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Research Article

A REVIEW ON THE USE OF PLANT SEEDS IN WATER TREATMENT

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ABSTRACT

Global population, which has been estimated by United Nations to hit 9.8 Billion by the middle of this century and the corresponding demand for clean, affordable and portable water, which is not readily available, especially for developing countries and even developed ones, has become a course for concern. It is estimated that 1.2 billion people lack access to clean drinking water and about 2.2 million people die annually, mostly of children under five due to consumption of unsafe water. The use of inorganic chemicals in treating water is fast becoming problematic, as it is associated with different deteriorating human health condition and pollution of water bodies. Simple to complex methods are involved in this, but the general procedure involves, collection of plant seeds, drying, grinding/extraction of active compounds and its application in water sample.

Keywords: Biocoagulation; Biodisinfection; Bioresource; Biosorption; Plant Seeds. Water Treatment

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1. INTRODUCTION

The use of inorganic or synthetic chemicals in water treatment has become a matter of concern, as it has been discovered to have side effects, and this has led to the need to research into alternatives that are extracted from natural sources and are renewable [1]. The conventional chemicals used in water treatment are also not ecofriendly, as they tend to affect non target organisms [2]. Aluminum being the most commonly used coagulant in developing countries, has been linked to the development of neurological diseases (e.g. pre-senile dementia or Alzheimer's disease), cognitive and intellectual deterioration leading to memory loss, neurological diseases that affect nervous system, cancer and a number of environmental issues [3].

In the Sub-Saharan region of Africa, 80 – 90 % of all infectious diseases are water borne; more than 1.2 million people lack safe drinking water in this region and 1.2 billion people globally [3,4]. The use of inorganic or synthetic water treatment chemicals is relatively expensive for locals in these regions. Apart from this high cost of treating water in this region, waterborne microorganisms are gradually developing resistance to currently used coagulants and disinfectants such as chlorine [4]. To meet the Sustainable Development Goals (SDGs) of providing safe drinking water, unconventional and complimentary approaches such as the application of plant seeds are currently being explored. Since conventional methods of assuring potable water in developing countries are unstable, the need to consider the application of sustainable technologies using locally available materials in treating surface water is an enviable alternative. One area that holds a lot of prospects for the future in this endeavor, is the use of plant seeds [6-9].

More recently, the interest of environmental researchers in these natural water treatment alternatives gotten from plant origin is relatively on the high side. These natural coagulants have been discovered to be biodegradable and are presumably safe for human health [10]. Aside from being biodegradable, these natural coagulant produces less voluminous sludge that amounts to only 20– 30% that of its alum treated counterpart [11].

Globally, a number of plants have been screened for their water treatment abilities, and this review have taken time to highlight specifically, such screening that where done from 2015 to early 2020 and have equally focused on works that were carried out on plant seeds only (table 1 and 2). This is not to rule out the potential of other plant parts in water treatment, but to define the scope of this review and a matter of interest.

1.1. Plants as Biocoagulants and Biodisinfectants

Biocoagulation and biodisinfection involves the use of biological materials like plants, animals, and microorganisms as coagulants and disinfectant. Coagulation is the process of cleaning turbid water to promote cluster of particles in water body and produce larger particles that can be more readily removed in succeeding solid-liquid treatment processes. Biocoagulation and biodisinfection are usually inseparable when it comes to this matter of discourse, they are usually considered together. Beyond human health and livestock treatments, plants have been used historically for water treatment.The use of plants in coagulation is not entirely novel. Early Egyptian writings affords us the opportunity to peep into this hallowed antiquity on the original usage of plants in water treatment which dates back to 2000 BC. The Biblical book of Exodus (15:23-27) is one of the earliest historical reference to phyto-purification of water; “And the people murmured against Moses, saying, “What shall we drink?” And he cried unto the Lord; and the Lord showed him a tree, which when he had cast into the waters, the waters were made sweet” [12]. Historically, there is evidence to also suggest that communities in the developing world have at one point or the other, used plant based materials as strategy for purifying drinking water [13]. Indigenous communities in certain countries like Nigeria are testaments to the use of plants as biocoagulants. The Igbos in Eastern Nigeria have been associated with using plants like Corn Silk, Palm fibres, as well as Banana and Plantain stem bark fibres for water purification purpose in the past. Similarly, some tribes in Northern Nigeria have used plants like Locust bean, Moringa, and Baobab in water treatment.

Recently, there has been a resurgence of interest in natural coagulants for water treatment in developing countries. These natural coagulants can be used alone or as a substitution for chemical coagulants and flocculants. They can be used for reducing turbidity and microorganisms in water, for water softening and for dewatering sludge [14]. Normally, inorganic coagulants are more effective than organic coagulants, but in high doses, they cause precipitates that are difficult to treat. This reason makes organic coagulants good alternative to inorganic ones. Consequently, plants especially, and specifically seeds, have found relevance as raw materials in the production of organic coagulants [15].

Table 1. Plants Used as Biocoagulant and Biodisinfectant

S/N	Scientific Name	Common Name	Family	Used as	References
1	*Adansonia digitata*	Baobab	Malvaceae	Coagulant and disnfectant	31
2.	*Arachis hypogaea*	Groundnut	Fabaceaea	Coagulant	32
3.	*Azadirachta indica*	neem	Meliaceae	Coagulant	33, 34
4.	*Carica papaya*	Paw paw	Caricaceae	Coagulant and disinfectant	34, 35, 36, 37
5.	*Cicer arietinum*	Chickpea	Fabaceaea	Coagulant	33, 38
6.	*Citrullus lanatus*	Water Melon	Cucurbitaceae	Coagulant	39, 40
7.	*Dolichos lablab*	Hyacinth bean	Fabaceaea	Coagulant	38
8.	*Elaeis guineensis*	Oil palm	Arecaceae	Coagulant	41
9	*Garcinia kola*	Bitter kola	Clusiaceae	Coagulant and disinfectant	37
10	*Hibiscus cannabinus*	Kenaf	Malvaceae	disinfectant	42
11	*Hibiscus sabdariffa*	Roselle	Malvaceae	disinfectant	42
12	*Leucaena leucocephala*	White popinac	Fabaceaea	Coagulant	41
13	*Magnifera indica*	mango	anacardiaceae	Coagulant	43
14	*Manilkara zapota*	Sapodilla	Sapotaceae	Coagulant	44
15	*Moringa oleifera*	Moringa	Moringaceae	Coagulant and disinfectant	33, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55
16	*Nephelium lappaceum*	Rambutan	Sapindaceae	Coagulant	34
17	*Pennisetum glaucum*	Pearl Millet	Poaceae	Coagulant	56
18	*Sesamum indicum*	Benne	Pedaliaceae	Coagulant	32
19	*Tamarindus indica*	Tamarind	Fabaceaea	Coagulant	38, 49
20	*Vigna unguiculata*	Black-eyed Pea	Fabaceaea	Coagulant	56

1.2 Plants as Biosorbents (for removal of heavy metals)

Biosorption is the property of certain biomolecules or types of biomass to bind and concentrate selected ions or other molecules from aqueous solutions [16]. Biosorption is a rapid phenomenon of passive metal sequestration by the non-growing biomass/adsorbents. The ejection of heavy-metal-ladened waste or wastewater directly into water bodies without proper treatment have become a big issue for humans and aquatic lives. The most familiar toxic pollutants are chromium, lead, cadmium, copper, and mercury. This is because these metals are very toxic at certain concentrations, non-biodegradable, persist in the environment and eventually bio-accumulate in the food chain [17]. Industrialization is the major cause of inclusion of heavy metals into the environment especially in the water bodies all over the world; approximately 10% of the wastes produced by developed countries contain heavy metals [18, 19]. Excess incorporation of these metals into the human system is reported to cause cancer, nervous system damage and ultimately death [20]. Prolonged exposure to Lead causes encephalopathy, cognitive impairment, behavioral disturbances, kidney damage, anemia and toxicity to the reproductive system [21]. Cadmium has been established as a very toxic heavy metal, with symptoms of headaches, nausea, vomiting, weakness, pulmonary edema and diarrhea in acute poisoning [22,23]. High dose of Copper (Cu) concentration can lead to weakness, anorexia and damage to the gastrointestinal tract. Excess Copper compound in the body may also have effect on aging, schizophrenia, mental illness, Wilson's and Alzheimer's disease [24]. Adverse health effects are also associated with Chromium (Cr) poisoning, like, occupational asthma, eye irritation and damage, perforated eardrums, respiratory irritation, kidney damage, liver damage, pulmonary congestion and edema, upper abdominal pain, nose irritation and damage, respiratory cancer, skin irritation, erosion and discoloration of the teeth, and allergic skin reaction, called allergic contact dermatitis [18]. Therefore, metal concentration must be brought below tolerable boundaries using effective treatment technologies.

Conventionally, techniques like chemical coagulation and precipitation, ion-exchange, electrochemical methods, adsorption using activated carbon, chemical precipitation, electrochemical reduction, sulfide precipitation, ion-exchange, reverse osmosis, electro dialysis, solvent extraction, and evaporation and membrane processes are employed in the removal of heavy metal pollution from water and wastewater [22,25-27]. All these methods are characterized by environmental challenges and high initial and running costs. Consequently, there is need for alternative methods [28]. Plants have found use as biosorbents in heavy metal – water treatment [29].

Applying biosorbents in controlling and removing metal pollution has been paid much attention and it is gradually becoming a topic of interest in the field of metal pollution control because of its potential application [30]. Overall, compared with the conventional heavy metal removal methods, the potential advantages of biosorbents process include; use of naturally abundant renewable biomaterials that can be produced cheaply, ability to treat large volumes of wastewater due to rapid kinetics, ability to handle multiple heavy metals and mixed wastes, high affinity, reducing residual metals to below 1 ppb in many cases, less need for additional expensive reagents which typically cause disposal and space problems, operation over a wide range of physiochemical conditions including temperature, pH, and presence of other ions, relatively low capital investment and low operational cost, greatly improved recovery of bound heavy metals from the biomass, and greatly reduced volume of hazardous waste produced [30].

Table 2. Plants Used as Biosorbent

S/N	Scientific Name	Common Name	Family	References
1	*Adansonia digitata*	Baobab	Malvaceae	31, 57, 58
2	*Carica papaya*	Paw paw	Caricaceae	59
3	*Ceratonia siliqua*	carob	Fabaceaea	60
4	*Coriandrum Sativum*	Chinese parsley	Apiaceae	61
5	*Cornus mas*	cranberry	Cornaceae	62
6	*Dimocarpus longan*	longan	Sapindaceae	63
7	*Halianthus annuus*	Sun flower	Asteraceae	64
8	*Linum usitatissimum*	Flax	Linaceae	65
9	*Magnifera indica*	Mango	Anacardiaceae	66
10	*Momordica charantia*	Bitter gourd	Cucurbitaceae	67
11	*Moringa oleifera*	Moringa	Moringaceae	68, 69
12	*Nigella sativa*	Black cumin	Ranunculaceae	70
13	*Olea europaea*	olive	Oleaceae	71
14	*Parkia Biglobosa*	African locus bean	Fabaceaea	72, 73
15	*Persea americana*	Avocado	Lauraceae	74, 75
16	*Phoenix dactylifera*	Date palm	Aracaceae	71, 76, 77
17	*Polyalthia longifolia*	Ashoka	Annonaceae	78
18	*Pongamia pinnata*	Indian beech	Fabaceaea	79
19	*Rosa canina*	Dog rose	Rosaceaee	62
20	*Syzygium cumini*	Black Plum	Myrtaceae	18

2. GENERAL METHODOLOGY

Below are simple steps for accomplishing water treatment with plant seeds, and this methodology holds true for preparation of plant materials as either biocoagulants, biodisinfectants or biosorbents(removal of heavy metals)[9, 80]. They include;

1) The seeds are extracted from the plant fruit.

2) They are dried for up to three days.

3) Thereafter grounded into fine powder.

4) Followed by initial measurement of physiochemical parameters of water before treatment with prepared material is carried out.

5) Thereafter, ground seed material is put into the water to be treated (the amount of seed material is dependent on the amount of water and its level of pollution).

6) The mixture is stirred for 5 to 10 minutes: the faster it is stirred; the less time is required.

7) Finally, after the sediments settle, the treated water is decanted and tested by measuring physiochemical parameters like pH, turbidity, colour etc. The coliform counts is also taken into consideration.

There have been a number of improvements (from simple to complex adjustments) on this steps, so as to achieve more efficient results; As simple as sieving of grinded coagulants to complex adjustments like defatting of coagulants using hexane or any alcohol to intentional extraction of coagulant's active agent using water [33,35,39,44,45,56]. Kukwa *et al.* (2017), have equally suggested the use of tap water as opposed to the use of distilled water for the extraction of biocoagulant active agent, suggesting that tap water contains more dissolved ions, allowing easier dissolution of the active agent, thereby enhancing coagulation activity of the natural coagulant.

3. MECHANISM OF ACTION

3.1 Biocoagulation and Biodisinfection

Coagulation/flocculation process have been found to depend on the following factors: the origin and the nature of the naturally occurring coagulant like its molecular weight; the process variables such as the type of equipment used, the type of reagent used in conjunction with it, the dosage of the coagulant, the residence time in the jar test apparatus and the rate of rotation;

the chemical and physical properties of the pollutants present (such as polarity) and finally the solution like temperature, pH, the zeta potential, the colour, the concentration of the colloidal particles, the presence or absence of impurities i.e., dissolved salts or trace elements such as ions and chemicals [81-83].

Furthermore, four basic mechanisms have been identified to be involved generally in water purification: Ionic layer compression, Adsorption and charge neutralization, entrapment in a flocculent mass, and Adsorption and inter-particle bridging [1]. Protein is reported to be the main component responsible for coagulation-flocculation process, thus, studies reported that seed is the place where high level of protein is accumulated (84). Other research suggest that there may be more; since the mechanism of coagulation established an idea that there may be interaction between the polymer and the dissolved particles in a solution due to the fact that natural polymer contain numerous charged functional groups residing in their polysaccharide chain such as –OH, –COOH, and –NH, making polysaccharide, an active component in coagulation [85]. Natural coagulants have been reported to be commonly composed of the combination of several macromolecules such as carbohydrates, protein and lipids. In many cases, the major building blocks are the polymer of polysaccharides and amino acids [86]. The chemical compositions of the active coagulating agent of seeds is a highly debated topic.

In settlement of this debate, it has been suggested that, since mechanism of action differ for different plant sources, for example the mechanism of coagulation activity for pearl millet is suggested to be adsorption due to the carboxyl group while Black-eyed pea's mechanism of coagulation is adsorption due to hydrogen bonding. It could only mean the active component in different plant sources differ significantly [56].

3.2 Biosorption

The mechanisms associated with heavy metal biosorption by biomass are still not clear; however, it is important to note that this process is not based on a single mechanism. Since metals may be present in the aquatic environment in dissolved or particulate forms, they can be dissolved as free hydrated ions or as complex ions chelated with inorganic ligands, such as hydroxide, chloride or carbonate, or they may be complexed with organic ligands such as amines, humic or fulvic acids and proteins. Metal sequestration occurs through complex mechanisms, including ion-exchange and complexation, and it is quite possible that at least some of these mechanisms act simultaneously to varying degrees depending on the biomass, the metal ion and the solution environment [19].

The biosorption process involves a solid phase commonly referred to as sorbent or biosorbent (biological material) and a liquid phase or solvent, normally water, containing a dissolved species to be sorbed or adsorbate (metal). Because of the higher affinity of the adsorbent for the adsorbate species, the latter is attracted and bound there by a variety of mechanisms. The process continues until equilibrium is established between the amount of solid-bound adsorbate species and its portion remaining in the solution. The degree of adsorbent affinity for the adsorbate determines its distribution between the solid and liquid phases [87].

The biosorption of heavy metals by the biomaterials might be attributed to the polysaccharides, proteins and lipids in the materials that contain hydroxyl, sulfhydryl, phosphates, carbonyl and amino groups. These functional groups can bind metal ions involving valance forces through sharing or exchange of electrons between biosorbent and metal [88].

4. ADVANTAGES OF THE USE OF SEEDS IN WATER TREATMENT

Application of plant based materials in the treatment of water has a number of advantages, although some drawbacks exist but the advantages surpass the drawbacks. These advantages include;

1. They are readily available and cheaper to produce [29,71].
2. They are eco-friendly, energy efficient, and from renewable sources [56,89].
3. The residual sludge at the end of the process are relatively smaller than their chemical counterpart [56,89].
4. They are basically non-toxic and therefore safe for human and aquatic life [36,56].
5. The seed extracts act as natural corrosion inhibitors, which eliminates concerns about pipe destruction [90].
6. They do not consume alkali, so pH adjustments can be limited [56,69].

5. LIMITATIONS OF THE USE OF SEEDS IN WATER TREATMENT

Many research works have clearly been able to point us to this greener alternative, as a panacea to the conventional water treatment methods. Their main advantages are their renewability, biodegradability, nontoxicity and relative cost effectiveness [91]. But its development in the future is constrained by some challenges;

1. They tend to have shorter life which is caused by biodegradability of active component, they lose strength and stability with time also [92]
2. Commercialization of the product is also a challenge. The four main factors militating the commercialization of natural coagulants product are finance, research and development, and market awareness [93,94].
3. Furthermore limitation of natural coagulants and disinfectants may include high organic load that is deposited [9,95,96].
4. Another disadvantage of natural coagulants (for example *Moringa oleifera*) is that it is only efficacious in highly turbid water [97].
5. Since some plants vary in their coagulation potential [98], identifying the species that really works will or can equally be a potential problem.
6. They are non-specific, especially when used in biosorption [99].

Cross flow filtration method has been proposed as a way to overcome some limitations put across by coagulants such as reduced shelf life and organic deposits [100]. Further research into how to overcome these limitations is paramount to the development of this field of science.

6. CONCLUSION

Considering the number of plants naturally endowed with either coagulative, disinfectant or biosorbent potential as highlighted in table 1 and 2 (the list is not exhaustive), this really goes out to show that plants surely hold a great future in water treatment; especially for rural dwellers, who cannot afford the conventional, chemical water treatment method. These natural sources remain available, renewable, non-toxic and affordable. Finally, a blend between different natural sources or natural sources and chemical/synthetic water treatment materials as aid, can greatly increase efficiency, and this area requires further study. Also, having seeds as natural coagulant supported by solar disinfection is an area yet to be fully exploited.

7. REFERENCES

[1] Nandini, G. K. and Sheba, M. S. Emanating trends in the usage of bio- coagulants in potable water treatment: a review. International Research Journal of Engineering Technology (IRJET), 2016, 3(11):970–974.

[2] Ahluwalia, S. S. and Goyal, D. Microbial and plant derived biomass for removal of heavy metals from wastewater. Bioresource Technology, 2007, 98: 2243-2257.

[3] Yin, C. Y. Emerging usage of plant-based coagulants for water and wastewater treatment. Process Biochemistry, 2010, 45: 1437-1444.

[4] Yongabi K., Lewis D., Harris P., (Eds.) (2012). Natural Materials for Sustainable Water Pollution management, Water Pollution. Avaliable online from http://www.intechopen.com/books/water-pollution/natural-materials-for-sustainable-water-pollution-management.

[5] Pritchard, M., Mkandawire, T., Edmondson, A., Neill, J.G.O., Kululanga, G. Po for purification of shallow well water in Malawi. Physics and Chemistry of the Earth, 2009, 34, 799 - 805.

[6] Dalen, M.B., Pam, J.S., Izang, A. and Ekele, R. Synergy between *Moringa oleifera* seed powder and alum in the seed powder and alum in the purification of domestic water. Science World Journal, 2009, 46-10.

[7] Subramanium, S., Vikashi, N., Maata, M. and Koshy, K. *Moringa oleifera* and other local seeds in water purification in developing countries. Research Journal of Chem Environment, 2011, 15 (2), 135-138.

[8] Yongabi K. A. Biocoagulants for Water and Waste Water Purification. International Review of Chemical Engineering, 2009, 2(3), Extracted by CEAM 2010.

[9] Edogbanya P.R.O., Ocholi O.J. and Apeji Y. A review on the use of plants' seeds as biosorbents in the removal of heavy metals from water. Advances in Agriculture, Science and Engineering Research, 2013, 3 (8), 1036-1044.

[10] Sciban, M., Mile, K., Mirjana, A. and Biljana, S. Removal of water turbidity by natural

coagulants obtained from chestnut and acorn. Bioresource Technology, 2009, 100: 6639-6643.

[11] Narasiah, K.S., Vogel, A. and Kramadhati, N.N. Coagulation of turbid waters using *Moringa oleifera* seeds from two distinct sources. Journal of Water Science and Technology. Water Supply, 2002, 2: 83-88.

[12] Jadhav, A.S. Advancement in drinking water treatments from ancient time. International Journal of Science and Environmental Technology, 2014, 3: 1415-1418.

[13] Miller, S. M., Furgate, E. J., Craver, V. O., Smith, J. A., and Zimmerman, J. B. Towards Understanding the Efficacy and Mechanism of Opuntia spp. as a Natural Coagulant for Potential Application in Water Treatment. Environmental Science and Technology, 2008, 42(12):4274-4279.

[14] Mirjana, A. G., Marina, S. and Nada, P. Proteins form common bean seed as a natural coagulant for potential application in water turbidity removal. Bioresource technology, 2010, 10(1): 2167-2172.

[15] Coniwanti,P, Mertha,I.D, dan Eprianie,D. Pengaruh Beberapa Jenis Koagulan Terhadap Pengolahan Limbah CairIndustri Tahu Dalam TinjauannyaTerhadap Turbidity, TSS dan COD. Jurnal Teknik Kimia Universitas Sriwijaya, 2013, 3(19).

[16] Volesky, B. Biosorption and me. Water research, 2007, 41(18), 4017-4029.

[17] Egila J.N., Dauda, B. E. N. and Jimoh, T. Biosorptive removal of cobalt (II) ions from aqueous solution by *Amaranthus hydridus* L. stalk wastes. Africa Journal of Biotechnology, 2010, 9(48): 8192-8198.

[18] Singh, S., Tripathi, A., and Srivastava, S. K. Removal of Hexavalent Chromium from Contaminated Waters Using *Syzygium Cumini* Seed Biosorbent. International Journal of Engineering Research and General Science, 2015, 3(3).

[19] Cleide S. T. Araújo, Dayene C. Carvalho, Helen C. Rezende, Ione L. S.Almeida, Luciana M. Coelho, Nívia M. M. Coelho, Thiago L. Marquesand Vanessa N. Alves, Dr. Yogesh Patil (Ed.), "Bioremediation of Waters Contaminated with Heavy Metals Using Moringa oleifera Seeds as Biosorbent Applied Bioremediation - Active and Passive Approaches" InTech, 2013.

[20] Rasheed, A., Farooq, F. and Rafique, U. Kinetic study of metal removal using apple peels: Closed batch approximation model. International Journal of Chemical and Environmental

Engineering, 2013, 4(5): 281-285.

[21] Fu, F. and Wang, Q. Removal of heavy metal ions from wastewaters: A review. Journal of Environmental Management, 2011, 92: 407–418.

[22] Farooq, U., Kozinski, J. A., Ain, M., and Athar, M. Biosorption of heavy metal ions using wheat based biosorbents – A review of the recent literature. Journal of Bioresource Technology, 2010, 101: 5043–5053.

[23] Kumar, R., Mudhoo, A., Lofrano, G., and Chandra, M. Biomass-derived biosorbents for metal ions sequestration: Adsorbent modification and activation methods and adsorbent regeneration. Journal of Environmental chemical engineering, 2014, 2:239–259.

[24] Hossain, M.A., Hao Ngo, Guo, H. W.S. and Nguyen, T.V. Removal of Copper from Water by Adsorption onto Banana Peels as Bioadsorbent. International Journal of Geomaterial, 2012b, 2: 227-234.

[25] Sharma A. and Bhattacharyya K. G. Adsorption of Chromium (VI) on *Azadirachta Indica* (Neem) Leaf Powder. Adsorption, 2004, 10, 327-338.

[26] Jianlong W., Xinmin Z. and Yi Q. Removal of Cr (VI) from Aqueous Solution by Macro porous Resin Adsorption. Journal of Environmental Science Health, 2000, 35 (7), 1211-1230.

[27] Gupta, S. and Babu, B. V. Adsorption of Cr(VI) by a Low-Cost Adsorbent Prepared from Neem Leaves, Proceedings of National Conference on Environmental Conservation (NCEC-2006), BITS-Pilani,, 2006, 175-180.

[28] Kapoor A, Viraraghavan T. Fungal biosorption - an alternative treatment option for heavy metal bearing wastewaters: a review. Bioresource Technology, 1995, 53:195-206.

[29] Kakoi, B. K. Pollutant Removal from Water Using Plant Materials (Unpublished Doctoral Theses). Jomo Kenyatta University of Agriculture and Technology, 2018, Pp 24-27

[30] Wang, J., and Chen, C. Biosorbents for heavy metals removal and their future. Biotechnology Advances, 2009, 27(2), 195-226.

[31] Edogbanya, P.R.O., Abolude, D.S., Adelanwa, M.A. and Ocholi, O.J. The Efficacy of the seeds of *Adansonia digitata* L. as a Biocoagulant and Disinfectant in Water Purification (unpublished Master's dissertation). Ahmadu Bello University, Zaria, 2015, pp 37-60.

[32] Abood, M. M., Azhari, N. N. B. and Abdelmoneim, A. O. The Use of Peanut and Sesame

Seeds as Natural Coagulant in the Water Treatment. Infrastructure University Kuala Lumpur Research Journal, 2017, 5(1): 1-10.

[33] Mudenur, C., L. Sorokhaibam, G., Bhandari, V., Raja, S. and Ranade, V.V. Green approach to Dye Wastewater Treatment using Biocoagulants. ACS Sustainable Chemical Engineering, 2016, 4(5), 2495-2507.

[34] Nair, K. G., Pertin, M., Kadavil, P. P. and Nadayil, J. Emerging Trends in the Usage of Bio-Coagulants in Waste Water Treatment. International Research Journal of Engineering and Technology, 2019, 6(4): 4308-4319.

[35] Kristianto, H., Kurniawan, M. A., Soetedjo, J. N. M. Utilization of Papaya Seeds as Natural Coagulant for Synthetic Textile Coloring Agent Wastewater Treatment. International Journal on Advanced Science Engineering Information Technology, 2018, 8(5): 2071-2077.

[36] Unnisa, S. A. and Bi, S. Z. *Carica papaya* seeds effectiveness as coagulant and solar disinfection in removal of turbidity and coliforms. Applied Water Science, 2018, 8:149.

[37] kingsely, O. J., Nnaji, J. C. and Ugwu, B. I. Biodisinfection and Coagulant Properties of Mixed *Garcinia kola* and *Carica papaya* Seeds Extract for Water Treatment. Chemical Science International Journal, 2017, 19(3): 1-9.

[38] Lakshmi, V., Janani, R. V., Anju, G. S. and Roopa V. Comparative Study of Natural Coagulants in Removing Turbidity from Industrial Waste Water. International Journal of Innovative Research in Science, Engineering and Technology, 2017, 6(6): 23-33.

[39] Kukwa. R. E., Odumu, A. A., Kukwa, D. T., Water Melon Seed (*Citrullus Lanathus*) As Potential Coagulant for Treatment of Surface Water. IOSR Journal of Applied Chemistry (IOSR-JAC), 2017, 10(7): 59-64.

[40] Muhammad, I. M., Abdulsalam, S., Abdulkarim, A. and Bello, A. A. Water Melon Seed as a Potential Coagulant for Water Treatment. Global Journal of Researches in Engineering, 2015, 15(1): 1-9.

[41] Abdullah, A. and Ahmad, T.A.B. White Popinac as Potential Phyto-Coagulant to Reduce Turbidity of River Water. Asian Research Publishing Network Journal of Engineering and Applied Sciences, 2016, 11(11): 181-195.

[42] Jones, A. N. and Bridgeman, J. Investigating the characteristic strength of flocs formed

from crude and purified hibiscus extracts in water treatment. Water Research, 2016b, 103:21–29.

[43] Adeniran K. A. and Dunmoye I. D. Relative Coagulation Potentials of Aluminum Sulphate and *Mangifera Indica* Seeds in Purifying Domestic Waste Water. Kathmandu University, Journal of Science, Engineering and Technology, 2017, 13(2): 26-38.

[44] Nautiyal, R., Uliana, S., Raj, I., Shah, B., Rathore, K. and Singh, A. Decentralized Treatment of Grey Water by Natural Coagulants in the Presence of Coagulation Aid. Proceedings of the 2nd World Congress on Civil, Structural, and Environmental Engineering. Barcelona, Spain – April 2 – 4, 2017 Paper No. AWSPT 158 ISSN: 2371-5294 doi:10.11159/awspt17.158.

[45] Magaji, U. F., Sahabi, D. M., Abubakar, M. K. and Muhammad, A. B. Biocoagulation Activity of *Moringa oleifera* Seeds for Water Treatment. The International Journal of Engineering And Science (IJES), 2015, 4(2): 19-26.

[46] Idiok, U. T. and Nwaiwu, N. E. Effect of Particle size on Turbidity Removal using Aqueous Extracts of *Moringa oleifera* Seed. American Journal of Engineering Research (AJER), 2019, 8(8): 139-147.

[47] Valverde, K. C.; Coldebella, P. F.; Salcedo Vieira, A. M.; Nishi, L.; Bongiovani, M. C.; Baptista, A. T. A. Preparations of *Moringa oleifera* seeds as coagulant in water treatment. Environmental Engineering and Management Journal, 2018, in press.

[48] Zaid, A. Q., Ghazali, S. B., Mutamim, N. S. A. and Olalere, O. A. Experimental optimization of *Moringa oleifera* seed powder as biocoagulants in water treatment process. Springer Nature Applied Sciences, 2019, 1:504.

[49] Muyassaroh, H. S. Effectiveness of Moringa Seeds Powder and Tamarind seeds Powder as natural Coagulant for Increasing Tofu Industrial Waste Water Quality. International Journal of Chemical Technology Research, 2017, 10(12): 248-255.

[50] Ugwu, S. N., Umuokoro, A. F., Ehiegu, E. A., Ugwuishiwu, B. O. and Enweremadu, C. C. Comparative study of the use of natural and artificial coagulants for the treatment of sullage (domestic wastewater). Cogent Engineering, 2017, 4: 1365676.

[51] Delelegn, A., Sahile, S. and Husen, A. Water Purification an Antibacterial efficacy of

Moringa oleifera Lam. Agriculture and Food Security, 2018, 7(1): 1-10.

[52] Nisha, R. R., Jegathambal, P., Parameswari, K. and Kirupa, K. Biocompatible Water Softening System, Using Cationic Protein from *Moringa oleifera* Extract. Applied Water Science, 2017, 7(6): 2933-2941.

[53] Adelodun, B. Ajibade, F. O., Ogunshina, K. C. Dosage and settling time course optimization of *Moringa oleifera* in municipal wastewater treatment using response surface methodology. Desalination and Water Treatment, 2019, 167: 45-56.

[54] Idris, M. A., Jami, M. S., Hammed, A. M. and Jamal, P. *Moringa oleifera* seed extract: A Review on Its Environmental Applications. International Journal of Applied Environmental Sciences, 2016, 11(6), 1469–1486.

[55] Verma, A., Saxena, A. K. and Tiwari, P. K. Various Utilization of *Moringa oleifera* for Waste Water Treatment. Journal of Advances and Scholarly Researches in Allied Education, 2018, 15(11): 79-85.

[56] Hussain, G. and Haydar, S. Exploring potential of pearl millet (Pennisetum glaucum) and black-eyed pea (Vigna unguiculata subsp. unguiculata) as bio-coagulants for water treatment. Desalination and Water Treatment, 2019, 143: 184–191.

[57] Abdus-Salam, N. and Adekola, S. K. Adsorption Studies of Zinc (II) on Magnetite, Baobab (*Adansonia digitata*) and Magnetite-Baobab Composite. Applied water Science, 2018, 8, 222.

[58] Adewuyi, A. and Pereira, F. V. Nitrilotriacetic Acid Functionalized *Adansonia digitata* Biosorbent: Preparation, Characterization and Sorption of Pb (II) and Cu (II) pollutants from aqueous Solution. Journal of Advanced Research, 2016, 7(6): 947-959.

[59] Sanusi, K. A., Umar, B. A. and Sani, I. M. Evaluation of the Application of *Carica papaya* Seed Modified Feldspar Clay for Adsorption of Pb^{+2} and Cu^{+2} in Aqueous Media: Equilibrium and Thermodynamic studies. Journal of Environmental Analytical Toxicology, 2016, 6: 351.

[60] Farnane, M., Machrouhi, A., Elhalil, A., Abdennouri, M., Qourzal, S., Tounsadi, H. and Barka, N. Hindawi Journal of Chemistry, 2018, 1-17. https://doi.org/10.1155/2018/5748493

[61 Laskar, M. A., Ali, S. K. and Siddiqui, S. The Potential of *Coriandrum Sativum* L. Seeds in the Remediation of Waste Water. International Journal of Advanced Science and Technology, 2016, 86: 41-50.

[62] Parlayici, S. and Pehlivan, E. Comparative study of Cr(VI) removal by bio-waste adsorbents: equilibrium, kinetics, and thermodynamic. Journal of Analytical Science and Technology, 2019, 10 (15): 1-8.

[63] Yang J, Yu M, Chen W. Adsorption of hexavalent chromium from aqueous solution by activated carbon prepared from Longan seed: kinetics, equilibrium and thermodynamics. Journal of Industrial Engineering Chemistry, 2015, 21:414–22.

[64] Saleh, M. E., El-Refaey, A. A. and Mahmoud, A. H. Effectiveness of Sunflower Seed Husk Biochar for Removing Copper Ions from Wastewater: a Comparative Study. Soil and Water Resources, 2016, 11:53-63.

[65] Jasim, N. A. and Hussein, T. K. Removal of Cadmium Ions from Aqueous Solutions Using Flax Seeds as an Adsorbent. Diyala Journal of Engineering Sciences, 2019, 12(4): 01-08.

[66] Pandia, S., Amien, S., Sanjaya, N. and Setiawan, A. The Use of Mango Seed Arum Manis Type (*Mangifera Indica* L) as Biosorbent. 1st Annual Applied Science and Engineering Conference IOP Publishing IOP Conference Series: Materials Science and Engineering, 2017, 180, 012154 doi:10.1088/1757-899X/180/1/012154

[67] Munichandran, M., Gangadhar, B. and Naidu, G. R. K. Bioremoval of Nickel and lead using bitter gourd (*Momordica charantia*) seeds. International Journal of Advanced Research in Science, Engineering and Technology, 2016, 3(8): 2475-2484.

[68] Garcia-Fayos, B., Arnal, J. M., Sancho, M. and Rodrigo, I. *Moringa oleifera* for drinking water treatment: influence of the solvent and method used in oil-extraction on the coagulant efficiency of the seed extract. Desalination and Water Treatment, 2016, 57, 23397–23404.

[69] Tavares, F. O., Pinto, L. A. M., Bassetti, F. J., Vieira, M. F., Bergamasco, R. and Vieira, A. M. S. Environmentally friendly biosorbents (husks, pods and seeds) from *Moringa oleifera* for Pb(II) removal from contaminated water. Environmental Technology, 2017, DOI: 10.1080/09593330.2017.1290150

[70] Belattar, N., Addala, A. and Elektorowicz, M. *Nigella sativa* L. Seeds Biomass as a Potential Sorbent in Sorption of Lead from Aqueous Solutions and Wastewaters. Oriental Journal of Chemistry, 2018, 34(2): 638-647.

[71] Mansour, S. A., Mohamed, R. I. and Ali, R. A. Removal of Heavy Metals from Aqueous

Solutions By Means of Agricultural Wastes: Assessments Based on Biological Assay and Chemical Analysis. Journal of Biological Innovation, 2016, 5(4): 480-505.

[72] Igboro, S. B., Alfa, M. I., Ismail, A., Dahunsi, S.O. and Komami, M., Evaluation of the Efficiency of *Parkia Biglobosa* (Locust Bean) Seed, Leaf and Bark Extracts for the Treatment Of Grey Water. Nigerian Journal of Scientific Research, 2016, 15(1): 75-83.

[73] Ogbodu, R. O., Omorogie, M. O., Unuabonah, E. I. and Babalola, J. O. Biosorption of Heavy Metals from Aqueous Solutions by *Parkia Biglobosa* Biomass: Equilibrium, Kinetics, and Thermodynamic Studies. Environmental Progress and Sustainable Energy, 2015, 34(6): 1694-1704.

[74] Wanja, N. E., Murungi, J., Wanjau, R and Hassanali, A. Application of chemically modified avocado seed for removal of Copper (II), Lead(II), and Cadmium(II) ions from aqueous solutions. International Journal of Research in Engineering & Applied Sciences, 2016, 6(8): 1-15.

[75] Mekonnen, E., Yitbarek, M., and Soreta, T. R. Kinetic and Thermodynamic Studies of the adsorption of Cr (VI) onto Some Selected Local Adsorbent. Journal of South African Chemical Institute, 2015, 68:45–52.

[76] El-marouani, M., Azoulay, K., Bencheikh, I., El-Fakir, L., Rghioui, L., El-Hajji, A., Sebbahi, S., El-Hajjaji S. and Kifani-Sahban, F. Application of raw and roasted date seeds for dyes removal from aqueous solution. Journal of Material and Environmental Sciences, 2018, 9(8): 2387-2396.

[77] Mohamed, A. A. J., Vuai, L. A., Kombo, M. and Chukwuma, O. J. Removal of selected metal ions using powder of seeds of Ajwaa dates from aqueous solution. Journal of Analytical and Pharmaceutical Research, 2019, 8(6): 228-232.

[78] Mundhe, K. S. Adsorption Study of Acetic Acid using Low Cost Biosorbent. International Journal of Current Microbiology and Applied Sciences, 2015, 4(12): 66-72.

[79] Darandale, G. R. Batch Adsorption Studies on Removal of Cr (VI) From Aqueous Solution by Using *Pongamia Pinnata* Seed Shell as Adsorbent. International Journal of Innovative Research in Science, Engineering and Technology, 2016, 5(6): 9262-9268.

[80] Jahn, S.A.A. Studies on natural water coagulants in the Sudan, with special reference to

Moringa oleifera seeds. Water SA (L2), 1981, 90-97.

[81] Hirohara, M., Takehara, M., Fukita, A., Kansai, K. and Hirohara, H. Flocculant and sludge treatment method. Japanese Patent, 1999, JP2001129310.

[82] Gottfried, A., Shepard, A. D., Hardiman, K. and Walsh, M. E. Impact of recycling filter backwash water on organic removal in coagulation-sedimentation processes. Water Resource, 2008, 42(46):83- 91.

[83] Renault, F., Sancey, B., and Badot, M. W. Chitosan for caogulation/flocculation process- an eco-friendly approach. European Polymer Journal, 2009, 45(5), 1337- 1348.

[84] Booth, J., Nykiforuk, C. Shen, Y., Zapalchinski, S., Szarka, S., Kuhlman, P. E., Morck, D. and Moloney, M. M. Seed based expression systems for plant molecular farming. Plant Biotechnology Journal, 2010, 8: 588-606.

[85] Kumar, V., Othman, N. and Asharuddin, S. Applications of Natural Coagulants to Treat Wastewater − A Review. MATEC Web of Conferences, 2017, 103, 06-16.

[86] Adinolfi, M., Corsaro, M. M., Lanzetta, R., Parrilli, M., Folkard, G., Grant, W. and Sutherland, J. Composition of the coagulant polysaccharide fraction from Strychnospotatorum seeds. Carbohydrate research, 1994, 263(1) 103-110.

[87] Ahalya, N., Ramachandra, T., and Kanamadi, R. Biosorption of Heavy metals. Research journal of Chemistry and Environment, 2003, 7(4), 71-79.

[88] Nieboer, E. and Richardson, D. H. S. The Replacement of the Nondescript Term 'Heavy Metal' by a Biologically and Chemically Significant Classification of Ions. Environmental Pollution Series B, Chemical and Physical, 1980, 1(1): 3-26.

[89] Mathuram, M., Meera, R. and Vijayaraghavan, G. Application of Locally Sourced Plants as Natural Coagulants for Dye Removal from Wastewater: A Review. Journal of Material and Environmental Science, 2018, 9(7): 2058-2067.

[90] Chigondo, M. and Chigondo, F. (2016). Journal of Chemistry, Volume 2016, Article ID 6208937. http://doi.org/10.1155/2016/6208937

[91] Sillanp, M., Ncibi, M., C., Matilainen, A., and Vepsalainen, M. Removal of natural organic matter in drinking water treatment by coagulation: A comprehensive review. Chemosphere, 2018, 190, 54-71.

[92] Lee, C. S., Robinson, J. and Chong, M. F. A review on application of flocculants in wastewater treatment. Proc. Safety and Env. Prot., 2014, 9(2) 489– 508.

[93] Choy, M., Dubé, C. M., Patterson, K., Barnes, S. R., Maras, P., Blood, A. B., Hasso, A. N., Obenaus, A. and Baram, T. Z. A novel, noninvasive, predictive epilepsy biomarker with clinical potential. Journal of Neuroscience, 2014, 34: 8672–8684.

[94] Sutherland, J., Folklard, G. and Poirier, Y. *Moringa oleifera*; the constraints to commercialization. International Workshop: 29th October–2nd November, 2001, Dar es Salaam, Tanzania.

[95] Ndabigengesere, A., Narasiah, K. S. and Talbot, B. G. Active agents and mechanisms of coagulation of turbid water using *Moringa oleifera*. Water Research, 1998, 29(2): 703-710.

[96] Okuda, T., Baes, A., Nishijima, W. and Okada M Improvement of extraction method of coagulation active components from *Moringa oleifera* seed. Water Research, 2001, 33:3373–3378.

[97] Gunaratna, K. R., Garcia, B., Andersson, S., and Dalhammar, G. Screening and Evaluation of Natural Coagulants for Water Treatment. Water Science and Technology - Water Supply, 2007, 7(5/6): 19.

[98] Jahn, S. A. A. Using Moringa Seeds as Coagulants in Developing Countries. Journal American Water Works Association, 1988, 80(6), 43-50.

[99] Gupta, V. K., Nayak, A., Bhushan, B. and Agarwal, S. A critical analysis on the efficiency of activated carbons from low-cost precursors for heavy metals remediation. Crit. Rev. Environ. Sci. Tech., 2015, 45: 613-668.

[100] Ali, E.N., Muyibi, S.A., Salleh, H.M., Alam, M.D.Z. and Salleh, M.R.M. Production of natural coagulants from *Moringa oleifera* seed for application in treatment of low turbid water. Journal of Water Resource and Protection, 2010, 2: 259-266.

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