Green Approach to Sewage Water Purification through Column Adsorption Using Biochar of Natural Materials

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Abstract- **The increasing contamination of water resources due to domestic and industrial activities necessitates the development of low-cost, sustainable methods for wastewater treatment. This study evaluates a multi-layered column filtration method employing natural adsorbents: wooden sawdust, acid-washed river sand, biochar from neem and tulsi leaves, and poplar bark ash. The column treated sewage wastewater, targeting specific pollutants through each layer. Water quality parameters like turbidity, pH, COD, BOD, and microbial load were assessed before and after treatment. Results demonstrated significant reductions, supporting this as a cost-effective, eco-friendly wastewater treatment solution.**

Keywords: **Sewage wastewater, natural adsorbents, biochar, filtration column, water purification, sustainability**

I. INTRODUCTION

Water, a vital component of life and industrial processes, faces increasing pollution from anthropogenic activities. The unique solvent properties of water allow it to carry a wide range of contaminants. Thus, wastewater requires treatment before disposal or reuse. Evaluating its quality includes physical (e.g., turbidity), chemical (e.g., pH, COD, BOD), and biological (e.g., microbial load) parameters.

Table 1: Water Quality Parameters and Classification

Chemical Parameters	Physical Parameters	Biological Parameters
Alkalinity, Sulphate, Nitrate, Calcium, Magnesium, Chloride, pH	TDS, TSS, TS, Hardness, Conductivity, Temperature, Turbidity	BOD, COD

Table 2: Standard Limits for Water Quality Parameters

Parameter	Standard Value
Total Alkalinity	600 mg/L
Total Hardness	500 mg/L
TDS	500 mg/L
Magnesium	150 mg/L
Chloride	250 mg/L
BOD	2 mg/L
COD	10 mg/L
Sulfate	250 mg/L
Nitrate	50 mg/L
Turbidity	<5 NTU
Conductivity	400 µS/cm

II. MATERIALS AND METHODS

A. Collection of Sewage Wastewater

Samples were collected from local domestic drainage outlets in airtight containers and tested promptly.

B. Adsorbent Preparation

- Wooden Sawdust: Washed, sieved, oven-dried at 60°C
- Acid-Washed River Sand: Treated with 1M HCl, rinsed until neutral, dried at 105°C
- Biochar (Neem & Tulsi): Carbonized at 400°C in muffle furnace
- Wood Ash (Poplar Bark): Collected post-combustion and sieved

C. Filtration Column Design

A vertical acrylic column (50 cm height × 5 cm diameter) was constructed with four layers:

Table 3: Adsorbent Layers and Functions

Layer	Material Used	Function
Bottom	Wood Ash	pH control, organic matter adsorption
Second	Biochar	Organic & microbial adsorption
Third	River Sand	Fine filtration
Top	Sawdust	Coarse filtration

D. Filtration Procedure

1 L of sewage was passed through the column at ~1 mL/min. Column flushed with distilled water after each run.

E. Analytical Techniques

- pH – Digital pH meter
- Turbidity – Nephelometric turbidity meter
- BOD – 5-day incubation at 20°C
- COD – Open reflux method
- Coliform – MPN method

II. RESULTS AND DISCUSSION

A. pH

Decreased from 7.8 to 7.2, indicating mild neutralization.

B. Turbidity

Reduced from 185 NTU to 21 NTU (88.6% reduction).

C. COD

Reduced from 410 mg/L to 138 mg/L (66.3%).

D. BOD

Reduced from 190 mg/L to 62 mg/L (67.4%).

E. Coliform Count

Reduced from >1600 to 220 MPN/100 mL (86.3%).

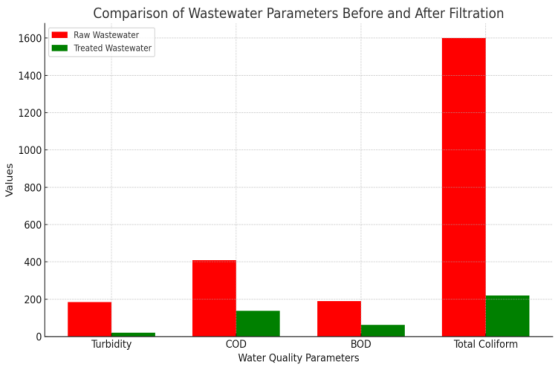
Table 4: Wastewater Quality Before and After Treatment

Parameter	Raw Wastewater	Treated Water	% Reduction
pH	7.8	7.2	—
Turbidity (NTU)	185	21	88.6%
COD (mg/L)	410	138	66.3%
BOD (mg/L)	190	62	67.4%
Coliform (MPN/100 mL)	>1600	220	86.3%

IV. CONCLUSION

The study validates a natural-material-based filtration column as an effective solution for sewage treatment. Each layer targets specific pollutants and collectively improves water quality significantly. The method is inexpensive, environment-friendly, and suitable for decentralized wastewater treatment. Future research could integrate disinfection (e.g., UV or chlorine) and scale-up for community use.

Figure 1: Bar Graph Showing Parameter Reductions Before and After Treatment



REFERENCES

[1] Ahmad, M., Rajapaksha, A. U., Lim, J. E., Zhang, M., Bolan, N., Mohan, D., & Ok, Y. S., "Biochar as a sorbent for contaminant management in soil and water: A review," *Chemosphere*, vol. 99, pp. 19–33, 2014. doi:10.1016/j.chemosphere.2013.10.071

[2] Mohan, D., Sarswat, A., Ok, Y. S., & Pittman Jr, C. U., "Organic and inorganic contaminants removal from water with biochar, a renewable, low cost and sustainable adsorbent – A critical review," *Bioresource Technology*, vol. 160, pp. 191–202, 2014. doi:10.1016/j.biortech.2014.01.120

[3] Inyang, M., Gao, B., Yao, Y., Xue, Y., Zimmerman, A., Mosa, A., & Ok, Y. S., "A review of biochar as a low-cost adsorbent for aqueous heavy metal removal," *Critical Reviews in Environmental Science and Technology*, vol. 46, no. 4, pp. 406–433, 2016. doi:10.1080/10643389.2015.1096880

[4] Lehmann, J., & Joseph, S. (Eds.), *Biochar for environmental management: Science, technology and implementation*, Routledge, 2015.

[5] Reddy, D. H. K., & Lee, S. M., "Application of magnetic chitosan composites for the removal of toxic metal and dyes from aqueous solutions," *Advances in Colloid and Interface Science*, vol. 201, pp. 68–93, 2013. doi:10.1016/j.cis.2013.10.002

[6] Singh, R., Singh, P. K., & Araujo, A., "Recent advances in biochar-based composites for wastewater treatment: A review," *Chemical Engineering Journal*, vol. 402, p. 126898, 2020. doi:10.1016/j.cej.2020.126898

[7] Wang, S., & Peng, Y., "Natural zeolites as effective adsorbents in water and wastewater treatment," *Chemical Engineering Journal*, vol. 156, no. 1, pp. 11–24, 2010. doi:10.1016/j.cej.2009.10.029

[8] Zhang, M., Gao, B., Yao, Y., Xue, Y., & Inyang, M., "Synthesis of porous MgO-biochar nanocomposites for removal of phosphate and nitrate from aqueous solutions," *Chemical Engineering Journal*, vol. 210, pp. 26–32, 2012. doi:10.1016/j.cej.2012.08.052

[9] Tan, X., Liu, Y., Zeng, G., Wang, X., Hu, X., Gu, Y., & Yang, Z., "Application of biochar for the removal of pollutants from aqueous solutions," *Chemosphere*, vol. 125, pp. 70–85, 2015. doi:10.1016/j.chemosphere.2014.12.058

[10] Mohan, D., & Pittman, C. U., "Arsenic removal from water/wastewater using adsorbents—A critical review," *Journal of Hazardous Materials*, vol. 142, no. 1-2, pp. 1–53, 2007. doi:10.1016/j.jhazmat.2007.01.006

[11] Chen, W., Meng, J., Han, X., Lan, Y., Tang, J., & Yang, X., "Biochar derived from waste biomass as sustainable adsorbent for contaminant removal in aqueous environments: A critical review," *Bioresource Technology*, vol. 292, p. 121896, 2019. doi:10.1016/j.biortech.2019.121896

[12] Méndez, A., & Gascó, G., "Biochar properties for wastewater treatment," in *Biochar in Agriculture for Achieving Sustainable Development Goals*, Springer, pp. 199–214, 2019. doi:10.1007/978-3-030-62417-0_10

[13] Zhang, D., Luo, W., & Lu, L., "Recent advances in biochar applications for water and wastewater treatment: A review," *Environmental Pollution*, vol. 300, p. 118945, 2022. doi:10.1016/j.envpol.2022.118945

[14] Foo, K. Y., & Hameed, B. H., "Insights into the modeling of adsorption isotherm systems," *Chemical Engineering Journal*, vol. 156, no. 1, pp. 2–10, 2010. doi:10.1016/j.cej.2009.09.013

[15] Malik, R., "Use of activated carbons prepared from sawdust and rice-husk for adsorption of acid dyes: A case study of Acid Yellow 36," *Dyes and Pigments*, vol. 56, no. 3, pp. 239–249, 2004. doi:10.1016/S0143-7208(02)00159-6

[16] Kearns, J. P., Wellborn, L. S., Summers, R. S., Knappe, D. R. U., & Andrews, S. A., "Drinking water treatment with biochar: A case study of nitrate removal," *Water Research*, vol. 61, pp. 32–40, 2014. doi:10.1016/j.watres.2014.05.014

[17] Bhatnagar, A., Hogland, W., Marques, M., & Sillanpää, M., "An overview of the modification methods of activated carbon for its water treatment applications," *Chemical Engineering Journal*, vol. 219, pp. 499–511, 2013. doi:10.1016/j.cej.2012.12.038

[18] Lu, H., Zhang, W., Yang, Y., Huang, X., Wang, S., & Qiu, R., "Relative distribution of Pb2+ sorption mechanisms by sludge-derived biochar," *Water Research*, vol. 46, no. 3, pp. 854–862, 2012. doi:10.1016/j.watres.2011.11.058

[19] Goyal, M., Kapoor, B. S., & Jain, A., "Removal of lead from aqueous solutions using adsorption on a low-cost material," *Environmental Science & Health Part A*, vol. 38, no. 7, pp. 1405–1420, 2003.

[20] Babel, S., & Kurniawan, T. A., "Low-cost adsorbents for heavy metals uptake from contaminated water: A review," *Journal of Hazardous Materials*, vol. 97, no. 1–3, pp. 219–243, 2003.

[21] Nasrullah, M., Liu, G., Zang, S., & Dong, R., "Adsorptive removal of heavy metals from aqueous solution using agricultural wastes: Mechanism, modeling and future perspective," *Journal of Environmental Chemical Engineering*, vol. 7, no. 6, p. 103487, 2019.

[22] Ghosh, D., Medhi, C. R., & Baruah, M. K., "Use of banana peel biochar for removal of Cr(VI) from aqueous solution," *Journal of Environmental Chemical Engineering*, vol. 8, no. 2, p. 103515, 2020.

[23] Jeyakumar, D., & Chandrasekaran, R., "Adsorption of lead(II) ions by activated carbons prepared from marine green algae: Equilibrium and kinetics studies," *International Journal of Industrial Chemistry*, vol. 5, p. 5, 2014. doi:10.1007/s40090-014-0015-8

[24] Ahmed, M. B., Zhou, J. L., Ngo, H. H., & Guo, W., "Adsorptive removal of antibiotics from water and wastewater: Progress and challenges," *Science of the Total Environment*, vol. 532, pp. 112–126, 2016.

[25] Sun, Y., Gao, B., Yao, Y., Fang, J., Zhang, M., Zhou, Y., & Chen, H., "Effects of feedstock type, production method, and pyrolysis temperature on biochar and hydrochar

properties," *Chemical Engineering Journal*, vol. 240, pp. 574–578, 2014.

[26] Yao, Y., Gao, B., Zhang, M., Inyang, M., & Zimmerman, A. R., "Removal of heavy metals from aqueous solutions by biochar derived from anaerobically digested biomass," *Bioresource Technology*, vol. 102, no. 20, pp. 8778–8782, 2012.

[27] Sharma, R. K., Wooten, J. B., Baliga, V. L., Lin, X., Chan, W. G., & Hajaligol, M. R., "Characterization of chars from pyrolysis of lignin," *Fuel*, vol. 83, no. 11–12, pp. 1469–1482, 2004.

[28] Kołodyńska, D., Wnętrzak, R., Leahy, J. J., Hayes, M. H. B., Kwapiński, W., & Hubicki, Z., "Kinetic and adsorptive characterization of biochar in metal ions removal," *Chemical Engineering Journal*, vol. 197, pp. 295–305, 2012.

[29] Sudha, R., & Saranya, A., "Biochar-based adsorbents for removal of nutrients from wastewater: A review," *Environmental Chemistry Letters*, vol. 19, pp. 1755–1778, 2021.

[30] Nascimento, F. L., Oliveira, L. C., de Lima, D. R., & Figueiredo, J. L., "Recent advances in sewage treatment using biochar," *Journal of Water Process Engineering*, vol. 42, p. 102160, 2021.

[31] Woo, S. H., & Park, J. M., "Biochar for nitrate and phosphate removal from water," *Environmental Engineering Research*, vol. 18, no. 3, pp. 179–185, 2013.

[32] Trakal, L., Veselý, M., Šimáček, P., & Komárek, M., "Sorption of Pb and Cu on biochars prepared from two different feedstocks: Relationship between biochar properties and metal retention," *Journal of Hazardous Materials*, vol. 273, pp. 110–116, 2014.

[33] Tripathi, M., Sahu, J. N., & Ganesan, P., "Effect of process parameters on production of biochar from biomass waste through pyrolysis: A review," *Renewable and Sustainable Energy Reviews*, vol. 55, pp. 467–481, 2016.

[34] Yin, Q., Zhang, B., Wang, R., & Zhao, Z., "Biochar as an adsorbent for inorganic nitrogen and phosphorus removal from water: A review," *Environmental Science and Pollution Research*, vol. 24, pp. 26297–26309, 2017.

[35] Jiang, J., Zhang, H., He, Y., & Jin, Y., "Biochar for nutrient removal in wastewater: A review," *Environmental Chemistry Letters*, vol. 18, no. 3, pp. 1085–1098, 2020.

[36] Singh, B., Singh, B. P., & Cowie, A. L., "Characterization and evaluation of biochars for their application as a soil amendment," *Soil Research*, vol. 48, no. 7, pp. 516–525, 2010.

[37] Hossain, M. K., Strezov, V., Chan, K. Y., Ziolkowski, A., & Nelson, P. F., "Influence of pyrolysis temperature on production and nutrient properties of wastewater sludge biochar," *Journal of Environmental Management*, vol. 92, no. 1, pp. 223–237, 2011.

[38] Ahmadpour, A., & Do, D. D., "The preparation of activated carbon from macadamia nutshell by chemical activation," *Carbon*, vol. 35, no. 12, pp. 1723–1732, 1997.

[39] Kizito, S., Wu, S., Kipkemoi, A., Li, F., & Dong, R., "Evaluating the effectiveness of biochar derived from different feedstocks to remove heavy metals in water," *Journal of Environmental Management*, vol. 146, pp. 546–554, 2017.

[40] Liang, J., Guo, X., Jin, H., & Yu, Z., "Removal of phosphate using biochar: A review," *Environmental Technology & Innovation*, vol. 17, p. 100582, 2020.