Low Cost Water Purification: Harnessing Adsorbents for Sustainable Treatment Solutions

A.Vimala Ebenezer,
Professor, Department of Civil Engineering,
Sri Bharathi Engineering College for Women,
Pudukkottai, INDIA
vimalajulius1@gmail.com
M.A.Raja,
Assistant Professor, Department of Civil Engineering,
Meenakshi Sundararajan Engineering College,
Chennai, INDIA
rajama@msec.edu.in

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Abstract: Water is essential for life, yet millions lack access to clean drinking water. Low-cost treatment methods are crucial to ensure equitable access to safe water and prevent waterborne diseases in underserved communities. The study devised a 12-liter water filter utilizing pebbles, sand, and adsorbents biochar of Julifora, cashew nut shell and rice husk. Results demonstrated the filter's effectiveness in sustaining pH levels while reducing chloride, fluoride, hardness and alkalinity. Particularly noteworthy was the capacity of cashew nut biochar to efficiently adsorb chloride, fluoride, hardness and alkalinity as 27%, 37%, 38% and 43% respectively. This indicates its promising role as an adsorbent for water purification. The findings underscore the potential of the designed filter in improving drinking water quality by mitigating contaminants. Further refinement and optimization of the filter could enhance its efficacy in meeting stringent water quality standards, addressing the pressing need for accessible and safe drinking water globally.
Key words: Water Treatment, Adsorption, Biochar, Low cost, removal efficiency

INTRODUCTION

Water is indispensable for sustaining life on Earth. It plays a vital role in various aspects, including supporting ecosystems, agriculture, and human health. Its scarcity poses significant challenges, impacting biodiversity and socio-economic stability [1-3]. Conservation and sustainable management practices are crucial to mitigate these challenges and ensure adequate water availability for current and future generations. Recognizing water's importance is fundamental for promoting responsible stewardship of this precious resource and fostering a sustainable future for all. Water pollution occurs through various means, including industrial discharge, agricultural runoff, improper waste disposal, and sewage leakage [4]. Chemicals, heavy metals, nutrients, and pathogens enter water bodies, contaminating them and endangering aquatic ecosystems and human health. Pollution also arises from oil spills, littering, and urban runoff, posing significant environmental and socio-economic challenges [5].

Treatment of water is essential to remove contaminants and pathogens, ensuring its safety for consumption and various uses. Through filtration, disinfection, and chemical processes, impurities are eliminated, safeguarding public health and preserving the integrity of water resources for sustainable development [6-8]. Various water treatment technologies include filtration, disinfection, membrane processes, and biological treatments. Chemical precipitation, ion exchange, and advanced oxidation processes are also common [9-10]. Each method offers distinct advantages, addressing specific contaminants and water quality needs for safe and sustainable water provision. Conventional water treatment methods rely on chemicals, energy, and produce waste [6, 11-12]. They may not effectively remove all contaminants and require infrastructure maintenance, posing environmental and operational challenges. The need for cheap water treatment methods is critical to provide affordable access to safe drinking water, particularly in developing regions. Low-cost solutions can ensure sustainability and equity in addressing global water challenges [13]. Adsorption is a process where molecules adhere to the surface of a solid material, removing contaminants from water. It's widely used in water treatment for its effectiveness in removing pollutants.

Biochar is a type of charcoal produced from organic materials like wood, agricultural waste, or biomass through a process called pyrolysis [14,5]. It is used in various applications, including soil amendment, carbon sequestration, and water filtration, due to its porous structure and ability to improve soil fertility and water retention. Biochar is utilized in water treatment primarily for its adsorption properties [16-17]. Its porous structure allows it to capture and remove contaminants from water, including heavy metals, organic pollutants, and certain chemicals. Biochar can be used in various water treatment applications, such as filtration systems, adsorption columns, and as a component in composite materials [18]. Additionally, biochar's high surface area provides sites for microbial colonization, contributing to the removal of contaminants through biological processes [8,19]. The objective of the present study is to treat the water fit for drinking and meet the BIS standards; to utilize low cost and locally available material; to obtain eco-friendly treatment; Lab study to achieve treatment on a large scale.

II. RELATED RESEARCH WORKS

Utilization of mesquite (Prosopis juliflora) woodbiochar for adsorption of nickel ions in aqueous solution. The maximum percent removal was obtained 91.72% at the pH 7 at 1.0% biochar. The maximum percent removal was obtained 91.72% at the pH 7 at 1.0% biochar [9]. Kumar et al, in an assessment of Uranium (VI) removal from groundwater using biochar produced from witchgrass at 300°C in subcritical water; The sorption capacity was estimated to be ca. 2.12 mg of Uranium(VI) g-1 of biochar; Increasetowards circumneutral pH resulted in the maximum adsorption of Ca as 4 mg U g-1 of biochar [20]. With biochar derived from orange peel and water treatment sludge (WS) at different pyrolytic temperatures (400, 600,and 700 °C).At pH range of 2.0 to 3.9 for orange peel biochar and 5.1 to 6.2 for WS biochar WS biochar, apparent fluoride adsorption showed nearly 100 % in the pH range of 2.0 to 4.5 [21]. Mohan et al studied Cadmium and Lead Remediation using Magnetic Oak Wood and Oak Bark Fast Pyrolysis Bio-chars. Biochars were obtained from fast pyrolysis at 400 and 4500. Batch sorption studies were performed at 25-450□ C, pHs of 2-10. Cadmium and Lead removal efficiency is high in 550□c of pyrolysis biochar [22]. Nhapi et al 2011used Carbonised rice husk for removal of heavy metals from industrial wastewater and achieved a result of 54.3%, 8.24%, 51.4% and 56.7% of Pb, Cd, Cu, Zn respectively [23].

III. METHODOLOGY

Sample water collection

Samples are collected from selected places of Tirunelveli and Tuticorin districts with the focusing point of sub surface water Thaikkavoor, Udangudi, Authoor, Moolakaraipatti, Tisaiyanvilai, kolunthattu following standard methods as per APHA, 2017 [14].

Preparation of biochar

(i) Julifora wood

Prosopis juliflora wood was collected from Udangudi in Tuticorin district. The collected samples were air dried at room temperature for 2-3 days then converted into biochar at 450° C in closed container at limited oxygen supply. Then the wood biochar was kept in oven at 60° C for 48 hr to reduce the moisture content. It was then crushed and is sieved at 2.36mm to 1.18 mm sieve.

a. Julifora b. Cashew shell c. Rice husk

Figure.1 Biochar of various materials

(ii) Cashew nut shell

Cashew nut shell was collected from Authoor in Tuticorin district. The collected samples was dried at 60°C for 2-3 days then converted into biochar at 450°C in closed container at limited oxygen supply. Then oil removed and dried at 60°C for 2 days. It was crushed and is sieved at 1.18mm to 600 sieve.

(iii) Rice husk

Rice husk was collected from Thaikkavoor in Tuticorin district. The collected samples was washed and dried at room temperature for 1 day and biochar at 350°C in closed container at limited oxygen supply. Then the biochar was kept in oven at 60° C for 48 hr to reduce the moisture content. It was crushed and is sieved at 500 to 300 sieve which is a suitable size to act as adsorbent.

Filtration Tank

A transparent plastic tank, measuring 40cm in length and 20cm in diameter, served as the filtration unit for adsorption treatment. It contained various adsorbents layered with gravel and sand to prevent displacement [15].

Treated water was collected at the tank's base. The sand used matched slow sand filter specifications. Adsorbent sites were established after two weeks of continuous water flow. Subsequent sample treatment proceeded once adsorbent sites were developed.

IV.CHARACTERIZATION METHODS

The initial values of various parameters such as pH, chloride, fluoride and nitrate were measured using ion meter using separate ion-selective electrodes. Sulphate and Phosphate were measured by spectrophotometer method. For hardness and alkalinity measurement titration method was adopted [14]. The values for each raw sample were measured and tabulated.

a. Ionmeter b. Spectrophotometer
Figure 2. Electronic Equipments

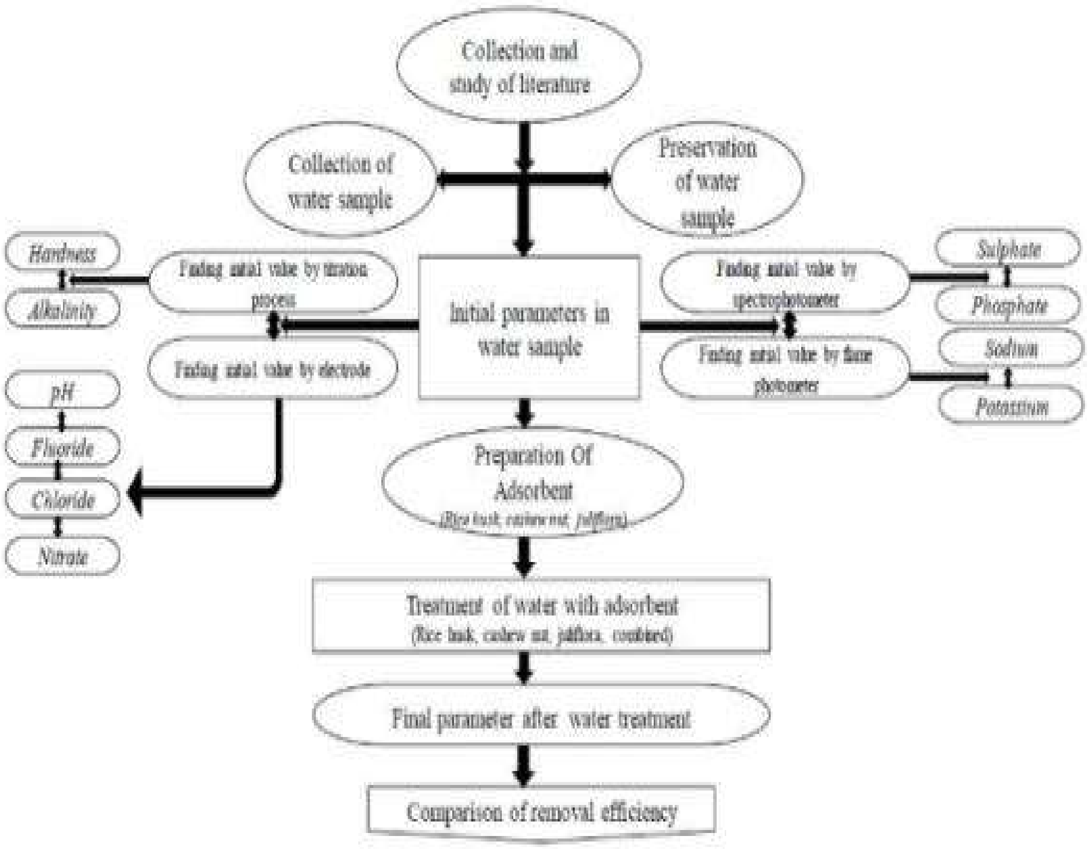

Figure 3 Methodology

IV. RESULTS AND DISCUSSION

The highest values of initial parameters were pH 7.96, hardness 432 mg/l, alkalinity 350 mg/l, fluoride 1.7 mg/l, chloride 430 mg/l. The cashew nut biochar adsorbent removal efficiency is excellent comparing to other adsorbent used. The juliflora biochar adsorbent removal efficiency is very poor comparing to other adsorbent used. This is due to the porous structured Prosopis juliflora wood biochar in a regular oval shaped form [12]. Thus, the pore space and agglomeration of biochar particles could enhance metal uptake and encourage mass transport of heavy metals through the inside of the sorbent which satisfies the results with Ramesh et al 2016 [16]. As a raw material, Prosopis juliflora wood is made up of polymers of lignocellulose (mainly hemicelluloses, cellulose, and lignin) after biochar having surface active groups (hydroxyl, carboxyl and amine etc) in their structures that are capable to bind heavy metals. The rice husk biochar adsorbent removal efficiency is medium comparing to other adsorbent used which is due to porous structured rice husk biochar in a regular oval shaped form. The pore space and agglomeration of biochar particles could enhance metal uptake and encourage mass transport of impurities through the inside of the sorbent which satisfies the results with Islamuddinet al 2016 [17]. The combined biochar provide excellent result in water treatment which is due to bonding of different biochar, provide new type to removal mechanism and change of surface area to attract more adsorbate in it.

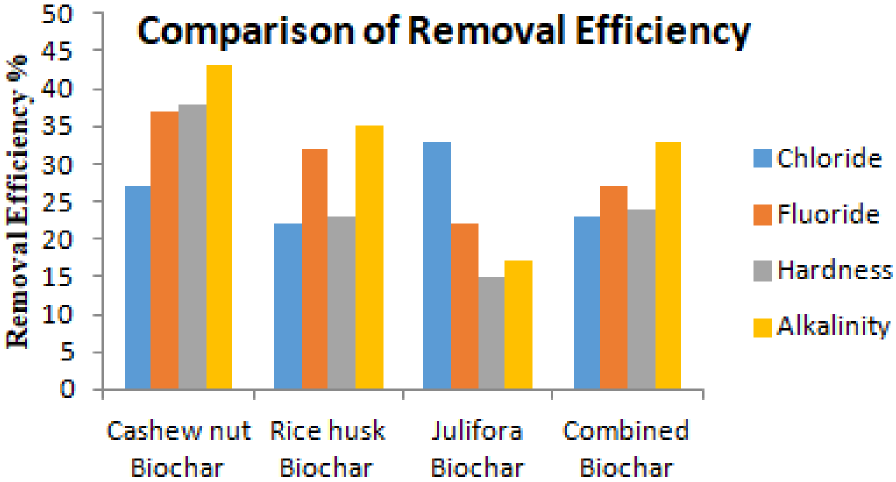

Figure 4 Comparison graph showing percent removal

V. CONCLUSION

The maximum removal efficiencies of alkalinity, hardness, fluoride and chloride are 43%, 38%, 37% and 27% using Cashew nut biochar adsorbent; 35%, 23%, 32% and 22% using Rice husk biochar adsorbent; 17%, 15%, 22% and 18% using Juliflora biochar adsorbent; 33%, 24%, 27% and 23% with Combined biochar adsorbent respectively. It can also be concluded that the filter designed is effective in removing many water quality parameters without consuming any power and wasting water unlike in reverse osmosis technologies.

REFERENCES

[1]. Khan, M., Hegde, R. & Shabiimam, M, Adsorption of lead by bentonite clay, Int. J. Sci. Res. Manag, 2017, 5, 5800–5804.

[2]. Talebi, S. S., Defluoridation of drinking water by metal impregnated multi-layer green graphene fabricated from trees pruning waste, Environ. Sci. Pollut. Res. 2021, 28, 18201–18215.

[3]. Lingamdinne, L. P., Lebaka, V. R., Koduru, J. R. & Chang, Y.-Y, Insights into manganese ferrite anchored graphene oxide to remove Cd(II) and U(VI) via batch and semi-batch columns and its potential antibacterial applications, Chemosphere, 2023, 310, 136888.

[4]. Angaru, G.K.R., Encapsulated zerovalent iron/nickel-fly ash zeolite foam for treating industrial waste water contaminated by heavy metals, Mater. Today Chem., 2021, 22, 100577. 34.

[5]. Miretzky, P., Munoz, C. & Carrillo-Chavez, A. Experimental binding of lead to a low cost on biosorbent: Nopal (Opuntia streptacantha), Bioresour. Technol., 2008, 99, 1211–1217.

[6]. Lingamdinne, L. P., Yang, J.-K., Chang, Y.-Y. & Koduru, J. R. Low-cost magnetized Lonicera japonica flower biomass for the sorption removal of heavy metals, Hydrometallurgy, 2016, 165, 81–89. 36.

[7]. Lingamdinne, L. P., Koduru, J. R., Jyothi, R. K., Chang, Y.-Y. & Yang, J.-K. Factors affect on bioremediation of Co (II) and Pb (II) onto Lonicera japonica flowers powder, Desalin. Water Treat., 2016, 57, 13066–13080.

[8]. Narasimharao, K. et al. Orange waste Biochar-Magnesium Silicate (OBMS) composite for enhanced removal of U(VI) ions from aqueous solutions. J. Water Process Eng., 2023, 51, 103359.

[9]. Akunwa, N. K., Muhammad, M. N. & Akunna, J. C. Treatment of metal-contaminated wastewater: A comparison of low-cost biosorbents. J. Environ. Manag., 2014, 146, 517–523.

[10]. Naef A.A.Qasem, Ramy H. Mohammed, Dahiru U. Lawal Removal of heavy metal ions from wastewater: a comprehensive and critical review, Clean Water, 2021.
[11]. Ahmad M., Lee S.S., Dou X., Mohan D., Sung J.K., Yang J.E. and O.K.Y.S., Effects of pyrolysis temperature on soybean stover-andpeanut shell-derived biochar properties and TCE adsorption in water, Bioresour. Technol., 2012,118, 36–54.
[12]. Angalaeeswari K. and Kamaludeen S.P.B., Utilization of mesquite (Prosopis juliflora) woodbiochar for adsorption of nickel ions in aqueous solution, International Journal ofChemical Studies, 2017, 5(4), 687-690.
[13]. Cao X.,Ma L., Gao B. and Harris W., Dairy-manure derived biochar effectively sorbs lead and atrazine, Environ. Sci. Technol., 2009, 43, 3285–3291.
[14]. APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater, 23rd ed., American Public Health Association: Washington, DC, USA, 2017.
[15]. Ismail S., Khan F., Zafar Iqbal M., Phytoremediation: Assessing Tolerance of Tree Species against Heavy Metal (PB and CD) Toxicity, Pakistan Journal of Botany, 2013,45, 2181-2186.
[16]. Ramesh, S., Sudarsan, J. S., Jothilingam, M., Low Cost Natural Adsorbent Technology for Water Treatment, Vol. 9, No. 3, 325 – 330.
[17]. Islamuddin, Ahmad, I, Nusrat Ali, Mumtaz, N., 'Domestic Wastewater Treatment by Low-Cost Natural Adsorbents, IJSRD - International Journal for Scientific Research & Development, 2016, Vol. 4, Issue 03.
[18]. Kim W.K., Shim T. Kim Y.S., Hyun S. Ryu C. Park Y.K., and Jung J., 'Characterization of cadmium removal from aqueous solution by biochar produced from a giant Miscanthus at different pyrolytic temperatures', Bioresour. Technol., 2013, 138, 266–270.
[19]. Chen B., Chen Z., Sorption of naphthalene and 1-naphthol by biochars of orange peels with different pyrolytic temperatures, Chemosphere, 2009, 76,127–133.
[20]. Kim W.K., Shim T.Kim Y.S., Hyun S. Ryu C. Park Y.K., and Jung J. Characterization of cadmium removal from aqueous solution by biochar produced from a giant Miscanthus at different pyrolytictemperatures, Bioresour. Technol., 2013, 138, 266–270.
[21]. Oh T.K., Choi B. Shinogi Y. and Chikushi J., Effect of pH conditions on actual and apparent fluoride adsorption by biochar in aqueous phase, Water, Air, Soil Pollut., 2012, 223, 3729–3738.
[22]. Regmi P.,Garcia J.L., Moscoso Kumar S., Cao X., Maob J. and Schafran G., Removal of copper and cadmium from aqueous solution using switchgrass biochar produced via hydrothermal carbonization process, Journal of Environmental Management, 2012, 109, 61-69.
[23]. Subhashini V., Swamy A.V.V.S., Phytoremediation of Pb and Ni Contaminated Soils Using Catharanthus roseus (L.), Universal Journal of Environmental Research and Technology, 2013, 3, 465-472.
[24]. Xu X., Cao X. and Zhao L., Comparison of rice husk-and dairy manure-derived biochars for simultaneously removing heavy metals from aqueous solutions: role of mineral components in biochars, Chemosphere, 2013, 92, 955–961.
[25]. Chandrakar, V., Jethwa, K., Ray, M. R., Ghodichore, N., Yadav, N., Deshmukh, P., Rathore, P. K., Biswas, P., Belchandan, Y., Removal of Turbidity from water using Low cost adsorbent, Eur. Chem. Bull. 2023, 12(Special issue 8), 8659-8665.