DEVELOPMENT OF LOW-COST FILTERS FOR THE TREATMENT OF WATER POLLUTED WITH FOOD WASTE LEACHATE

Neelu Das[*], Vivek Srivastava[*], Rumi Goswami[*], Abhishek Kumar[*]

[*] Central Institute of Technology Kokrajhar, Department of Civil Engineering, Kokrajhar, Assam, India

corresponding author: Neelu Das, e-mail: nl.das@cit.ac.in

Professional paper
Received: June 19th, 2021
Accepted: September 14th, 2021
HAE-2147
https://doi.org/10.33765/thate.13.1.4

ABSTRACT

This study investigates the efficacy of conventional and modified bio-sand filters as a low-cost filtering device for the treatment of groundwater contaminated with food waste leachate. Two kinds of waste materials, areca nut husk and water hyacinth stems, have been selected to alter the bio-sand filter. In conventional bio-sand filters, the ashes of these wastes are used as a filter medium. The ashes' physical characteristics, such as pH, ash content, and moisture content, have been measured. In leachate polluted water and purified water, tests for total solids, acidity, alkalinity, hardness, chloride content, pH, turbidity, dissolved oxygen, biological oxygen demand, and chemical oxygen demand have been performed. According to the testing findings, the developed filters are efficient in decreasing chloride, hardness, turbidity, chemical oxygen demand, and biological oxygen demand. The same filters have also detected an increase in dissolved oxygen. According to this study, these low-cost filters might be used as a preliminary treatment system for leachate created by food waste recycling plants.

Keywords: *areca nut husk ash, water hyacinth ash, bio-sand filter, leachate, biological oxygen demand (BOD), chemical oxygen demand (COD)*

INTRODUCTION

India is burying itself in its trash as a massive amount of waste is produced daily and disposed of without appropriate management methods. Food waste is created in high concentration point sources, such as restaurants, hospitals, marketplaces, and residential complexes every year, with the majority of it ending up in landfills. Several studies have shown that landfills release harmful gases that cause lung and heart problems [1]. When organic, inorganic, dissolved, and suspended waste materials come into touch with one other on landfill sites, decomposition occurs, resulting in hazardous compounds leaking into groundwater. This deoxygenates water rapidly, resulting in a high BOD. When it reaches rivers or lakes, it is the cause of aquatic life's death [2]. In recent years, sources of water bodies have been in significant danger of being polluted by contaminants. Liquid contaminants seep into the earth, ultimately contaminating the groundwater supply [3]. Contaminants are any undesirable solid or liquid substances that accidentally find their way into groundwater [4]. Many studies have indicated that drinking leachate-contaminated water increases the risk of bladder cancer, leukaemia [5], and birth abnormalities in children, such as low birth weight, which causes them to be shorter than others [6]. Unfortunately, it has been seen that owing to a lack of awareness among the general public, they accept or construct landfills near their homes. Over time, it spreads to a broader region, posing a danger to the human population. Accordingly [6], water bodies should not be built within a 7-kilometers radius of a waste dump.

The use of waste products instead of other traditional materials helps save natural resources and energy and helps solve disposal issues [7]. Tire shreds, fly ash, blast furnace slag, steel slag, cement kiln dust, silica fume, and crushed glasses are some of the recyclable materials discovered to be very useful in civil engineering applications. Rice husk, sugarcane freight, olive, corn cob, coir pith, maize, peanut hull, tea leaves, and other agricultural wastes have been investigated as low-cost adsorbents. This research will use two types of brown waste: areca nut and water hyacinth, both rather plentiful in India. Before the areca nut is eaten, the husk is removed. The removed husk was found to weigh between 5.5 and 6 metric tons per acre each year, posing a significant disposal issue. On the water's surface, water hyacinth develops dense mats. It is distinguished by its rapid growth rates and broad dispersion abilities. Over the past several decades, the adsorption process has emerged as the most efficient and effective wastewater treatment method. The use of activated carbon as an adsorbent with a wide surface area, minimal reactivity with acids and bases [8], and high capacity for the removal of organic and inorganic contaminants from aqueous or gaseous environments is gaining popularity [9]. Activated carbon is efficient in the removal of ammonium nitrogen from leachate. Various filters are efficient in the treatment of leachate. A granular-activated carbon column has been employed to stabilize leachate in Germany, and COD has been reduced to the tune of 91 % [10]. Research in Greece has utilized powdered activated carbon, which removed 95 % of COD [11]. Granular-activated carbon with limestone has been used in Malaysia to remove up to 40 % ammonium nitrogen [12]. Another research has used ceramic membrane filters manufactured from leftover sugarcane bagasse ash to treat nitrate-rich water (synthetic and real groundwater). The bagasse ash filters produced a clear permeate free of suspended particles. According to the obtained results, waste-derived products, such as bagasse ash filters, showed potential in water treatment [13]. The basic material for purifying drinking water in low-income Indian homes was rice husk ash. Rice husk ash was cast in a cement and pebble matrix to create a filter bed capable of trapping up to 95 % of turbidity and microorganisms in water. Another breakthrough includes embedding silver nanoparticles in a rice husk ash matrix to produce a bactericidal filtration bed that has been marketed in India as a low-cost home water purifier. Other breakthroughs include impregnating rice husk ash with iron hydroxide to remove arsenic from water and impregnating rice husk ash with the aluminium hydroxide to remove fluoride ions from water [14].

Activated carbons are effective in removing contaminants from water. According to certain studies, rice husk ash and bagasse ash are also employed in water filters; therefore, an effort is made to utilize a layer of areca nut husk ash, and water hyacinth ash in addition to the standard sand filter for the preliminary treatment of water polluted with food leachate. The planet is now experiencing its worst environmental disaster. This research will help develop a low-cost ash-sand filter that will benefit over 100 million people in India who are suffering from the health effects of drinking contaminated water and an innovative and long-term food waste leachate disposal plan that is both environmentally and economically beneficial.

MATERIALS AND METHODS

Sand and gravel

Sand is made up of sub-angular, hard, long-lasting, and dense grains of siliceous material. The sand for this study has been gathered from the banks of the Gaurang river, and the sands passing through 1.18 mm, 600 µm, and 300 µm IS sieves have been used. The test included gravel that passed 16 mm, 12 mm, and 10 mm sieves, as well as a 4.75 mm IS sieve. It was water washed, cleaned, dried in the open sun for 5 - 6 h, and screened to eliminate unwanted particles from the surface of sand and gravel.

Areca nut husk ash and water hyacinth stem ash

Betel nut is another name for areca nut. The nut within the fresh fruit's shell is soft enough to cut with a regular knife, while the husk is green. The husk of the mature fruit becomes yellow or orange. The fruit within hardens as it dries. Areca nut may also be utilized as an adsorbent material due to its fibrous structure. Water hyacinth (*Eichhornia crassipes*) is an invasive species that is a free-floating perennial aquatic plant. The water hyacinth may reach a height of 1 m over the water surface with its broad, thick, glossy, ovate leaves. Areca nut husk and water hyacinth stems have been collected from ponds and areca nut gardens in Kokrajhar. They were cleaned completely, dried in the sun, and burned in an electric muffle furnace at a rate of 10 °C per min up to 700 °C for 6 h to eliminate volatiles, as shown in Figures 1 and 2. The ash is allowed to cool to ambient temperature once the burning procedure is finished. It is processed for 30 min in a ball mill before being filtered through a 150 sieve as per IS: 1727-1967 [15].

a) b)

Figure 1. Water hyacinth stem ash: a) after muffle burning, b) after grinding and sieving

a) b)

Figure 2. Areca nut husk ash: a) after muffle burning, b) after grinding and sieving

Filtration unit

Filtration is the separation of suspended solid particles from a liquid by forcing the latter to flow through the pores of another material. Three distinct filters have been developed for this research work:

- Experiment 1 - sand + gravel,
- Experiment 2 - sand + gravel + water hyacinth stem ash,
- Experiment 3 - sand + gravel + areca nut husk ash.

The details of the incorporated sand and gravel layer are specified in Table 1 and Table 2.

The filtering media, as depicted in Figure 3, has been set accordingly:

- a synthetic sponge with a thickness of 2 cm was used to cover the base and top, as shown in the figure,

- on the base, there are two layers of general laboratory cellulose filter paper,
- from the bottom to the top, three layers of gravel are provided,
- from the top layer of gravel to the lowest layer of ash, three layers of sand are provided,
- above the top layer of sand, there lies a 2 cm thick layer of ash,
- a 3 cm hole is provided at the base for the filter to flow through after filtering,
- the top is left open to allow for simple cleaning.

Table 1. Details of the gravel layer

Passing size of gravel	Retaining size of gravel	The thickness of the gravel layer
16 mm	12 mm	2 cm
12 mm	10 mm	2 cm
10 mm	4.75 mm	2 cm

Table 2. Details of the sand layer

Passing size of sand	Retaining size of sand	The thickness of sand layer
1.18 mm	600 µm	2 cm
600 µm	300 µm	2 cm
300 µm	150 µm	2 cm

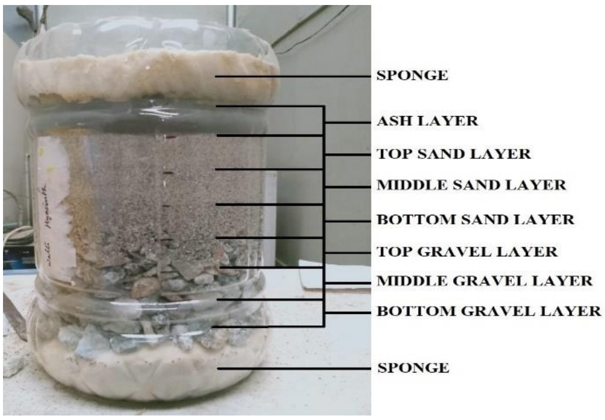

Figure 3. The arrangement of the filtering media

Leachate contaminated water

Biodegradable trash accounts for more than 30 % of total household waste. Kitchen trash and food waste are separated from biodegradable waste. Vegetable peels and discarded parts are included in kitchen waste. Food waste is made up of food that has been thrown away or has not been consumed. In a biogas plant built in the institution, biodegradable waste from the college cafeteria and dormitories is digested at a rate of about 500 kg per day. The breakdown of biodegradable waste takes place in the anaerobic digester. The effluent that emerges from the drain has a dark brownish colour. Excess overflow liquid is collected from the plant, and the leachate-contaminated water (sample 1) is obtained by mixing 1 ml of leachate with groundwater to make 1 l. Similarly, for sample 2, the leachate is produced in the laboratory by feeding kitchen waste, food waste, and garden waste into a small-scale anaerobic digester. The resulting leachate is then diluted with groundwater in the same ratio as for sample 2. The leachate is generated by in-vessel composting method with the following:

- percentage of kitchen waste - 68.2 %,
- percentage of food waste - 22.7 %,
- percentage of paper waste - 4.5 %,
- percentage of grass cuttings - 4.5 %,
- C:N ratio as calculated 29.1:1.

Characterization of areca nut husk ash and water hyacinth ash

For areca nut husk ash and water hyacinth ash basic ash characterization tests, such as pH (IS 3025 part 11) [16], moisture content (by ASTM D2216-98 [17]), and ash content (by ASTM E1534-93 [18]) have been performed.

Characterization of leachate-contaminated water and filtered water

To determine the proposed filters' efficiency, both samples of leachate-polluted water have been filtered through three filters: sand filter, water hyacinth stem ash filter, and areca nut husk ash filter. On both the raw samples and the filtered water from the produced filters, different physicochemical parameters such as pH, total solids, acidity, alkalinity, chloride content, hardness, turbidity, COD, dissolved oxygen (DO), and BOD_5 have been analysed. The tested samples were kept in BOD incubator for 5 days of incubation. These tests were conducted according to IS 3025:1987 [19] and IS 10500:2012 [20].

RESULTS AND DISCUSSION

Physical and chemical analysis of ashes

The chemical composition of the ash is determined according to IS: 1350 (Part III)-1969 [21], IS: 1355-1984 [22], and Vogel's textbook of quantitative inorganic analysis for the preparation and storage of analysis solution [23]. Physical properties, such as specific gravity and fineness by sieving are determined according to IS: 1727-1967 [15]. Table 3 shows chemical composition of areca nut husk ash and water hyacinth stem ash. The areca nut husk ash includes silica as the main component, as can be observed. Alumina, iron oxide, calcium oxide, and a considerable quantity of alkali are also present. More than 45 % of the total material composition comprises silica, alumina, and iron oxide. Water hyacinth stem ash, on the other hand, has a high alkali content (K_2O and Na_2O) and low silica values. The total amount of silica, alumina, and iron oxide in the overall material composition is less than 13 %, while the calcium oxide concentration is significant. The amount of sulphur trioxide is about 3 %.

Table 3. Physical and chemical properties of areca nut husk ash and water hyacinth stem ash

Properties	Areca nut husk ash	Water hyacinth stem ash
A) physical properties		
Specific gravity	2.197	2.168
Fineness	79 % (residue on 75 µm sieve)	87 % (residue on 75 µm sieve)
B) chemical composition		
SiO_2 (silica)	28.44 %	4.40 %
Al_2O_3 (alumina)	3.64 %	2.20 %
Fe_2O_3 (iron oxide)	1.91 %	1.27 %
CaO (calcium oxide)	2.71 %	22.61 %
MgO (magnesia)	3.87 %	14.01 %
SO_3 (sulphur trioxide)	7.80 %	3.09 %
Na_2O (sodium oxide)	0.24 %	0.35 %
K_2O (potassium oxide)	26.52 %	14.82 %

Characterization of ashes

The parameters for ash characterization are listed in Table 4.

Table 4. Characterization of ashes

Sl. No.	Properties	Water hyacinth stem ash	Areca nut husk ash
1	pH	8.3	8.1
2	moisture content, %	0.21	0.13
3	ash content, %	1.75	1.91

Physiochemical parameters of the water

The physiochemical properties of the water contaminated with food leachate (prepared samples 1 and 2) together with filtered water are listed in Table 5. The pH of water is an essential indication of its quality and the degree to which it has been contaminated [24]. pH is found to be within the range for both filters. It has been seen that the capacity for the removal of the total solids from water was higher for the water hyacinth ash filter than the areca nut husk ash filter, which is 44 - 58 % and 25 - 33 %, respectively.

Alkalinity gauges the water's buffering ability against pH fluctuations, and as the alkalinity in filtered water rises, so does its buffering capacity. Acidity is reduced to 100 % in water hyacinth ash and 33 - 75 % in areca nut husk ash. These filters have also been highly efficient in reducing chloride, hardness, and turbidity in water. The amount of DO recorded for sample 1 is 0.6 mg/L, whereas, after filtration, it is recorded as 1.4 mg/L, 2 mg/L, and 0.9 mg/L for the sand filter, water hyacinth ash filter, and areca nut ash filter, respectively. Similarly, for sample 2, it is 4.9 mg/L, and after filtration, 5.8 mg/L, 8.2 mg/L, and 6.1 mg/L for the sand filter, water hyacinth ash filter, and areca nut husk ash filter, respectively. Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Biochemical oxygen demand (BOD) measures the quantity of oxygen used by microorganisms in the oxidation of organic matter. The value of BOD is found to be 1.6 mg/L for sample 1, and after filtration, it is found to be 0.5, 0.8, and 0.3mg/L for sand, water hyacinth ash, and areca nut husk ash filter, respectively. Whereas in sample 2 the BOD is found to be 4.7 mg/L, and after filtration, it is 2.9, 0.7, 1.1 mg/L for sand, water hyacinth ash, and areca nut husk ash filter, respectively. COD is regarded as an important factor in assessing pollution levels in the water. It is found to reduce up to 75 % in sand filters, 81 % in water hyacinth ash filter, and 66 - 69 % in areca nut husk ash filter. Because the amount of CaO in water hyacinth stem ash is considerable, when it comes into contact with water, it produces $Ca(OH)_2$ and introduces the chemical stability that calcium hydroxide may enhance output water, total hardness, total alkalinity, and total dissolved solids.

Table 5. Physiochemical parameters of the samples and filtered water

Parameters	Sample Water-1	Experiment 1	Experiment 2	Experiment 3	Sample Water-2	Experiment 1	Experiment 2	Experiment 3
pH	7.41	7.31	8.27	7.32	7.32	7.39	8.22	8.04
Total Solids (g)	0.24	0.16	0.1	0.18	0.018	0.013	0.01	0.012
Acidity (mg/L)	12	8	0	8	16	12	0	4
Alkalinity (mg/L)	160	212	328	220	152	172	340	268
Chloride content (mg/L)	20	16	14	12	44	28	16	20
Hardness (mg/L)	88	68	64	72	164	76	60	68
Turbidity (NTU)	4	2.2	0.7	2.3	4.7	2.2	1.3	2.4
COD (mg/L)	1060	270	200	360	1120	260	210	340
DO (mg/L)	0.6	1.4	2	0.9	4.9	5.8	8.2	6.1
BOD (mg/L)	1.6	0.5	0.8	0.3	4.7	2.9	0.7	1.1

Furthermore, the presence of CaO in the ashes produced an exothermic reaction of calcium oxide hydration when they came into contact with the leachate. The heat released in this reaction may be responsible for destroying organic molecules in the treated water. Some earlier research found that removal effectiveness improved linearly with the increasing doses of CaO in water treatment and that organic component removal could also be accomplished using calcium hydroxide coagulation/flocculation. On the other hand, potassium hydroxide alone makes about one-fourth of the composition in areca nut ash. It is widely recognized as a pH control agent for its ability to reduce water hardness. In the production of activated carbon, potassium hydroxide is often employed as an activating agent. KOH activation results in activated carbon with a higher specific surface area and excellent pore formation.

CONCLUSION

From the results of this research, it can be concluded that all water quality indicators reflect overall water quality. The abundant DO, lower value of BOD_5, and COD show that the filtered water is suitable for use. Based on the different characteristics examined in this study, it is determined that both water hyacinth ash and areca nut husk ash filters are very effective in filtering effluents. This research is a preliminary investigation of the water quality of polluted water by food leachate. It demonstrates that effluents are a cause of pollution. If appropriate alternative arrangements are not made, such as treatment of effluents before release or infiltration into groundwater, the situation may be raising concerns among the region's residents or the surrounding area. As a result, stringent legislation is needed to control environmental risks and preserve groundwater.

REFERENCES

[1] T.I.S. Swati, V.K. Vijay, P. Ghosh, Scenario of landfilling in India: Problems, challenges, and recommendations, In: Handbook of Environmental Materials Management, ed.: C. Hussain, Springer, 2018, 1-16. https://doi.org/10.1007/978-3-319-58538-3_167-1

[2] The effects of landfills on the environment, Sciencing, 2018, https://sciencing.com/effects-landfills-environment-8662463.html, Accessed: December 10, 2019.

[3] A. Bagchi, Design of landfills and integrated solid waste management, 3rd edition, John Wiley & Sons, Hoboken, New Jersey, 2004.

[4] D.H. Speidel, L.C. Ruedisili, A.F. Agnew, Perspectives on Water: Uses and abuses, Oxford University press, 1988.

[5] G.M. Albion, Landfill Waste Pollution and Control, In: Hazardous Waste, Detection, Control and Treatment, Part B, ed.: B. Abbon, Elsevier Science, BV Amsterdam, 1995, 1199-1214.

[6] H. Dolk, The role of the assessment of spatial variation and clustering in environmental surveillance of birth defects, European journal of epidemiology 15(1999) 9, 839-845. https://doi.org/10.1023/A:1007569831029

[7] M. Prezzi, P. Bandini, J.A.H. Carraro, P.J.M. Monteirol, Use of recyclable materials in sustainable civil engineering applications, Advances in Civil Engineering, Volume 2011, Article ID 896016. https://doi.org/10.1155/2011/896016

[8] W. Li, K. Yang, J. Peng, L. Zhang, S. Guo, H. Xia, Effects of carbonization temperatures on characteristics of porosity in coconut shell chars and activated carbons derived from carbonized coconut shell chars, Industrial crops and products 28(2008) 2, 190-198. https://doi.org/10.1016/j.indcrop.2008.02.012

[9] P. Chingombe, B. Saha, R.J. Wakeman, Surface modification and characterisation of a coal-based activated carbon, Carbon 43(2005) 15, 3132-3143.

https://doi.org/10.1016/j.carbon.2005.06.021

[10] B. Morawe, D.S. Ramteke, A. Vogelpohl, Activated carbon column performance studies of biologically treated landfill leachate, Chemical Engineering and Processing: Process Intensification 34(1995) 3, 299-303. https://doi.org/10.1016/0255-2701(94)04017-6

[11] E. Diamadopoulos, Characterization and treatment of recirculation-stabilized leachate, Water research 28(1994) 12, 2439-2445. https://doi.org/10.1016/0043-1354(94)90062-0

[12] H.A. Aziz, M.N. Adlan, M.S.M. Zahari, S. Alias, Removal of ammoniacal nitrogen (N-NH3) from municipal solid waste leachate by using activated carbon and limestone, Waste management & research 22(2004) 5, 371-375. https://doi.org/10.1177%2F0734242X04047661

[13] S. Basu, S.K. Singh, P.K. Tewari, V.S. Batra, M. Balakrishnan, Treatment of nitrate-rich water in a baffled membrane bioreactor (BMBR) employing waste derived materials, Journal of environmental management 146(2014), 16-21. https://doi.org/10.1016/j.jenvman.2014.07.022

[14] C. Malhotra, R. Patil, S. Kausley, D. Ahmad, Novel uses of rice-husk-ash (a natural silica-carbon matrix) in low-cost water purification applications, AIP Conference Proceedings 1538(2013) 1, 113-119. https://doi.org/10.1063/1.4810040

[15] IS: 1727-1967, Methods of Test for Pozzolanic Materials, Bureau of Indian standards, New Delhi, India.

[16] IS: 3025-1983 (part II), Methods of sampling and test (physical and chemical) for water and waste water, Bureau of Indian standards, New Delhi, India.

[17] ASTM D2216-98, Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass, ASTM International, USA.

[18] ASTM E1534-93, Standard Test Method for Determination of Ash Content of Particulate Wood Fuels, ASTM International, USA.

[19] IS 3025(1987), Methods of sampling and test (physical and chemical) for water and wastewater, Bureau of Indian standards, New Delhi, India.

[20] IS 10500:2012, Drinking water - specification, Bureau of Indian standards, New Delhi, India.

[21] IS: 1350 (Part III)-1969, Methods for Test of Coal and Coke - Determination of Sulphur, Bureau of Indian standards, New Delhi, India.

[22] IS: 1355-1984, Methods of Determination of the Chemical Composition of Ash of Coal and Coke, Bureau of Indian standards, New Delhi, India.

[23] J. Basett, C.R. Denney, G.H. Jerrery, J. Mendham, Vogel's textbook of quantitative inorganic analysis, Longman Group, England, 1986.

[24] D. Kumar, J.P. Gaur, Metal biosorption by two cyanobacterial mats in relation to pH, biomass concentration, pretreatment and reuse, Bioresource technology 102(2011) 3, 2529-2535. https://doi.org/10.1016/j.biortech.2010.11.061