A Review on Potential Application of *Moringa oleifera* Seeds as Alternative Natural Coagulant in Water Treatment.

[1]Dr.A.Radha and [2]Dr.M. Mumtaz

[1]Department of Zoology, K.N.G.Arts College for Women (Autonomous) Thanjavur-7,Tamil Nadu, India

[2]Department of Zoology, M. S. S. Wakf Board College, Madurai-20, Tamilnadu, India

Abstract

Water is a resource that is essential for life and is required by almost every living organism. This resource is, however, becoming very limited in its pure state due to the many anthropogenic means of contamination which arise from the different industrial advancements made over the years. Water pollution is a serious problem for the entire worldand contributed to negative environmental and human health impacts.Drinking water needs to be treated in order to remove impurities and bacteria to meet the quality guidelines which satisfy 5 nephelometric turbidity units (NTU) for drinking water requirement according to the World Health Organization. Plants are rich in secondary metabolites and are being used for the treatment of various ailments. *Moringa oleifera* (MO) is a multipurpose tree with considerable potential and its cultivation is currently being actively promoted in many developing countries. Seeds of this tropical tree contain water-soluble, positively charged proteins that act as an effective coagulant for water and wastewater treatment.The coagulant particles and properties which have been confirmed in laboratory studies due to this coagulating properties that have been used for various aspects of water treatment such as turbidity, alkalinity, total dissolved solids and hardness. However, its bio-sorption behavior for the removal of toxic metals from water bodies has not been given adequate attention. The seeds are neither harmful to humans nor animals. It is quite efficient in reducing microorganisms' presence in raw water. Thus, water treated using such naturalcoagulant is more recommendable to use compared to one treated with alum. Treating water at different dosage is recommended and yielded a positive outcome. This is one of the merits of Moringa seeds over alum.The seeds are environmentally friendly because they do not further deteriorate the environment. Also, due to its availability and maximum effluent removal from both domestic and synthetic wastewater, the application of the seeds in wastewater treatment is undeniable intrinsically.

Keywords:*Moringa oleifera*, Turbid Water, NaturalCoagulant, Heavy metals, .Water purification.

INTRODUCTION

Access to safe drinking water is one of the main human rights. However, today, more than 700 million people live without access to safe drinking water, especially in rural areas.Water occupies about 70% of the earth's space with only 0.4% available for use (Mein & Larson, 1973).Growing human activities not only have increased demand for potable water but have also increased the generation of wastewater (UN Report, 2013). For millions of people, a shortage of clean drinking water is a reality they must face every day. Sometimes they simply do not have enough; in other cases, the available water is contaminated. In developing countries, poor water quality is the leading cause of health problems. Eighty percent of all illnesses in developing countries are caused by polluted water. It is estimated that 2 million people die from these illnesses every year.Pollution of surface and groundwater from agriculture, domestic and industrial activities has not been regularly monitored and recorded as a problem. This may be due to the absence of a problem or the lack of monitoring facilities in the Pacific Island Countries (Litidamu, Young, & Valemei, 2005).

There is the limited possibility of an increase in the supply of fresh water due to competing demands of increasing populations throughout the world; also, water-related problems are expected to increase further due to climate changes and due to population growth over the next two decades (Ahmad, Hanif, Nadeem, Jamil, & Zafar, 2008). It is estimated that worldwide population will increase by about 2.9 billion people between now and 2050 (according to UN's average projections) (Basra, Iqbal, Ur-Rehman, & Ejaz, 2014). Shortage of fresh water supply is also a result of the exploitation of water resources for domestic, industry, and irrigation purposesis, however, important to subject water from every source to varying forms of treatment or purification before consumption, or discharge in the case of wastewater. These forms of purification are aimed at making water potable and attractive. The level of threat water poses determines the choice of treatment to be employed(Ali, Muyibi, Salleh, Alam, & Salleh, 2010a). Before distribution for consumption, raw water is subjected to the following conventional procedures: screening, plain sedimentation, coagulation-flocculation followed by sedimentation, filtration,and disinfection(Ndabigengesere & Narasiah, 1998).

Heavy Metals and Water Sources

Much strict legislationhas been introduced in various countries to control water pollution. Various regulatorybodies have prescribed the maximum permissible limits for toxic heavy metals discharge into aquatic systems. Thepermissible limits for heavy metals in industrial effluents discharge set by the World Health Organization (WHO) are 0.05-1.5(Cu), 0.1(Cd), 5-15(Zn), 0.1(Pb), 0.1-1 (Fe), and 0.05-0.5 (Mn), 0.02 (Ni), in ppm. (Fisher & Litigation).Metal ions are being reported as priority pollutants, due to their dispensability in natural water ecosystems andalso due to their toxicity (Demirbas, 2008). The problem associated with the existence of metal ions as pollutants is their non-biodegradability and high persistence in the environment. They accumulate in living tissues, leading tovarious diseases and disorders (Ngah & Hanafiah, 2008). The toxic metal compounds that are disseminated into the environment by anthropogenic activitiescontaminate not only surface water bodies such as ponds, lakes and reservoirs but even ground water after seepage into the water table. There are many heavy metals that are resultants of industrial and domestic activities. Some ofthem are Copper (Cu), Arsenic (As), Chromium (Cr), Lead (Pb), Nickel (Ni), Cadmium (Cd), mercury (Hg), zinc(Zn), manganese (Mn), etc. Most of the heavy metals are released from anthropogenic sources such as mineral ores,metallurgical industries, paints and ceramics, wood preservatives, dyes and pesticide manufacturingindustries(Gassenschmidt, Jany, Bernhard, & Niebergall, 1995).

Drainage of sewage water without treatment and its use for irrigation purpose are possible ways of heavy metals accumulation in plants food chain (Farah, Zia, Rehman, & Sheikh, 2002; Lesmana, Febriana, Soetaredjo, Sunarso, & Ismadji, 2009).Heavy metals toxicity can effect in damaged or reducedfunction of mental and central nervous systems, lower levels of energy and damaged blood composition, liver,lungs, kidneys and other vital organs. (Ahmaruzzaman, 2011)Chromium is emitted into air, water and ground water in the form of a particulate. Cr (VI) is highly reactivecompared to Cr (III) and causes oxidative damage to the lungs, liver and gastrointestinal tract. The permissible limitof Cr (VI) in drinking water is 50µg /L whereas the major rivers of our country are polluted with much more higherconcentrations exceeding the tolerable limits. (CWC report 2014). Nickel (Ni) is released from smelting operations,battery industry, thermal power plants and others.The source of Cadmium (Cd) in water bodies is from Zincsmelting, e-waste,

paint sludge, incinerations, waste batteries& fuel combustion.Lead (Pb)is a by-product of lead-acid batteries, E-waste, Smelting operations, paints, coal-based thermal power plants, ceramics and bangle industry.Zinc is an essential trace element found in virtually all food and potable water in the form of salts or organic complexes (Organization, 2004). Zinc is found in industrial waste and used in metal plating. Therefore, sources of zinc in water are mainly from industrial discharge and natural sources (Xue & Sigg, 1994).

Synthetic Coagulants in Water Purification

Many coagulants are widely used in conventionalwater treatment processes for potable waterproduction. These coagulants can be classified intoan inorganic coagulant, synthetic organic polymer, andnaturally occurring coagulant. Syntheticpolyelectrolytes are used as primary coagulant aswell as coagulant aid to improve the strength ofparticle aggregates, enhance coagulation anddeposition (filtration) (Suleyman A Muyibi & Evison, 1995).Naturally occurring coagulants are usually presumedsafe for human health while there is a fear by usingaluminum salts that may induce Alzheimer's disease(Martyn et al., 1989). The turbidity is conventionally removed by treating the water with expensive chemicals, many of which are imported at great cost and these are frequently unavailable. Large water treatment centers to the water purification by adding coagulants to the water such as alum. The production of drinking water is a major problem of developing countries and particularly those in the tropical area of Africa. There are serious problems regarding the water supplies in the towns with a high density of population, because the quantity and quality of groundwater are not sufficient to ensure the total potable water demands. Thousands of chemicals have been identified in drinking water supplies around the world and are considered potentially hazardous to human health at relatively high concentrations (Organization, 2004). Several conventional methods are used for waste water treatment including coagulation-flocculation followed by sedimentation, filtration, precipitation, ion exchange resins and reverse osmosis before its distribution to consumers (Chang, Chang, Lin, & Hsu, 2002; Suleyman Aremu Muyibi, Noor, Ong, & Kai, 2001).

Many inorganic coagulants, synthetic inorganic polymer and naturally occurring coagulants are also widely used in conventional water treatment processes (Suleyman Aremu Muyibi et al., 2001). Nonetheless, use of ploy ammonium chloride, poly aluminumsilicasulphate and inorganic alum salt is most common (Brisson et al., 1991; Najm, Paul, Mueller, & Wyckoff, 1998)And use of aluminium containing coagulants is expensive and synthetic organic polymers have strong carcinogenic properties(Curran, Miller, Zokas, &

Verma, 1984). Further, aluminium is the causative agent of neurological disorder presenile dementia and alum itself may induce Alzheimer's disease(Crapper, Krishnan, & Dalton, 1973) and have low coagulation efficiency when reacting with natural alkalinity inthe water leading to pH reduction (Ndabigengesere &Narasiah, 1998).Aluminiumsulphate (Al2(SO4)318H2O) stands out as the most used synthetic coagulant in Brazil when it comes to water treatment of public supplies as a result of its high efficiency in suspended solids removal and low cost. However, its effect is strongly dependent on pH, especially in the range from 5.5 to 8 (Boisvert & Lewis, 1997; Suleyman Aremu Muyibi et al., 2001)and at the end of the treatment there is the possibility of a high concentration of residual aluminium remaining in water(Boisvert & Lewis, 1997), which can be associated with the acceleration of degenerative processes of Alzheimer's disease (Chang et al., 2002; Farah et al., 2002; Lesmana et al., 2009). There is also the problem of the reaction between aluminium and the natural alkalinity present in water, which leads to a pH reduction(Miller, Marion, & Robinson, 1984). This review evaluates *Moringa oleifera*(the local Fijian variety) seeds as natural coagulants and reports an economical and environmentally safe method of water purification. This will show the way to improve the quality of drinking water in rural areas.

***Moringa oleifera* seeds as natural coagulant**

Agricultural wastes are a potential source forbiosorbents as they have lingo-cellulosic compounds as major constituents and also other polar functional groupssuch as alcohols, aldehydes, carboxylic, ketones, phenolic, thiol and ether groups.These groups have the ability to bind heavy metals by donating an electron pair to complex the metal ions insolution(Demirbas, 2008)Many plants such as Neem, Garlic, Turmeric and drumstick are reported to have biosorbent properties thatchelate the heavy metals from water sources. Chemically modified biosorbents have been developed to enhance theheavy metal chelation property. This property has been promising because of its simplicity, in line with conventional-exchange technology, due to its efficiency and availability of biomass and waste bio-products. These biosorbents are eco-friendly, easy to procure and develop and do not pose and toxic effects or side effects to alter the potability of drinking water.Natural coagulants have been used for centuries in traditional water treatment practices throughout certain areas of the developing world. Crushed Moringa seeds clarify and purify water to suit domestic use and lower the bacterial concentration in the water making it safe for drinking. By using Moringa seeds people will no longer be depending on expensive means originating from the West. Using Moringa to purify

water replaces chemicals such as aluminiumsulphate, which is dangerous to people and the environment, and are expensive.

Bioremediation is a waste water management technique that facilitates removal or neutralization of pollutants from acontaminated site. Many plants and their extracts have been used for bioremediation of heavy metals in the process ofphytoremediation. *Moringa olifera*, also known as drumstick is a fast growing, drought resistant plant that belongs to the family of*Moringaceae*.*Moringaolifera*seeds have been reported to have bioremedial property which can be enhanced on chemical modification.The dryseed suspension is known to be a natural coagulant and coagulant aid (Folkard et al., 1989). In Sudan, dry *Moringa oleifera*seeds are used in placeof alum by rural women to treat highly turbid Nilewater.Safe drinkingwater is essential to the health and welfare of acommunity, and water from all sources must havesome form of purification before consumption.Various methods are used to make water safe andattractive to the consumer. The method employeddepends on the character of the raw water. One ofthe problems with the treatment of surface water is thelarge seasonal variation in turbidity (McConnachie, Folkard, Mtawali, & Sutherland, 1999).In these processes, coagulants play a very vital role in the reduction of water turbidity and removal of other contaminants.

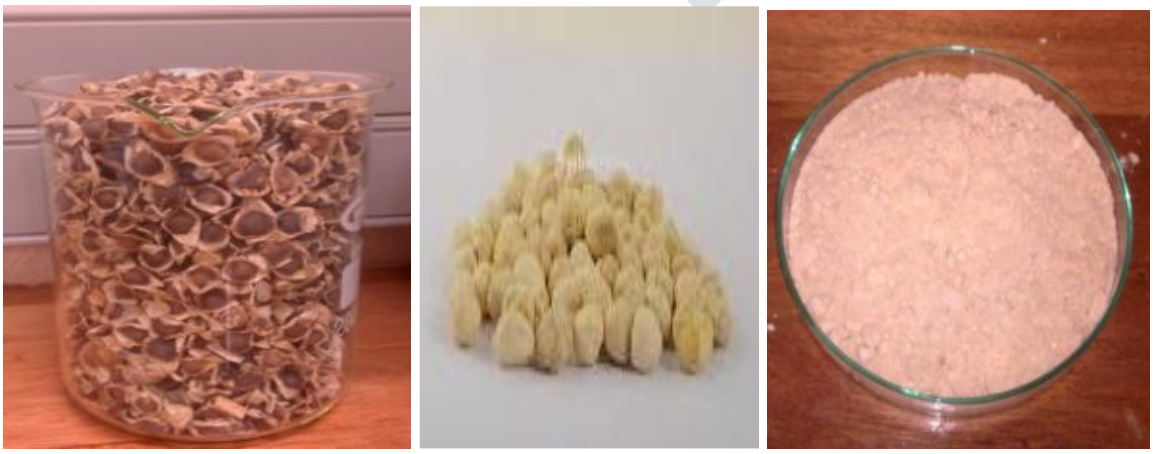
Compared to other natural chemical coagulants, *Moringaoleifera* has various advantages such as low cost,production of biodegradable sludge and lower sludge volume, and also it has no effect on the pH of the water. *M.oleifera* seeds were found to possess turbidity removal and anti-microbial properties (Madsen, Schlundt, & El Fadil, 1987; Olsen, 1987), although the anti-microbial mechanism of seeds is not yet understood completely. In the water treatment step involving coagulation is conducted by physicochemical modification of colloidal particles that characterize the color and turbidity by adding coagulant chemicals, reduce the forces responsible for keeping the particles apart and suspended (Richter & Rosselló-Móra, 2009). Naturally occurring coagulants are usually presumed safe for human health. , many types of research have shown that compounds from *M. oleifera* seeds can reduce water effluent to a recommendable level. This seed was used as a primary coagulant for raw-water and synthetic turbid water purification for turbidity removal.

The (Electric Conductivity) of untreated sewage water was lower than treated water due to the solubility of minerals. More decrease in EC of sewage water with *Moringa oleifera* seeds was due to the

presence of lower molecular weight water-soluble proteins which carry a positive charge (Agarwal, 2007; Ali et al., 2010a). Addition of optimized concentrations of moringa seeds or other coagulants into untreated and treated sewage water, the seed proteins produce positive charges attracting negatively charged particles removing anions in gaseous form (Amagloh & Benang, 2009).*Moringa oleifera* seeds had coagulating and softening properties in addition to pH reductant and can handle groundwater with moderate to high alkalinity (Muyibi∗, Mohd Noor, Ahmadun, & Ameen, 2002).Various parts of *M.oleifera* from many sources have been analyzed for compounds such as glucosinolates and phenolics (flavonoids,anthocyanins, proanthocyanidins, and cinnamates. Every glucosinolatesas a central carbon atom which issupposedly bonded to the glucose group (to form asulfateketoxime) via a sulfur atom and also bonded to a sulphate group via a nitrogen atom. These functional groups that contain sulfur and nitrogen are responsible for good metal sequestration from aqueous solution.Earlier studies have found the *Moringa oleifera* seeds are non-toxic, and recommended its use as a coagulant in water treatment in developing countries. *Moringa oleifera* is the best natural coagulant discovered so far that can replace alum (Ali, Muyibi, Salleh, Alam, & Salleh, 2010b).

Method of *Moringa* powder (MOPowder) Preparation

Seeds of *Moringa oleifera* Lam. were collected,Seeds were given washings with distilled water to remove impurities if any and dried at 65°C for 24 h. The brown seed coats were removed and the white kernels crushed in a mortar and pestle. The resultant white seed powder was sieved through a tea strainer and the fine seed fraction kept in an air-tight container until needed.



A) The seed before the coat was removed; B) the seed after the removal of the seed coat; and C) the seed kernel blended into fine particles.

The effectiveness of *Moringa oleifera* seed in domestic sewage treatment:

Many studies highlight the efficiency of *Moringa oleifera* seed extract as coagulant used in coagulation of model turbid water.In one investigation wasstrongly supported on the effectiveness of *Moringa oleifera* seed for the treatment of domestic sewage was carried out in 15 liters plastic pots. The treatments included: the control culture (no *Moringa* seed), 2 g of *Moringa oleifera*, 4 g of *Moringa oleifera* and 6 g *Moringa oleifera*. Physical, bacteriological and chemical properties of domestic sewage were investigated before and after treatment. The turbidity value was reduced drastically for the treatments. Water hardness was reduced from 64.2 mg/l to 36 mg/l for the treatments. Alksalinity was reduced from 148 mg/l to 114 mg/l for the treatments, total solids were reduced from 1280 mg/l to 1129 mg/l for the treatments, suspended solids were reduced from 384 mg/l to 306.3 mg/l for the treatments, dissolved oxygen was reduced from 124.8 mg/l to 112.7 mg/l for the treatments, dissolved solids were reduced from 896 mg/l to 820.3 mg/l for the treatments, and acidity was increased from 0.84 to 2.02 for the treatments. The pH value was reduced from 9.6 to 7.5 for the treatments. BOD was reduced from 96.5 mg/l to 80.2 mg/l for the treatments and COD was reduced from 81.6 mg/l to 72 mg/l for the treatments. Generally, the results showed that the higher the quantity of *Moringa oleifera* seed applied to sewage, the better the purification of the sewage. In some other studies showed the seed powder exhibits a remarkable reduction in turbidity and coliform count which makes the seed powder a good source for water purification.*M. Oleifera* seeds extract is a potential source for water treatment due to its efficacy. When used for the treatment of wastewater, excellent results were obtained, due to its availability and maximum effluent removal from both domestic and synthetic wastewater,

Discussion

Plants are rich in secondary metabolites and are being used for the treatment of various ailments in the indigenous system of medicine. Many developing countries are facing illnesses, and deaths among children are caused by germs, which get into the mouth via water and food. In addition, it has been estimated that up to 80% of all disease and sickness in the world is caused by inadequate sanitation, polluted water or unavailability of water. In many parts of the world river water which can be highly turbid is used for drinking purposes.Thousands of chemicals have been identified in drinking water supplies around the world and are considered potentially hazardous to human health at relatively high concentrations (Organization,

2004). There is much talk of a water crisis, of which the most obvious manifestation is that 1.2 billion people lack access to safe and affordable water for their domestic use. Another worrisome issue is that large world populists are living in rural areas, have an income below the one-dollar-per-day poverty line and lack access to quality water for their livelihoods. It is, however, important to subject water from every source to varying forms of treatment or purification before consumption, or discharge in the case of wastewater.However, chemical coagulants are not readily available in developing countries, can be quite expensive for people living in remote rural areas in developing countries, and can pose adverse effects on public health if not applied at the correct dosage. Therefore, the use of natural coagulants of plant origin is a viable alternative to chemical coagulants.

Naturally occurring coagulants are usually presumed safe for human health. Earlier studies have found the*Moringa oleifera* seed as an alternative natural coagulant for potential application in water treatment.*Moringa oleifera* seeds are non-toxic and recommended its use as a coagulant in water treatment in developing countries. Moringa oleifera is the best natural coagulant discovered so far that can replace alum (Ali et al., 2010b). It has been widely documented that extracts from plants such as Moringaoleifera have proven effective in the removal of suspended solids, in turbidity removal, in the softening of hard water, and also in the reduction of slurry produced as compared with that produced by chemical coagulants. The seeds are environmentally friendly because they do not further deteriorate the environment

Conclusion

Providing safe drinking water to societyis the major challenge for a district administration, it could be possible only by having a low-cost and safe alternativewater treatmenttechnology.The use of local *Moringa* seeds as primary coagulants for clarification is useful in the production of drinking water in developing countries where the purchase of other chemical coagulants are expensive and the operating costs are high for metal removal. *Moringa oleifera* seed as a natural coagulant maintains the neutral state of water after treatment. Hence, the use of *Moringa oleifera* seed could be more suitable and have a distinct advantage over the use of chemical coagulants such as alum in water treatment for rural communities in developing countries.*Moringaoleifera*seeds stand out as a promising natural coagulant by an economical and environmentally safe method of water purification.

References

- Agarwal, A. K. (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. *Progress in energy and combustion science*, *33*(3), 233-271.
- Ahmad, I., Hanif, M. A., Nadeem, R., Jamil, M. S., & Zafar, M. S. (2008). Nutritive evaluation of medicinal plants being used as condiments in South Asian Region. *Journal of the Chemical Society of Pakistan*, *30*(3), 400-405.
- Ahmaruzzaman, M. (2011). Industrial wastes as low-cost potential adsorbents for the treatment of wastewater laden with heavy metals. *Advances in colloid and interface science*, *166*(1-2), 36-59.
- Ali, E. N., Muyibi, S. A., Salleh, H. M., Alam, M. Z., & Salleh, M. R. M. (2010a). Production of natural coagulant from Moringa oleifera seed for application in treatment of low turbidity water. *Journal of Water Resource and Protection*, *2*(03), 259.
- Ali, E. N., Muyibi, S. A., Salleh, H. M., Alam, M. Z., & Salleh, M. R. M. (2010b). *Production technique of natural coagulant from Moringa oleifera seeds.* Paper presented at the Fourteenth International Water Technology Conference, IWTC.
- Amagloh, F. K., & Benang, A. (2009). Effectiveness of Moringa oleifera seed as coagulant for water purification. *African Journal of Agricultural Research*, *4*(2), 119-123.
- Basra, S., Iqbal, Z., Ur-Rehman, H., & Ejaz, M. (2014). Time Course Changes in pH, Electrical Conductivity and Heavy Metals (Pb, Cr) of Wastewater Using Moringa oleifera Lam. Seed and Alum, a Comparative Evaluation. *Journal of applied research and technology*, *12*(3), 560-567.
- Boisvert, G., & Lewis, L. J. (1997). Self-diffusion of adatoms, dimers, and vacancies on Cu (100). *Physical Review B*, *56*(12), 7643.
- Brisson, G., Boisvert, P., Peronnet, F., Perrault, H., Boisvert, D., & Lafond, J. (1991). A simple and disposable sweat collector. *European journal of applied physiology and occupational physiology*, *63*(3-4), 269-272.
- Chang, Y.-K., Chang, J.-E., Lin, T.-T., & Hsu, Y.-M. (2002). Integrated copper-containing wastewater treatment using xanthate process. *Journal of hazardous materials*, *94*(1), 89-99.
- Crapper, D., Krishnan, S., & Dalton, A. (1973). Brain aluminum distribution in Alzheimer's disease and experimental neurofibrillary degeneration. *Science*, *180*(4085), 511-513.
- Curran, A. T., Miller, D., Zokas, L., & Verma, I. M. (1984). Viral and cellular fos proteins: a comparative analysis. *Cell*, *36*(2), 259-268.
- Demirbas, A. (2008). Heavy metal adsorption onto agro-based waste materials: a review. *Journal of hazardous materials*, *157*(2-3), 220-229.
- Farah, N., Zia, M., Rehman, K., & Sheikh, M. (2002). Quality characteristics and treatment of drinking water of Faisalabad city. *Int. J. Agric. Biol*, *3*(347), 9.
- Fisher, E., & Litigation, C. C. Obsession and Expertise: Reflecting on the Scholarly Response to Massachusetts v EPA'(2013). *Law Policy*, *35*, 236.

- Folkard, M., Prise, K., Vojnovic, B., Davies, S., Roper, M., & Michael, B. (1989). The irradiation of V79 mammalian cells by protons with energies below 2 MeV: part I: experimental arrangement and measurements of cell survival. *International journal of radiation biology, 56*(3), 221-237.
- Gassenschmidt, U., Jany, K. D., Bernhard, T., & Niebergall, H. (1995). Isolation and characterization of a flocculating protein from Moringa oleifera Lam. *Biochimica et Biophysica Acta (BBA)-General Subjects, 1243*(3), 477-481.
- Lesmana, S. O., Febriana, N., Soetaredjo, F. E., Sunarso, J., & Ismadji, S. (2009). Studies on potential applications of biomass for the separation of heavy metals from water and wastewater. *Biochemical Engineering Journal, 44*(1), 19-41.
- Litidamu, N., Young, T., & Valemei, I. (2005). An assessment of health impacts from environmental hazards in Fiji.
- Madsen, M., Schlundt, J., & El Fadil, E. O. (1987). Effect of water coagulation by seeds of Moringa oleifera on. *Journal of Tropical Medicine and Hygiene, 90*, 101-109.
- Martyn, C., Osmond, C., Edwardson, J., Barker, D., Harris, E., & Lacey, R. (1989). Geographical relation between Alzheimer's disease and aluminium in drinking water. *The Lancet, 333*(8629), 59-62.
- McConnachie, G., Folkard, G., Mtawali, M., & Sutherland, J. (1999). Field trials of appropriate hydraulic flocculation processes. *Water Research, 33*(6), 1425-1434.
- Mein, R. G., & Larson, C. L. (1973). Modeling infiltration during a steady rain. *Water resources research, 9*(2), 384-394.
- Miller, R. H., Marion, P. L., & Robinson, W. S. (1984). Hepatitis B viral DNA-RNA hybrid molecules in particles from infected liver are converted to viral DNA molecules during an endogenous DNA polymerase reaction. *Virology, 139*(1), 64-72.
- Muyibi, S. A., & Evison, L. M. (1995). Moringa oleifera seeds for softening hardwater. *Water Research, 29*(4), 1099-1104.
- Muyibi, S. A., Noor, M. J. M. M., Ong, D. T., & Kai, K. W. (2001). Moringa oleifera seeds as a flocculant in waste sludge treatment. *International journal of environmental studies, 58*(2), 185-195.
- Muyibi∗, S. A., Mohd Noor, M. J., Ahmadun, F.-R., & Ameen, E. (2002). Bench scale studies for pretreatment of sanitary landfill leachate with Moringa oleifera seeds extract. *International journal of environmental studies, 59*(5), 513-535.
- Najm, H. N., Paul, P. H., Mueller, C. J., & Wyckoff, P. S. (1998). On the adequacy of certain experimental observables as measurements of flame burning rate. *Combustion and flame, 113*(3), 312-332.
- Ndabigengesere, A., & Narasiah, K. S. (1998). Quality of water treated by coagulation using Moringa oleifera seeds. *Water Research, 32*(3), 781-791.
- Ngah, W. W., & Hanafiah, M. (2008). Removal of heavy metal ions from wastewater by chemically modified plant wastes as adsorbents: a review. *Bioresource technology, 99*(10), 3935-3948.
- Olsen, A. (1987). Low technology water purification by bentonite clay and Moringa oleifera seed flocculation as performed in Sudanese villages: effects on Schistosoma mansoni cercariae. *Water Research, 21*(5), 517-522.

- Organization, W. H. (2004). *Guidelines for drinking-water quality: recommendations* (Vol. 1): World Health Organization.
- Richter, M., & Rosselló-Móra, R. (2009). Shifting the genomic gold standard for the prokaryotic species definition. *Proceedings of the National Academy of Sciences, 106*(45), 19126-19131.
- Xue, H. B., & Sigg, L. (1994). Zinc speciation in lake waters and its determination by ligand exchange with EDTA and differential pulse anodic stripping voltammetry. *Analytica Chimica Acta, 284*(3), 505-515.