Comparative Analysis of Baobab (Adonsonia Digitata) and Tamarind (Tamarindus Indica) Seeds as Biocoagulant in Contaminated Water Treatment

[1]Waziri. A. GALADIMA, [2]Muhammad. N. IDRIS, [3]Babagana. GUTTI

[1]Department of Science Laboratory Technology, Ramat Polytechnic, Maiduguri
[2&3] Department of Chemical Engineering, University of Maiduguri
Correspondence e-mail: wazirigaltima@gmail.com

Abstract

Water is a basic resource; it is also the most essential liquid substance, and the substance of life is highly dependent on its availability. Drinking water treatment involves several unit processes. Commonly used chemicals for the treatment are synthetic organic and inorganic substances; these chemicals are expensive and are readily not available in developing nations. They also constitute a number of health hazard. the aim of this study was to evaluate contaminated water using locally available natural plant seeds as bio-coagulant. The dried seeds sample were collected, washed, dried, pulverized, grinded and later extracted using n-hexane through Soxhlet extractor model turbid water used for the bio coagulant study was prepared using kaolin. The experimental design was completed randomized design (CRD). Experiments were performed in triplicates baobab seed only, tamarind seed only and hybridized seeds of baobab and tamarind in different ratios using 0mg/l as control, 10mg/l, 20mg/l, 30mg/l, 40mg/l and 50mg/l of both samples seed extracts. Analysis of variance (anova) was adapted to compare the means of the various parameters measured the level of significance was taken at ($p<0.05$) from Duncan multiple range test (DMRT). the outcome revealed that as a bio coagulant, an optimum doze of 30mg/l of hybridize sample in the ratio of 2:1 of baobab and tamarind (HBT) seeds powder was able to reduce turbidity of model water significantly ($p<0.05$). Finally, from the investigation carried out, the hbt possess bio-coagulant potentials when harnesses and utilized properly for water purification. The study succeeded in elemental and proximate analysis of the seed samples.

Keywords: Bio-Coagulant, Chemical Oxygen Demand, Synthetic Chemical Turbidity, Total Dissolved Solid.

I. Introduction

Water is a basic resource; it is also the most essential liquid substance, and the sustenance of life is highly dependent on its availability (FAO 2014). The importance of water cannot be overemphasized, as it is used for domestic, agricultural, industrial, economic and commercial purposes. In the year 2015, it was estimated that 663 million people worldwide still utilize unimproved drinking water sources, including unprotected wells, springs and surface water (WHO 2015). It is also reported that almost half of all the people using unimproved drinking water sources live in Sub-Saharan Africa, while one-fifth live in Southern Asia (WHO 2015). It is estimated that 79% of people using unimproved sources and 93% of people using surface water live in rural areas (WHO 2015).

The environment has a way of multiplying and giving back what man gives to it, so man has become a snare to himself, by constantly discharging harmful substances into his environment (Edogbanya et al; 2013). According to AQUASTAT, an estimate of about 109 m^3/year municipal wastewater is produced

annually (FAO 2006). Polluted water causes serious health implications worldwide. Waterborne diseases such as diarrhea and water-related vector-borne diseases like malaria are among the leading causes of death, especially affecting children and other vulnerable groups. Polluted water causes serious health implications worldwide (WWAP 2015).

Drinking water treatment involves several unit processes. Commonly used chemicals for the various treatment units are synthetic organic and inorganic substances (such as alum, chlorine, acryl amide and activated carbon); usually, these chemicals are expensive and are not readily available, especially in developing nations. Apart from these, they also constitute several health problems for instance; the use of alum has been reported to cause Alzheimer's disease; (Crapper et al 1973). While some synthetic organic polymers such as acryl amide have strong neurotoxin and carcinogenic effect; chlorine being a strong oxidizing agent reacts with natural organic matter (NOM) to form disinfection by-products (DBPs) such as Haloacetic Acids (HAAs), Trihalomethanes (THM), Halogenic Acetic Acid, Haloacetonnitrils, Chlorine Hydrates, Chloramines, Chlorophenolsetc, and these DBPs have been associated with increased risk for cancer and other health-related issues. They have also been reported to be non-eco-friendly, as they tend to affect non-target organisms and are usually non-biodegradable.

II. Statement of the Problem

Contaminated water has become a global challenge these days and issue of concern across the world. It is estimated that about 750 million people, continuously rely on unimproved drinking water sources of whom almost a quarter (187.5 million people) still rely on direct use of contaminated surface water (WHO and UNICEF 2014) The use of chemicals in the treatment of water is expensive, and the chemicals are not readily available especially in the developing nation. Chemicals used in the treatment of water have been reported to be hazardous to man and his environment.

III. Aim and objectives of the study:

The aim is to treat (purify) contaminated water using locally available natural plants as bio-coagulant. The objectives of the study are to:

i. extract active components from Baobab *(Adansonia digitata)* and Tamarind *(Tamarindus indica)* seeds.
ii. further analyse the effect of bio-coagulants on the following turbidity, pH, colour, hardness, alkalinity, total dissolved solids of contaminated water.
iii. hybridize the Baobab *(Adonsonia digitata)* and Tamarind *(Tamarindus indica)* seed samples in different ratios as bio-coagulant.

IV. Significance of the Study:

Several plants seeds have been reported to contain coagulant proteins, which are responsible for their bio-coagulative, disinfectant, and biosorptive properties that enhance the purification of water. The use of alternative technique (such as using plant seeds) in the purification of water has not been fully explored,

and the findings of this work would give vital information that would contribute towards the solving of the problems related to contaminated water (especially in the rural areas).

V. Scope and Limitation

The scope of the work is to perform comparative analysis which is limited to Baobab and Tamarind Seeds.

Kinetic Models for Biosorption

The mechanism of adsorption and its potential rate-controlling steps that include mass transport and chemical reaction processes is usually investigated using kinetic models. In addition, information on the kinetics of metal uptake is required to select the optimum condition for full-scale batch metal removal processes (Febrianto et al., 2009). Adsorption kinetics is expressed as the rate of solute removal that controls the residence time of the sorbate in the solid–solution interface. In practice, kinetic studies are carried out in batch reactions using various initial sorbate concentrations, sorbent doses, particle sizes, agitation speeds, pH values and temperatures along with different sorbent and sorbate types. Then, linear regression is used to determine the best-fitting kinetic rate equation. There are several kinetic models but the most commonly used are the pseudo first and second order rate model in biosorption models (Febrianto et al., 2009).

The Pseudo-first-order kinetic model

The Lagergren first-order rate expression based on solid capacity is generally expressed as:

$$\frac{dq}{dt} = k_1(qe - q) \qquad (2.1)$$

It can be expressed in linear form as:

$$Log\,(q_e - q) = Log\,(q_e) - \frac{k_1 t}{2.303} \qquad (2.2)$$

Where:

q_e (mg g^{-1}) = the solid phase concentration of the metal ions at equilibrium,
q (mg g^{-1}) = the average solid phase concentration of metal ions at contact time t (min) and
k_1(min^{-1}) = the pseudo-first-order rate constant.
The rate constant k1 (min-1) could be obtained from the plot of Log (qe – q) versus t Febrianto et al., (2009); Njoku, (2011).

The Pseudo-second-order kinetic model

The Ho Pseudo-second-order Kinetic Model is derived based on the sorption capacity of the solid phase and is expressed as in equation 2.3:

$$\frac{dq}{dt} = k_1\,(q_e - \text{q})2 = \qquad (2.3)$$

It can also be expressed in linear form as in equation 2.4:

$$\frac{t}{q} = \frac{1}{(k_2 q_e^2)} + \left(\frac{1}{q_e}\right)t \qquad (2.4)$$

Where k_2 is the pseudo-second-order rate constant.

A plot of *t/q* versus *t* gives a straight line and the values of the constants k_2 (g mg^{-1}) and qe (mg g^{-1}) can be calculated (Febrianto et al., 2009); (Njoku, 2011).

Kinetic Models for Biosorption

The mechanism of adsorption and its potential rate-controlling steps that include mass transport and chemical reaction processes is usually investigated using kinetic models. In addition, information on the kinetics of metal uptake is required to select the optimum condition for full-scale batch metal removal processes (Febrianto et al., 2009). Adsorption kinetics is expressed as the rate of solute removal that controls the residence time of the sorbate in the solid–solution interface. In practice, kinetic studies are carried out in batch reactions using various initial sorbate concentrations, sorbent doses, particle sizes, agitation speeds, pH values and temperatures along with different sorbent and sorbate types. Then, linear regression is used to determine the best-fitting kinetic rate equation. There are several kinetic models but the most commonly used are the pseudo first and second order rate model in biosorption models (Febrianto et al., 2009).

Classification Baobab (Adansonia digitata)

Kingdom:	-	Plantae
Division:	-	Magnoliphyta
Class:	-	Equisetopsida
Subclass:	-	Magnoliidae
Superorder:	-	Rosana
Order:	-	Malvales
Family:	-	Malvaceae
Genus:	-	Adansonia
Species:	-	Adansoniadigitata

(Royal Botanical Gardens, Kew)

Tamarindus indica is probably indigenous to tropical Africa, (Morton et al 1987). But has been cultivated for so long in the Indian subcontinent that it is sometimes reported to be indigenous there (Tamale et al 1995). It grows wild in Africa in locales as diverse as Sudan, Cameroon, Nigeria, Kenya, Zambia, Somalia, Tanzania and Malawi. In Arabia, it is found growing wild in Oman, especially Dhofar, where it grows on the sea-facing slopes of mountains. It reached South Asia likely through human transportation and cultivation several thousand years ago Tamale et al (1995). It is widely distributed throughout the tropics, from Africa to South Asia, northern Australia, and throughout Oceania, Southeast Asia, Taiwan and China.

In the 16th century, it was introduced to Mexico and Central America, and to a lesser degree to South America, by Spanish and Portuguese colonists, to the degree that it became a staple ingredient in the region's cuisine Tamale et al (1995). Today, India is the largest producer of tamarind. The consumption of tamarind is widespread due to its central role in the cuisines of the Indian subcontinent, Southeast Asia, and the Americas, especially Mexico.

Classification of Tamarind *(Tamarindus indica)*

Scientific:	-	Classification
Kingdom:	-	Plantae
Clade:	-	Tracheophytes
Order:	-	Fabales
Family:	-	Fabaceae
Subfamily:	-	Detarioideae
Tribe:	-	Amherstieae
Genus:	-	TamarindusL.
Species:	-	T. indica

VI. Materials and Methods

The study was carried out in three experimental stages viz:

i. Extraction of the active components of the samples,
ii. Evaluation of the samples and
iii. Characterization of bio-coagulants and there effects on model turbid water.

Materials

i. Distilled water
ii. Weighing balance
iii. Measuring cylinder
iv. Beaker
v. Conical flask
vi. Mortar and pestle
vii. Sieve
viii. Incubator
ix. Hydrogen Tetraoxosulphate (VI) acid (H_2SO_4)
x. Sodium Hydroxide (NaOH)
xi. Fe $(NH_4)_2(SO_4)_2$
xii. $K_2Cr_2O_7$
xiii. Ag_2SO_4
xiv. buffer solution

xv. Powdered seed of Baobab
xvi. Powdered seed of Tamarind

IV. Methodology

Collection, Identification and Preparation of Sample Baobab (*Adansonia digitata*)

Baobab (*Adansonia digitata*) seed samples were purchased at Monday market in Maiduguri, Borno, state and taken to Botany Laboratory in Biological Science Department, University of Maiduguri for proper identification. Dried fruit of *Adansonia digitata* were properly washed with distilled water, sun dried, pulverised into powder using mortar and pestle, sieved, and stored in an airtight container.

Tamarind (*Tamarindus indica*) seeds

Tamarind seeds were collected from a tamarind tree plantation at Dalori village 15 kilometer along Maiduguri, Bama road in Konduga LGA in Borno state, Nigeria and was properly identification at the Botany Laboratory in Biological Science Department, University of Maiduguri. The tamarind seeds were divided in to two; half of the sample was soaked in cold water for about 24h before they were washed to separate the seeds from the pulp and rewashed to remove adhering pulps. The other half was soaked in boiled water for 1.5h. The seeds containers were labelled tamarind cold water sample and tamarind hot water sample for easy identification. The seeds were allowed to dry under ambient temperature first and then, placed in an oven for about 8h at 50°C. This was carried out thus to make crushing of the tamarind seeds easy. The crushing of the seed samples was carried out for size reduction using mortar and pestle. The crushed seed samples were ground using a blender to produce the tamarind seed powder that was sieved to form medium fine powder used as the coagulant. The samples collected were preserved at optimum temperature of about 40^0C. The samples collected were analysed to find out the physical, chemical, and biological contents, based on the analysis the samples were treated by using organic methods as given below:

Extraction of active component from tamarind (*Tamarindus indica*) seeds

Extraction of the powdered tamarind seed samples was carried out using n-hexane in electro-thermal Soxhlet extractor. 50g of powdered seeds was weighed and put into the thimble of the Soxhlet extractor, the apparatus was mounted and allowed to run for 60min, after which the powder was removed and dried over a hot plate at low heat to evaporate the n-hexane. The tamarind cake residue after oil extraction was used in the preparation of the extract. Six different concentrations (0mg/L, 10mg/L, 20mg/L, 30mg/L, 40mg/L and 50mg/L) of the coagulant reagent were prepared by suspending the required weighed amount of de-fatted powdered seed in to conical flask and 20ml of distilled water was added in order to prepare stock solution and then transferred the stock solution in to 1000ml beaker of distilled water, which was then stirred for 15 min using the flocculator (PCI Ltd England) in order to extract active components. After that, the suspension was filtered through What-man filter paper No. 1 (Bichi et al., 2012; Choubey et al., 2012). Before each experiment a fresh coagulant regent was prepared, because keeping it overnight reduced the effectiveness.

Extraction of active component from Baobab Seeds *(Adansonia digitata)*

The *Adonsonia digitata* seeds were sorted, washed and dried. Some of the seeds were crushed for proximate and elemental analysis, while the rest were kept in a black polythene bag, sealed and stored in a dark cool place until required for analysis, this method is described by (Nkafamiya et al; 2007). The powdered Baobab seed samples were also de-fatted like that of tamarind using n-hexane in electro-thermal Soxhlet extractor. Another 40g of powdered seeds was weighed in put into the thimble of the Soxhlet extractor, the apparatus was mounted and allowed to run for 60min, after which the powder is removed and dried over a hot plate at low heat to evaporate the n-hexane. The Baobab cake residue after extraction was used in the preparation of the extract. Also, six different concentrations (0mg/l, 10mg/l, 20mg/l, 30mg/l, 40mg/l and 50mg/l) of the coagulant reagent were prepared by suspending the required weighed amount of de-fatted powdered seed into conical flask and 20ml of distilled water was added in other to prepare stock solution using 1000ml of model water in a beaker, which was then stirred for 15 minutes using the flocculator (PCI Ltd England) in order to extract active components. After that, the suspension was filtered through What-man filter paper No. 1 (Bichi et al., 2012); (Choubey et al., 2012). Before each experiment a fresh coagulant regent was prepared, because keeping it overnight reduced the effectiveness.

Methods for Proximate Analysis

i. Moisture content
ii. Ash content
iii. Crude fibre
iv. Dry matter
v. Crude protein
vi. Ether extract
vii. Nitrogen free extract

Bio-coagulation Studies

Preparation of model turbid water

Turbid water was prepared by adding 10g kaolin to 1L tap water. The suspension was stirred for 1h to achieve uniform dispersion of kaolin particles, and then it was allowed to remain for 24hours for completing hydration of the particles. This suspension was used as the stock. Turbid water used for the study was prepared by diluting 50ml of stock solution in 1000ml of water (This gave an initial turbidity of about 379 nephelometric turbidity units –NTU) Okuda et al., (2001); Antov et al (2010).

viii. Results and Discussion

The study revealed that the elemental analysis shown in (Table.1) below presented both micro and macro elements. The Potassium content of the two samples as shown on table 4.1 are higher than the values of (Osman 2004), while the sodium and calcium were all in agreement as reported by (Sidibe 2002) whereas

the phosphorus content which was slightly lower than that of (Sidibe 2002) but in agreement with report presented by (El-Siddiq, 2002 & Igbow 1997). The iron which is an essential component was also in agreement with the reported value of (Fleuret 1980). Therefore, the slight variation of the tamarind samples (hot and cold) in the table 4.1 was due to the Thermal activity of the hot water.

Table: 1 Elemental Analysis of Baobab *(Adonsonia Digitata)* and Tamarind *(Tamarindus indica)* Seeds

Element	Baobab Seeds	Tamarind Seeds	
		Hot	Cold
Macroelement (mg/100g)			
Potasium (K)	122.33	155.49	179.12
Sodium (Na)	85.06	87.041	101.62
Calcium (Ca)	86.08	201.0	229.30
Magnesium (Mg)	2.43	1.99	2.11
Phosphorus (P)	0.28	0.00	2.26
Microelement			
Iron (Fe)	50.28	53.74	56.81
Copper (Cu)	0.29	0.00	0.03
Zinc (Zn)	0.43	0.55	0.64

The moisture content of the two seeds samples (Table 4.2) were higher than the value of 9.4% estimated by Merangoni et al (1988) and lower than the rate 11.4% - 22.7% reported by Ishola et al (1990), Bhattachanya et al, (1993) and Morad et al (1978). The protein content of the two samples agreed with the result of 21 -25 % reported by Yusuf et al (2007). The Ash values agreed with the rate 2.1% - 4.2% reported by Morad et al, Ishola et al, (1980); Battacharya et al; (1993) but lower than 4.58% reported by Marangoni et al (1988). The Fibre content of the two samples were within the range 0.7 – 8.2% reported by Bhattacharya et al; (1993) but higher than the value of 2.33% mentioned by Marangoni et al (1988).

Proximate Analysis of Baobab *(Adonsonia Digitata)* and Tamarind *(Tamarindus indica)* Seeds

Constituents (g/100g)	Baobab Seeds	Tamarind Seeds	
		Hot	Cold
Moisture	8.92	11.98	11.64
Ash Content	4.54	3.29	3.60
Crude Fibre	5.63	6.18	6.00
Dry Matter	91.08	87.24	88.68
Crude Protein	8.87	15.66	18.21
Ether Extract	8.17	10.84	11.66
Nitrogen Free Extra	63.87	51.35	48.89

The phytochemical profile of Baobab and Tamarind Seed Extract shown in the Table 4.3 revealed the present of Alkaloid, flavonoid, phenol, saponin and Tanin in the seeds. The higher values of 33.3g/100g from Baobab and 19.62g/100g of Tamarind seeds of flavonoid and leaf values of 2.46g/100g of Baobab and 3.83g/100g of Tamarind have been reported to be associated with the different pharmacological activities of plant (Del-Rio et al; 1997).

ix. Conclusion and Recommendation

Conducting Jar test for the bio coagulants such as Baobab seeds, tamarind seeds and Hybrid of Baobab and tamarind seeds, shows that Hybrid of Baobab and tamarind seeds is a better coagulant in removing turbidity. It has extensively developed internal pore structure. Due to Hybridization, internal pore network is created and thus HBTSP gets its unique characteristics leading to high surface area, porosity, and greater strength. Also, Fourier Transform Infrared Spectroscopy (FTIR) studies showed the functional groups available on the surface of Baobab *(Adansonia digitata),* Tamarind seed bio-sorbent. *Adansonia digitata* seeds possess potentials as a bio-coagulant. It was not significantly effective when used as a bio-coagulant for highly turbid water, since it was unable to bring turbidity down within the acceptable limit of less than 5 NTU (USEPA, 2012). But combination of the two bio-coagulant lead to its significant improvement.

Recommendation and Further Studies

1. The efficiency of hybrid Baobab and Tamarind seeds as a bio-coagulant must be improved by isolation and purification of the bio-coagulant protein especially when combined other seeds with higher disinfectants quality.
2. The efficacy of Baobab *and* Tamarind seeds as a bio-sorbent may also be improved by the chemical or physical modification of the nature of the bio-sorbent (e.g. by converting them to activated carbon).
3. HBT seed powder bio-coagulant may be used to complement or replace other conventional coagulants like alum when properly optimized.
4. Scanning Electron Microscope (S.E.M) and X-ray diffraction (XRD) studies may be carried out to understand the morphology and interlayer structure of the HBT seed powder bio-sorbent.
5. Energy Dispersive X-ray analysis (EDAX) may be carried out to ascertain the composition of each element present in the Hybridized Baobab and Tamarind (HBT) sample.

References

Ahalya, N., Ramachandra, T.V. and Kanamadi, R.D. (2005). Biosorption of Chromium (VI) from aqueous solutions by the husk of bengal gram (Cicerarientinum). Electronic Journalof Biotechnology, 3: 258-264.

Ajayi, I.A., Dawodi, F.A., Oderinde, R.A. (2003). Fatty acid composition and metal content of Adansoniadigitata seeds and seed oil. La RivistaItalianadelleSostanze Grasse, 80, 41 43.

Andy, E.O. and Eteshola, E. (1984) Nutritive value of a mixture of tigernut tubers (Cyprusesculentus) and Baobab seeds. Journal of the Science of Food and Agriculture, 35 (1984): 437 – 440.

Antov, M., ˇ S´ciban, M., Prodanovi´c, J., Kuki´c, D.,Vasi´c, V., Dordevi´c, T., and Miloˇsevi´c, M. (2018). Common oak (Quercusrobur) a corn as a source of natural coagulants for water turbidity removal. Industrial Crops and Products, 117,340 346.DOI:10.1016/j.indcrop.2018.03.022

Azad, Salim (2018). "Tamarindo—Tamarindusindica". In Sueli Rodrigues; Ebenezer de Oliveira Silva; Edy Sousa de Brito (eds.). Exotic Fruits. Academic Press. pp. 403 412. doi:10.1016/B978-0-12-803138-4.00055-1. ISBN 978-0-12-803138-4.

"BBC Food:Ingredients—Tamarind recipes". BBC. Retrieved February 23,2015.

Bhattacharya S, Bal S. Mukherjee R.K (1993) some physical and engineering properites of tamarind (TamarindusIndica) seed J. Food Engineering 18: 77 – 89.

Bichi, M. H., Agunwamba, J. C. and Muyibi, S. A. (2012). Optimization of operating conditions for the application of Moringaoleifera (Zogale) seeds extract in water disinfection using response surface methodology. African Journal of Biotechnology, 11(92): 15875-15887.

Bodlund, I. (2013). Coagulant protein from plant materials: Potential water treatment agent. School of Biotechnology, Royal Institute of Technology (KTH), AlbaNova University Center, Stockholm, Sweden, pp. 1- 37.

Choubey, S., Rajput, S.K. and Bapat, K.N.(2012). Comparison of efficiency of some naturalcoagulants-bioremediation. International Journal of Emerging Technology and Advanced Engineering, 2(10):430-434

Choy,S.Y., Prasad,K.M.N., Wu,T.Y., Raghunandan,M.E., and Ramanan,R.N. (2014). Utilization of plant –based natural coagulants as future alternatives towards sustainable water clarification. Journal of Environmental Sciences, 26(11), 2178-2189. DOI:10.1016/j.jes.2014.09.024

Christman, S. "Tamarindusindica". FloriData. Retrieved January 11, 2010.

Das, N., Vimala, R. and Karthika, P. (2008). Biosorption of heavy metals- An overview. Indian Journal of Biotechnology, 7: 159-169.

D'Cruz, Mark. "Ma-Ke Bonsai Care Guide for Tamarindusindica". Ma-Ke Bonsai. Retrieved August 19, 2011.

De Caluwé, E., Halamová, K. and Van Damme, P. (2010). Adansoniadigitata L. – a review of traditional uses, phytochemistry and pharmacology. Afrika focus, 23 (1): 11-51.

Del-Rio A. B.G Obudulio, J. Costillo, F. G Mann and A Otuno (1997) uses and properties of Citrus Flavonoids T. Agric Food Chem. 46:4505 - 4515

Diaz, A., Rincon, N., Escorihuela, A., Fernandez, N., Chacin, E. and Forster, C.F. (1999). A preliminary evaluation of turbidity removal by natural coagulants indigenous toVenezuela. Process Biochemistry, 35: 391-395

Diop, A.G., Sakho, M., Dornier., M., Cisse, M., Reynes, M. (2005). Le baobab africain(AdansoniadigitataL.): principalescaractéristquesetutilisations. Fruits, 61, 55-69.

Doerr, B. (2005). Moringa water treatment, an echo technical note. Retrieved from http://miracletrees.org/moringa_water_purification.html

*Doughari, J. H. (December 2006). "Antimicrobial Activity of Tamarindusindica". Tropical Journal of Pharmaceutical Research. **5** (2): 597–603. doi:10.4314/tjpr.v5i2.14637.*

Dovie, B. D. K. (2003). Rural economy and livelihoods from the non-timber forest products trade. Compromising sustainability in southern Africa. International Journal of Sustainable Development and World Ecology, 10:247-262

Edogbanya PR, Ocholi OJ, Apeji Y (2013). A review on the use of plants seeds as biosorbents in the removal of heavy metals from water. AdvAgricSciEngRes; 3:1036-44.

Egila J. N., Dauda, B. E. N., Iyaka, Y. A. and Jimoh, T. (2011). Agricultural waste as a low cost adsorbent for heavy metal removal from wastewater. Intl. Journal of Physical Science, 6 (8): 2152-2157

El-Siddig, K. (2006). Tamarind:Tamarindusindica L.ISBN 9780854328598.

Febrianto, J., Kosasiha, A.N., Sunarsob, J., Jua, Y., Indraswatib, N. and Ismadjia, S.(2009).Equilibrium and kinetic studies in adsorption of heavy metals using biosorbent: A summary of recent studies. Journal of Hazardrous Materials, 162, 616–645.

Fleuret, A. (1980). Non-food uses of plants in Usambara. Economic Botany, 34: 320333.

Food and Agricultural Organization of the United Nations (FAO). AQUASTAT; 2006. Available from: http://www.fao.org/nr/water/aquastat/wastewater/index.stm. [Last accessed on June, 2015].

Food and Agriculture Organization of the United Nations (FAO). Water – the Most Basic Resource But Also the Most Essential; 2014. Available from:http://www.fao.org/zhc/detail-events/en/c/231215/. [Last accessed on June,2015].

Gang, S. and Weixing, S. (1998). Sunflower stalks as Adsorbents for the removal of metal ions from wastewater. Indian Engineering Chemistry Research, 37: 13241328.

Gavrilescu, M. (2004). Removal of Heavy metals from the environment by biosorption. Engineering in life Sciences, 4(3): 219-232.

Gebauer, J., El-Siddig, K., Ebert, G. (2002). Baobab (Adansoniadigitata L.): a Review on aMultipurpose Tree with Promising Future in the Sudan.Gartenbauwissenschaft, 67, 155 160.

Ghebremichael, K., Gunaratna, K., Henriksson, H., Brumer, H., and Dalhammar, G. (2005). A simple purification and activity assay of the coagulant protein from Moringaoleifera seed. Water Research, 39(11), 2338-2344. DOI:10.1016/j.watres.2005.04.012

Gohulavani, G. and Andal, N.M. (2013) Removal of nickel from aqueous solution using Azaridachtaindica seed shell powder as adsorbent. Research and Reviews: Journal of Chemistry, 2 (1):78-84.

Gupte, A., Karjikar, M. and Nair, J. (2012) Biosorption of copper using mucilaginous seeds of Ocimumbasilicum. ActaBiologicaIndica, 1(1):113-119

Hadi, N.A., Rohaizar, N.A. and Wong, C.S. (2011). Removal of Cu (II) from water by adsorption on papaya seed. Asian Transactions on Engineering, 1 (5): 49-55.

Havinga, Reinout M.; Hartl, Anna; Putscher, Johanna; Prehsler, Sarah; Buchmann, Christine; Vogl, Christian R. (February 2010). "TamarindusIndica L. (Fabaceae): Patterns of Use in Traditional African Medicine". Journal of Ethnopharmacology. ***127*** *(3): 573 588. doi:10.1016/j.jep.2009.11.028. PMID 19963055.*

Igboeli, L.C., Addy, E.O.H., Salami, L.I. (1997). Effects of some processing techniques on the antinutrientcontentsof baobab seeds (Adansoniadigitata). Bioresource Technology, 59, 29-31.

Igwe, J. C. and Abia, A.A. (2006). A bioseparation process for removing heavy metals from waste water using biosorbents. African Journal of Biotechnology. 5 (12):1167-1179.

Igwe, J.C. and Abia, A.A. (2005). Sorption kinetics and intraparticulate diffusivities of Cd, Pb and Zn ions on maize cob. African Journal of Biotechnology, 4(6):509-512.

Ishola M.M. Agbaji EB, Agbaji As (1990) Chemical study of TamarindusIndica (Tsamiya) Fruits grown in Nigeria Journal of Science, Food and Agriculture 51: 141: 143

Jahn, S.A.A. and Dirar, H. (1979). Studies on natural water coagulants in the Sudan, with special reference to Moringaoleifera seeds. WATER SA 5:90–97.

Jimoh, T. O., Yisa J., Ajai, A. I. and Musa, A. (2013). Kinetics and Thermodynamics Studies of the Biosorption of Pb(II), Cd(II) and Zn(II) Ions from Aqueous Solution by Sweet Orange (Citrus sinensis) Seeds. International Journal of Modern Chemistry, 4, 1, 19-37

Kumari, P., Sharma, P., Shalini, S. and Srivastava, M.M. (2006). Biosorption studies on shelled Moringaoleifera Lamarck seed powder: removal and recovery of arsenic from aqueous system, International Journal of Mineral Processes, 78: 131- 139.

Lima, E. C., Royera, B., Vaghettia, J.C.P., Brasila, J.L., Simona, N.M., dos Santos, A.A., Pavana, F.A., Diasa, L.P.S., Benvenuttia, E.V. and da Silvab, E.A. (2007). Adsorption of Cu(II) on Araucaria angustifolia wastes: Determination of the optimal conditions by statistic design of experiments. Journal of Hazardous Materials, 140: 211–220.

Mancy, T.B., Mathew, M.M. and Stanley, S.A. (2013). Comparative analysis of cost effective biosorbents in the removal of chromium and iron from aqueous solution. Advances in Biotecnology. 12(12):01-05.

Mariod, A. A., Mirghani, M. E. S., & Hussein, I. (2017). Unconventional Oil Seeds and Oil Sources. *Adansonia Digitata Baobab Seed Oil*, 267–271.

Marangoni A, Ali L. Kemesha S. (1988) Composition and Properties of seeds of the tree legumes *Tamarindus Indica* J. Food Sources 53:1452 - 1455.

Marobhe, N.J., Dalhammar, G. and Gunaratna, K.R. (2007). Simple and rapid methods for purification and characterization of active coagulants from the seeds of Vigna unguiculata and Parkinsoniaaculeata. Environmental technology, 28:671–681.

Meneghel, P.A., Conclaves A.C., Fernanda, R., Dragunski, D.C., lindino A.C., Strey L. (2013). Biosorption of cadmium (Cd) using Moringaoleifera (lam) seeds. Water Air Soil Pollution, 224 (1383): 1-13.

Mihelcic, J., andZimmerman, J.(2012).IngenieríaAmbiental: fundamentos, sustentabilidad, diseño (1ra ed.). M´exico: Alfaomega.

Morad M.M. Mogoli ELSB, Sedly KA (1978) physicochemical properties of Egyptian tamarind seed oil FetteSeifenAntrictmitty 80:357 - 359

Morton, Julia F. (1987). Fruits of Warm Climates. Wipf and Stock Publishers. pp. 115 121. ISBN 978-0-9653360-7-9.

Nathan, Joan (2004). "Georgian Chicken in Pomegranate and Tamarind Sauce". New York Times

Ndabigengesere A, Narasiah KS, Talbot BG. (1995). Active agents and mechanism of coagulation of turbid waters using Moringaoleifera. Water Resources; 29:703-10.

Njoku, V.O., Ayuk, A.A., Ejike, E.E., Oguzie, E.E., Duru, C.E. and Bello, O.S. (2011). Cocoa pod husk as a low cost biosorbent for the removal of Pb(II) and Cu(II) from Aqueous solutions. Australian Journal of Basic and Applied Sciences, 5 (8): 101110.

Nkafamiya, I.I., Osemeahon, S.A., Dahiru, D., Umaru, H.A. (2007). Studies on the chemical composition and physicochemical properties of the seeds of baobab (Adansonia digitata). African Journal of Biotechnology, 6, 756-759.

Nkana, Z. G. and Iddi, S. (1991). Utilization of Baobab (Adansoniadigitata) in Kondoa District, Central Tanzania. Faculty of Forestry, Sokoine University of Agriculture Morogoro. pp. 1- 50.

Oboh, O. I. and Aluyor, E.O. (2008). The removal of heavy metal ions from aqueous solutions using soursop seeds as biosorbent. African Journal of Biotechnology. 7 (24): 4508-4511.

Okuda T, Baes AU, Nishijima W, Okada M. (2001). Isolation and characterization of coagulant extracted from Moringaoleifera seed by salt solution. Water Res; 35:405-10.

Omorogie, M.O., Babalola J.O., Unuabonah, E.I. and Gong, J.R. (2012). Kinetics and thermodynamics of heavy metal ions sequestration onto novel Naucleadiderrichii seed biomass. Bioresource Technology, 118: 576–579.

Osman, M.A. (2004). Chemical and Nutrient Analysis of Baobab (Adansoniadigitata) Fruit and Seed Protein Solubility.Plant Foods for Human Nutrition, 59, 29-33.

Palmer, E. and Pitman, N. (1972). Trees of Southern Africa. A.A BalKema, Cape Town. Vol. 2.

Peruc¸o, J., Lenz, G., Fiori, R., and Bergamasco, R. (2013). Coagulants and Natural Polymers: Perspectives for the Treatment of Water. Plastic and Polymer Technology, 2(3), 55-62.

Pritchard, M., Mkandawire, T., Edmondson, A., Neill, J.G.O. and Kululanga, G. (2009). Potential of using plant extracts for purification of shallow well water in Malawi, Physics and Chemistry of the Earth, 34: 799-805.

Quora website, retrieved from https://www.quora.com/Are-tamarind-seeds-edible-What-can you-do-with-them

Raj, K.R., Kardam, A. and Srivastava, S. (2013). PEI modified Leucaenaleucocephala seed powder, a potential biosorbent for the decontamination of arsenic species from water bodies: bioremediation. Applied Water Science, 3:327–333.

Salma, U.; Miah, A. G.; Tareq, K. M. A.; Maki, T.; Tsujii, H. (April 1, 2007). "Effect of Dietary Rhodobactercapsulatus on Egg-Yolk Cholesterol and Laying Hen Performance". Poultry Science. ***86*** *(4): 714–*

Saritha, V., Srinivas, N., and Vuppala, N. (2017). Analysis and optimization of coagulation and flocculation process. Applied Water Science,7(1), 451-460. DOI: 10.1007/ s13201-014 0262-y

Scheuring, J.F., Sidibé, M., Frigg, M. (1999). Malian agronomic research identifies local baobab tree as source of vitamin A and vitamin C. Sight and Life, 1, 21-24.

Sen, T.K. (2012). Agricultural by-product biomass for removal of pollutants from aqueous solution by adsorption, Journal of EnvironmentalResources and Development, 6 (3): 524-533.

Sharma, P. Kumari, P. Srivastava, M.M. and Srivastava, S. (2007). Ternary biosorption studies of Cd (II), Cr(III) and Ni(II) on shelled Moringaoleifera seeds, Bioresource Technology, 98:474-477.

Shrivastava, A.K. and Khaladkar, H.S. (2013). Novel method for micro determination of lead in water samples. Scientific Reviews Chemical Communication, 3(1): 4353.

Sibibe,M., Williams, J.T. (2002). Baobab (Adansoniadigitata). Fruits for the future 8 (2), 13 15.

Silva,M.(2015).Potabilización. ProcesosyDiseños de Plantas (1ra.).Quito,Ecuador:Edicumbre.

Stanley, S.A., Mathew, M.M. and Mancy, T.B. (2013). Removal of chromium (VI) and iron (III) from aqueous solution using agricultural byproducts. Journal of Chemical and Pharmaceutical Resources, 4:301-309.

Suay, L., and Ballester, F. (2002). Revisión de los estudiossobreexposiciónalaluminio yenfermedad de Alzheimer. Revista Española de SaludP´ublica, 76(6), 645-658.DOI: 10.1590/S1135-57272002000600002

Subramanium, S., Vikashni, N., Maata, M. andKoshy, K.(2011). Moringaoleifera and other local seeds in water purification in developing countries .Research Journal of Chemistry and Environment, 15 (2): 135-138

Tamale, E.; Jones, N.; Pswarayi-Riddihough, I. (August 1995). Technologies Related to Participatory Forestry in Tropical and Subtropical Countries. World Bank Publications. ISBN 978-0-8213-3399-0.

United States Environmental Protection agency (USEPA). (2004). Drinking water treatment. Retrievedfrom water.epa.gov/.../2009_08_28_sdwa_fs_30ann_treatment_web.pdf

WHO, UNICEF. Progress on Sanitation and Drinking Water − 2015 Update and MDG Assessment. Geneva: WHO Press; 2015. p. 1-80.

Wickens, G.E. (1982). The Baobab – Africa's upside-down tree. Kew Bulletin, 37, 173-209.

World Health Organization (WHO) (2011). Guidelines for Drinking-water Quality. Malta: WHO. Recuperado de http://apps.who.int/iris/bitstream/10665/44584/19789241 548151_eng.pdf.

WWAP (United Nations World Water Assessment Programme). The United Nations World Water Development Report 2015: Water for a Sustainable World. Paris: UNESCO;2015. Available from: http:// www.unesdoc.unesco.org/images/0023/002318/231823E.pdf.[Last accessed on June, 2015].

Yao, Z.Y., Qi, J.H. and Wanga, L.H. (2010). Equilibrium, kinetic and thermodynamic studies on the biosorption of Cu(II) onto chestnut shell. Journal of Hazardous Materials,174: 137143.

Yongabi, K., Lewis, D. and Harris, P. (2012). Water Pollution: Natural Materials for http://www.intechopen.com/books/water-pollution/natural-materials-forsustainable water-pollution-management

Yongabi, K.A, Lewis, D. and Harris, P.L. (2011). Indigenous plant based coagulants/ disinfectants and sand filter media for surface water treatment in Bamenda, Cameroon,African Journal of Biotechnology, 10 (43): 8625-8629.

Yusuf A.A Mofio M.B Amed B.A (2007) Proximate and Numerical composition of Tamarindus indica seeds, science World J2: 1 – 4.

Zamani, A., Shokri, R., Yaftian, M. and Parizanganeh, A. (2013). Adsorption of lead, zinc and cadmium ions from contaminated water onto Peganumharmala seeds as biosorbent. International Journal of Engineering. 10 (1): 93-102.