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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.

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