm which is often oblique with dull green on both sides, and lighter coloured beneath. The plant produces fragrant scented flowers, which are bisexual (Sofowora, 1984). There are five pale green hairy sepals about 1.25cm long with fine white cream petals, which are unequal and a little longer than the sepals with slander style. The capsules of the fruits are pendulous, linear, acuminate obtusely frigonous and ribbed. The capsule is usually 20 – 45cm long but sometimes up to 120cm long. It contains numerous globular seeds about 1cm wide with three membranous wings at the base and apex (Sofowora, 1984).

Fig. 4. Plate1 *Moringa seed podanatomy from the tropics (Yongabi, 2006)*

Moringa oleifera lam is variously called in a number of languages; *Moringa oleifera* lam or *Moringa pterygosperma* in English, Horse radish tree, Drumstrick, Bentree, Radish tree, Mother's best friend, west Indian ben (Lowell, 2001) while in French, Bèn ailé, Benzolive and in Italian; Sandalo ceruleo (Lowell, 2001).

II.3. Chemical Constituents of Moringa Oleifera (lam)

Moringa Oleifera Lam contains several phytochemicals, some of which are of high interest because of their medicinal value. In particular, Moringa Oleifera or Moringaceae family is rich in a fairly unique group of glycoside compounds called glucosinolates and isothiocyanates. The effectiveness of the Moringa plant in treating ovarian cancer has been linked to the ability benzyl isothiocyanate (BITC) and phenethyl isothiocyanate (PEITC) to induce apoptosis in ovarian cancer cells in vitro (Kalkunte et al, 2006; Satyan et al, 2006. There is even evidence supporting the antitumour activity of isothiocyanates in cancers of the lung, breast, skin, esophagus and pancreas.

Moringa oleifera leaves contains 2 nitrile glycosides, naizirin and niazirinin, and 3 Mustard oil glycosides, 4 [c4' – O – actyl-alpha – L – rhamnosyloxy) benzyl] Isothrocyanate, niaziminin A and B which are reported to have hypotensive activity. Besides, beta-sitosterol, glycerol-1-(9-Octa decanoate), 3, - 0 – (6' – 0 – oleoyl – beta – D – glucopyranosy) – beta –sitosterol and beta – sitosterol – 3 – 0 – beta – D glucopyranoside have been identified. The root bark of Moringa Olefera contains two alkaloids; total alkaloids 0.1%, which are Moringine known to be identical to benylamine and Moringinine known to belong to the sympathomimetric group of bases. Many other Minors phytochemicals in traces such as; essential oil with pungent smell, phytosterol, waxes, and resins are found in the entire plant. Furthermore, a rich and rare combination of zeatin, qurcetin, beta-sitosterol, caffeoy/quinic acid, pteygospermin and kaempferol have been identified in the plant as well.

These components are also found in other Moringa species except for varying quantities, but studies are still inadequate on the other species (Munyaziza and Yongabi, 2007).

In some parts of Northern Nigeria in the early days some indigenous people walk with crushed seeds of *Moringa* when going to the farm, and would use it to treat any suspicious water they came across, before drinking, especially while on farms that are far away from homes with difficulty of getting potable water. There are a number of publications on the medicinal potential of the *Moringa* tree as a whole. (Jahn, 1984, Folkard et al, 1990; Folkard et al; 1996; Folkard et al 2000; Kebreab, 2004 and Yongabi, K.A, 2004)..

Another biocoagulant of fungal origin is the sclerotia of pleurotus tuberregium

The selerotium of *Pleurotus tuberregium* (Fr.) Singer has been reported to possess coagulative activity (Yongabi, 2004), This was the first report on this mushroom as a biococoagulant. The samples of the mushroom selerotium were gotten from Bai-Bikom in Kumba, in the South West Region of Cameroon. The studies showed that some mushrooms can clarify turbid water and as well reduce total aerobic bacterial counts. The selerotium as well as the mushroom fruit itself has a number of medicinal and nutritional applications to the people of Cameroon. (Yongabi et al, 2004), while the selerotium can be considered a biocoagulants, the mycelia could be used as a biofilter (Yongabi, 2004)..

Corn silk, palm fibres as well as banana or plantain stem bark fibres have been used in many indigenous communities in Cameroon as well as amongst the Igbos in Eastern Nigeria for various local filtration purposes. Amongst the palm wine dealers in the North West and South West Region of Cameroon, the use of these fibres to filter turbid palm wine before sale is a common practice. Similarly, these fibres have also been employed for filtration of turbid water when there is no sackcloth in most parts of rural Cameroon particularly in the olden days. This trend is similar in Eastern and Western parts of Nigeria and has not been validated

The beauty of this knowledge is to provide a platform for screening new biomaterials for water purification. **It** is worth noting that as much as some communities still remember and practice their traditional knowledge especially in water management, many still do not have or might have forgotten these old methods and now abandoned and lost. A number of communities in rural Africa do not treat their drinking water at all yet. The implication of this has invariably tantamount to increase in the rates of infectious diseases.

II.4. Coagulation Potentials of Parkia Biglobossa (Locust bean seeds)

Some tribes in Northern Nigeria have used seeds of *Parkia biglobossa* as biocoagulants for a long time (Sofowora, 1984). The seeds of the plant are pulverised and added to very turbid water and allowed to stand for an hour. The supernatant is then filtered using sackcloth and the water is then boiled for an hour (for long-term storage). In rural areas, the water is then stored in clay pots raised on a sand pile at home (this keeps the water cool). In a survey, a respondent stated strongly (an elderly man of about 102 years) expressed optimism that water treated that way (as described above) is better to him than water treated with Alum and other chemicals (chlorine) as is done today. To him, the challenges posed by poor water and sanitations are scaring and wonder about the situation in the future. That in their days, there were few people and one could just walk around and fetch water at any nearby stream without much suspicion as it is today. One could practically see that the water is clean, but in an era of environmental pollution, the situation has changed dramatically and population explosion.

In 1937, Dalziel reported the coagulative and disincentive property of locus bean seeds. The plant (tree) itself has a number of medicinal uses, such as in the management of diabetes – the leaves amongst others. The seeds have been fermented locally to produce a local sweetener /condiment for local soup recipes (Burkill, 1984a).

II.5. Wastewater Purification Potential and Indigenous Uses of Jatropha Curcas (physic nut)

The seed powder of physic nut (*Jatropha curcas)* is very useful in wastewater treatment. This plant belongs to the family Euphorbiaceae. Reports on the potentials of this plant in wastewater treatment exist (Yongabi, K.A., 2004;). Continuous studies show a very high coagulation potential as well as disinfection. The latex from the leaves equally poses some coagulation activity on turbid water apart from serving as a haemostat (stops clotting). The latex has been used in the treatment of scabies and lice in man (Yongabi, K.A. unpublished). There are creams/lotions made from the sees of this plants as well as for water treatment for irrigation on use (Personal Communication).

Activated carbon from the husk adsorbs heavy metals from contaminated water. Generally, the seed biomass is made up of about 35% oils rich in cosmetic value and equally used as lubricant oils for engines.

The roots of the plant holds the soil in tact and, therefore, good to be planted around areas gullible to erosion (Shabon et al 2005).

II.6. Garri Flour (Mannihot Esculanta Crantz) to Clarify Turbid Water

Garri is a fermented product of cassava and a common food widely eaten and cherished across Africa, especially Southern and Eastern part of Nigeria and Cameroon. The Bankundus, a tribe in the South Western part of Cameroon, has farming as their major preoccupation. Cassava (*Mannihot esculenta Crantz)* farming is one very intensive crop commonly cultivated by the women Garri from cassava is a source of income for the women.

The women have often sprayed garri flour in streams to attract fish when fishing. They sprinkle garri in streams/brooks/Rivers, to attract the fish to their nets.

In doing this, they incidentally noticed that when they sprinkle garri flour in muddy waters, after a while the water becomes fairly clear, and this has even enhanced their fishing as they can spot locate fishes in the water (personal communication, 2004). Garri being used as a fish food and at the same time biocoagulants in turbid waters could be very useful in integrated fish farming/water management in an integrated biosystem, thus promoting sustainable agriculture in developing nations. Cassava contains a toxic (neurotoxin) cyanide but the level varries with the cassava variety. There is the red cassava variety (the peel is reddish) with very low cyanide content and a variety of local products like tapioca/garri and local meals are prepared from. This cassava variety can be boiled and eaten directly without passing through any fermentation process. The white variety (the peel is whitish) cannot be used for water treatment as such due to its high cyanide content.

A discussion on garri production and degradation of toxic cyanoigenic glucosides is reported by Nduka Okafor (Okafor and Ejiofor (1986). The coagulation effect is due to starch in the garri, starch based products have traditionally been used by the water treatment industry as a coagulant or flocculate aid. Potato starch is preferred because of its high potassium content. Sticky starch at the base of the green leaf is antiseptic, coagulant, and starch from cassava has a multiplicity of medical and industrial application viz starchy mashed root used as a tooth paste, root flour of cassava in a cup of hot water or eating the young flower head to bind diarrhoea and dysentery.

III. The Use of Typha in Phytoremediation and Water Purification

Typha produces a good rhizome root system and there is a need to study the starch/flour for coagulation activity. Foo's experience with Typha shows high water clarification potentials

III.1. Lime Juice (Citrus Aurantifolia) for Drinking Water Disinfections/ Clarificationy

Lime /Lemon juice has been squeezed directly into a bucket of turbid water for purification. A number of communities adopted and used this in the past to treat dirty water apart from making dirty water fairly clear, it has a greater disinfective property. In some communities, two small lime fruits to a bucket of water.

Limes are acidic and thus toxic to a range of microorganisms. The fruit juice as well as the rhind has shown inhibition on *Escherichia coli isolates, Staphylococcus aureus. Baccillus sp, Proteus mirabilis.* Isolated from a range of specimens including highly turbid water (Yongabi, K.A., unpublished). This study and the traditional practice is in line with an earlier reports of Dalsgaard and Reinchert (1997).

Foo (2004) further acknowledged the world wide practice of adding lime to drinking water or slices of lime fruits into a jar of drinking water, and that it also provides a pleasant aroma to the final treated water.

The acidity in lime juice is responsible for its disinfective property. Adding lime juice to water (1 – 5% final concentration) to lower the pH bringing it to 4.5 will reduce *Vibrio cholerae* by 99.99% in abrut 120 minutes. This implies that a pH of less than 4.5 and a treatment time (contact time) of 120 minutes is key to reducing *Vibrio cholerae*. This would, probably, have the same effect on other microbes in water and thus ensure a good quality of drinking water. The pH of water can be lowered with lime/lemon juice to kill the microbes and the pH can be raised using Moringa seed powder to neutral (7.0) for drinking. In a comparative analysis, Foo (2004) reported that the disinfective property of limes is a slightly higher than that of lemon and this can be attributed slightly to the disparity in their acidities. Lime is more acidic than lemon. *Citrus* spp possess higher disinfectant ability in water than coagulation activity (Dalsgaard and Reinchert, 1997). However, the most reliable and widely studied biocoagulant is *Moringa oleifera*.

Moringa oleifera seed have about one year and three months depending on the geographic/climatic region as well as conditions of storage. However, it seems there are some biocoagulants with a fairly longer shelf-life on bench than Moringa oleifera, and the effect can be appreciated on the storage time when water is treated with Moringa and other biocoagulants. Garri and *Aloe barbadensis* as a biocoagulants has a longer shelf life than *Moringa oliefera*. Similarly, starch-based biocoagulants have a longer shelf life than protein-based biocoagulants (Yongabi, 2009). There are similarities of cultures across the globe, so some of the traditional methods of water treatment cited here in may be similar in other parts of the world. There is the need to revive these methods and find out how biocoagulant lives can be improved. The problem of water quality in rural Africa is chronic and will never be solved in the near future if concerted efforts towards the appraisal and, perhaps, revival of the local technologies are not implemented in an organised manner i.e looking for cheaper alternatives rather than expensive high technology. Another problem is that even with donor assistance in development of potable water supply schemes using high technology, most rural areas where people rely on subsistence farming cannot manage or maintain their water sources using such high technology. The dwindling economic condition in most African countries will necessitate alternative technology with local available materials to complete the existing conventional water treatment rather than importing chemicals from abroad at elevated costs whereas the indigenous ones could be developed. Kebreab (2004).

IV. Clarification Using Plants and Plant Materials

Some previous studies have screened a number of plants as disinfectant for water treatment, Acrorus calamus linn (buch) (araceae) Roots, Anaphalis Cunefolia Hook (Compositae) Entireplant, Arnebial nobills Rachanger (Ratangot) (Boraginaceae) Root, Eclipta aibba (linn) Hassk (Bhgangra) Entireplant compositae, Hypericum spp (Gut ifera) wholeplant, Azadirachta Indica L juss leaf (meliaceae), Moringa oleifera Moringaceae fruits, roots, bark, wood stem (Jahn, 1981) and stryctnos potatorum.

Native plants have traditionally been used to improve quality of water in many countries in Africa and Latin America viz. Seeds of Moringa used in Guatemala, peach and bean seeds are used in Bolivia as coagulant aids clarify water. It has been reported that dried beans (vicia fave) and peach seeds (percica vulgaris) have been used in Bolivia and other countries of water treatment. Similarly, Schoenoplectus tatora, an aquatic plant has been used in Bolivia and Peru for Water Quality treatment (Kebreab, 2004; Miller et al, 2008).

Schoenoplectus tatora like cattail is used to remove phosphorus and nitrogen before being discharged to natural drainage systems.

The use of aquaculture as a means of treating waste water took centre stage and this involves both natural and artificial wetlands as well as the production of algae, higher plants (submerged and emerse), vertebrates and fish to remove contaminants such as Manganese, Chromium, Copper, zinc and lead from water. Similarly, water hyacinth (Eichhornia crassipes) has been widely used for the treatment of wastewater, amongst other plants like duck weed, seaweed and alligator weed (Kranert and Hillebrecth, 2001; Shaban et al 2005 and Shuaibu and Yongabi, 2005). Progress continues in the area through invitro experiments employing hydroponics, cultivation of grasses using domestic wastewater is promising as, it removes organic matter and suspended solids through physical, adsorption and absorption and other mechanisms. But in Africa there technologies are yet to yield dividends and may not be possible in the foreseeable future.

A number of seed extracts have been known to flocculate particles in water and the following procedure has been used according to Jahn (1981) and which if developed may yield dividends. It include;

1) Extract the seeds from the plant fruit
2) Dry seeds for up to three days
3) Grind the seeds to a fine powder
4) Prepare a mixture of water and ground seed material (the volume of water depend on the type of seed material used) in case of Moringa leifera, add 100cm^3 of water for each seed; for peach or bean seeds, add, l of water to each 0.3 to 0.5g of ground material.
5) Mix this solution for 5 to 10 minutes: the faster it is stirred, the less time is required.
6) Finally, after the sediments settle, decant the treated water, testing it for P^H, color and turbidity. But with wetland system, water hyacinth is the most popular plant used in phytoremediation.

The conclusion is drawn that biocoagulants have been used in many African indigenous communities from antiquity with great benefits. In an era of increasing environmental concerns, water scarcity admist the draw backs of chemical coagulants and poor sanitary facilities in most low income earning countries, the need to further develop natural coagulants as alternative environmentally favourable water purifying chemicals is exigent.

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