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Application Of Peanut Shell Bio Adsorbent To Improve Water Quality Parameters Of Formazine And Clay Suspension

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Abstract

Bio adsorbents have been proven to be more effective than coagulants in reducing turbidity and improving water quality throughout the water treatment process. This is owing to the fact that the former does not leave any residues in the treated water. The current study is based on the preparation of bio adsorbent samples from waste peanut shells, which are then utilized to treat formazine and clay suspensions that have been artificially generated. Low temperature carbonization and microwave pyrolysis were used to prepare adsorbent samples of two different particle sizes, Mesh-18 and Mesh-50. One of the samples was acid pretreated to see if there was any influence of surface modification on adsorption effectiveness. To replicate chemical and natural suspensions, turbidity 200 NTU formazine and clay suspensions were generated. After treating these suspensions with all adsorbent samples, changes in water quality metrics such as turbidity, pH, conductivity, TDS, and salinity were measured. According to the results of the experiments, the adsorbent treatment increased the values of pH, TDS, ionic conductivity, and salinity while decreasing the value of turbidity. When a bio adsorbent sample generated using the microwave pyrolysis method was employed, a significant reduction (up to 96.5%) in the turbidity value of both formazine and clay suspension was found.

Keywords: Agricultural waste management; bio adsorbent; peanut shells; turbidity; waste-water treatment

Introduction

The availability and sustenance of natural resources in the present scenario of globalization has raised two major issues of water conservation and waste-water management, which need to be addressed with prime concern[1]–[6]. Waste generated from agricultural and industrial activities when mixed in water, possess severe threat to environment, humans, living species, etc. and becomes difficult to control due to the increasing population and food demand[7], [8]. These wastes contain different bio degradable & non-biodegradable substances which are capable of affecting not only public health but also the environment due to their toxicity and difficulty in remediation[8], [9].Treatment of potable-water and waste-water containing high turbidity requires a suitable and effective method of turbidity reduction which will be easy to use and widely applicable. It isthe need of the hour to develop low-cost and effective methods for waste-water remediation. Among various executable solutions, the most viable methods generally used are electro coagulation flotation[15], ion-exchange[16], precipitation[17], nano filtration[18], membrane filtration[19], and adsorption[12], [20].

Generally surface water from different fresh water resources has a high level of turbidity which can be removed by flocculation/ coagulation processes using suitable chemicals[21], [22]. Many flocculants and coagulants are widely used in conventional water treatment processes[15], [23]– [25]. These materials can be inorganic coagulants like aluminum[26], [27]and ferric salts[28] or synthetic organic polymers like poly-acryl amide derivatives[29]and polyethylene imine[30]. These coagulants are very efficient in turbidity removal however they are very expensive and not readily available[31]. Major limitations in their usage are their high sensitivity towards pH value of water and introduction of secondary contaminants in drinking water like traces of toxic synthetic polymeric coagulants or residual iron and aluminum ions[13], [16], [32]. In addition to this, researchers have found a correlation between Alzheimer's disease and the residual aluminum ions in the treated waters[33]– [35]. After treatment with coagulation-flocculation process with synthetic polymer coagulants, the sludge formed is difficult to recycle because of the non-biodegradability of synthetic polymers[15], [36]. In both potable-water and waste-water treatment, turbidity reduction by the flocculation–coagulation process needs eco-friendly and low-cost coagulants with higher coagulation capabilities[8], [16], [31]. Lin et al.[17] applied chemical oxo-precipitation (COP) method and studied the effect of high turbidity seawater on removal of boron and transparent exo-polymer. A series of jar tests for seawater sampled from a desalinization pilot plant intake were conducted under various COP conditions in seawater. Either $FeCl_3$ or $BaCl_2$ was found to be unsuitable as a marine coagulant in COP. Wongcharee et. al.[18] studied the removal of natural organic matter and ammonia from dam water by increased coagulation combined with adsorption on nano-adsorbent (ACZ) powdered composite. Adsorption on ACZ showed significant reduction of dissolved organic carbon (DOC) and notable elimination of ammonia. The structural and material properties of the nano-adsorbent have led to the high-performance achievement in 30 minutes. Park et al.[19] utilizes ceramic microfiltration membranes for high turbidity water treatment. In the research, the fouling characteristics of a ceramic microfiltration membrane were investigated in a high-turbidity environment. Poly-aluminum chloride was selected as the optimum coagulant during the process. The comparative analysis between the ceramic and polymer membrane shows that there was no major difference in the removal efficiency, but the ceramic membrane had better water flux and lower membrane fouling potential, making it more effective to treat high turbidity water. The most extensively and effectively used method is the process of adsorption. It is universal, has low maintenance cost, and is applicable for the removal of turbidity at high concentrations[12], [37]. Pyrzynska [12] studied the removal of cadmium (Cd (II)) from wastewaters with low-cost adsorbents. Chemically modified bio sorbent was found to exhibit better adsorption ability than unmodified forms. It can be linked to the higher number of binding sites, improved ion-exchange ability, and the creation of new functional groups that favor Cd (II) uptake. Such improvements boost adsorption efficiency to varying degrees, but at the same time increases cost and their advantages over traditional adsorbents, as well as raise serious environmental concerns about the generation of toxic waste. Anantha et. al.[20] performed a comparative study of the photocatalytic, adsorption and electrochemical methods for the removal of cationic dyes from aqueous solutions. The synthesized TiO_2 nanoparticles (NPs) were used for the removal of methylene blue (MB) dye from waste-water. The effect of different experimental parameters such as pH, adsorbent dosage, dye concentration, photocatalyst concentration on the effluent's degradation efficiency was studied.

Groundnut (peanut) is India’s most popular oilseed crop and has a significant role in the national edible oil economy [38]. After processing, this crop produces huge amount of organic waste which is purely biodegradable and can be used for composting. But limiting factors are odor problem, generation of leachate and unsanitary condition in the compost yard[39]. Therefore, it is necessary to find alternative methods for management and disposal of biodegradable agricultural waste. Peanut shell (Arachis hypogea) has all the potential to be used as bio adsorbent due to its structural formation. It consists mainly of cellulose network and hence very effective in the removal of turbidity[40]. The phenolic hydroxyl groups and carboxyl groups contained in the peanut shell exhibit strong adsorption effects after chemical modification, making the performance of the activated carbon ideal. Thus, peanut shell can be used to prepare activated carbon for wastewater treatment[41], [42].Various researchers used waste peanut shells in the process of waste-water treatment[41], [43]–[46].Wu et al.[41]synthesized peanut shell activated carbon (PSAC) as dye adsorbents for waste-water treatment by using 50% phosphoric acid as an activator and studied adsorption of reactive brilliant blue X-BR. Kainth [47] used activated rice husk and grinded groundnut shell for the development of low cost adsorbent for turbidity reduction. It was observed that the groundnut shell powder is more effective than rice husk. Wani and Patil [44] used ground nut husk for treatment of dairy waste-water and found reduction of 98% in BOD value, 58% in total solids and 28% in COD value. Sowmya et. al.[45] studied the removal of toxic metals from industrial waste-water and observed that the toxic metals present in the industrial waste-water can be removed up to the minimum concentration range of pollution control board. Nkansah et al.[46] uses of sawdust and peanut shell powder as adsorbents for phosphorus removal from water and studied the effect of adsorbent dosage, contact time, and adsorbate concentration on adsorption process. The obtained results showed that at adsorbate concentrations of 10 mg/l for a period of 180 min at an adsorbent dosage of 0.4 g, 78% and 39% of phosphorus was removed by sawdust and peanut shell powder, respectively. It was also noted that the maximum removal of phosphorus occurred with an adsorbent mass of 0.4 g of sawdust and 0.6 g of peanut shell powder. Jeyaseelan and Chauhan [48]studied removal of Congo Red from aqueous solution using groundnut shells. It was found that the percentage efficiency for the removal of Congo red was up to 83% under optimized conditions.

The current study examines the effect of bio adsorbents on water quality parameters in natural and conventional chemical suspensions by using several approaches to prepare size selective bio adsorbent powder samples from waste peanut shells.

Experimental Methodology

Preparation of bio adsorbent samples from waste peanut shell:

Locally available raw peanuts were used for the study. Peanut shells were separated, washed, dried in air and powdered using a mixer, at room temperature. The sample was dried at 60^{o}C for 24 hours in ambient air in a hot air oven, cooled, grinded and sieved using Mesh size 18 (~1 mm nominal sieve opening) and 50 (~0.3 mm nominal sieve opening) to form adsorbent (M-18) and adsorbent (M-50) respectively. A small quantity of M-50 adsorbents was subjected to Microwave Pyrolisis (MPS) at 720 W for 20 minutes. The resultant sample was filtered using Mesh Size 50 to prepare MPS-M50.Acid pretreatment of adsorbent-MPS was done by adding 50 ml of 1N HCl to 2 gm of adsorbent in a beaker and then left for 24 hours. The resultant obtained was washed, dried and filtered. This adsorbent sample was termed as ATMPS-50 **(Figure.1)**.

Preparation of standard formazine & clay suspension:

Formazine suspension was prepared by mixing equal volumes of 1 gm/100 ml solution of hydrazine sulfate and 10 gm/100 ml solution of hexamethylenetetramine and then allowed to stand at 25 ± 1 °C for 24 hours. The solution develops a white particulate suspension of turbidity 4000 NTU. 5 ml of this solution was taken in 100 ml standard volumetric flask and diluted up to the mark with DI water to achieve the formazine suspension of 200 NTU turbidity.

Clay suspension was prepared by dissolving 10 gm of Fuller's Earth Powder (Multani Mitti Powder) in 1 L of deionized water in a beaker. It was stirred in a magnetic stirrer for 08 hours in ambient conditions and was allowed to settle for 24 hours at room temperature and the supernatant was decanted for further use. 100 ml of supernatant was used to make 500 ml of standard clay suspension in 500 ml standard volumetric flask and the turbidity was set at 200 NTU.

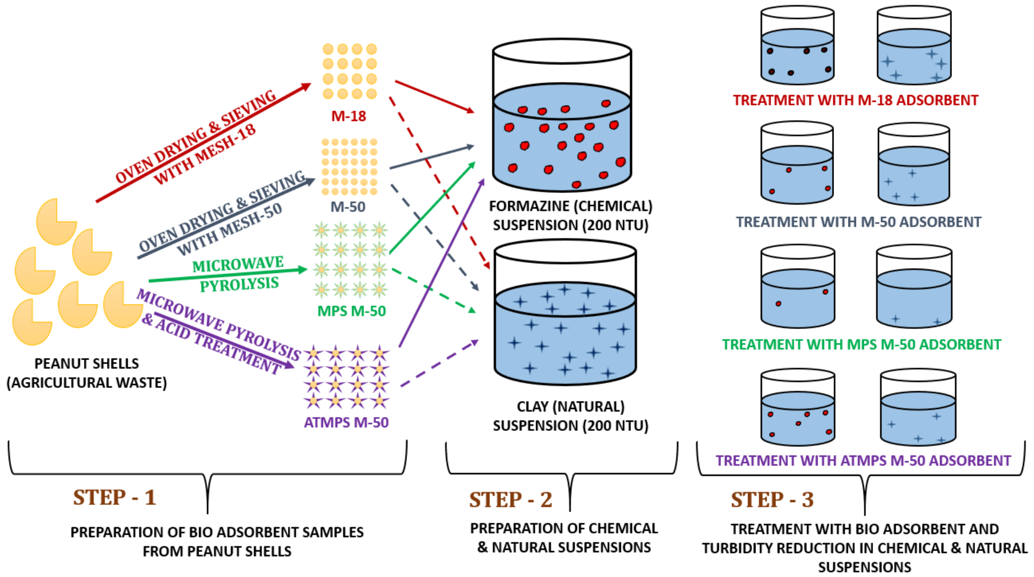


Figure 1. Stepwise Experimental Methodology

Treatment of standard formazine and clay suspension by bio adsorbents:

In a series of experiments,0.2 gm of adsorbent sample (M-18, M-50, MPS M-50 and ATMPS M-50), taken one at a time, was added to 40 ml of chemical and natural suspensions separately and stirredin a magnetic stirrer for 30 minutes. The suspension was then allowed to settle down for 15 minutes. After 15 minutes of retention time, water quality parameters were tested in supernatant. Parameters such as, pH, ionic conductivity, salinity, TDS and turbidity were tested as per American Public Health Association (APHA) norms in standard formazine suspension and clay suspension before and after treatment by bioadsorbent.

Table. 1. Effect of bio adsorbent treatment on chemical & natural suspensions.

Sample name	Suspension	pH		TDS (ppm)		Ionic Conductivity (µS)		Salinity (ppm)		Turbidity (NTU)	
		Before	After	Before	After	Before	After	Before	After	Before	After
M-18	Formazine suspension	6.83	6.21	313	318	438	604	194	268	200	180
	Clay suspension	6.675	6.98	343	354	478	503	217	222	195	179
M-50	Formazine suspension	6.83	6.9	313	318	438	453	194	204	200	174

	Clay suspension	6.75	6.93	343	430	478	561	217	250	195	177
MPS-M50	**Formazine suspension**	6.83	6.62	313	637	438	900	194	408	200	7
	Clay suspension	6.75	6.88	343	482	478	679	217	308	195	35
ATMPS-M50	**Formazine suspension**	6.67	8.3	330	333	464	473	208	211	164	15
	Clay suspension	6.43	5.6	129	186	181	260	83.3	115	198	65

Table. 2. Percentage change in water quality parameter after the bio adsorbent treatment

Sample name	**Suspension**	**pH**	**TDS (ppm)**	**Ionic Conductivity (µS)**	**Salinity (ppm)**	**Turbidity (NTU)**
		% Change	**% Change**	**% Change**	**% Change**	**% Change**
M-18	**Formazine suspension**	-9.07	1.59	37.89	38.14	10.00
	Clay suspension	4.56	3.20	5.23	2.30	8.20
M-50	**Formazine suspension**	1.02	1.59	3.42	5.15	13.00
	Clay suspension	2.66	25.36	17.36	15.20	9.23
MPS-M50	**Formazine suspension**	-3.07	103.5	105.47	110.30	96.5
	Clay suspension	1.92	40.52	42.05	41.93	82.05
ATMPS-M50	**Formazine suspension**	24.43	0.91	1.94	1.44	90.85
	Clay suspension	-12.90	44.18	43.64	38.05	67.17

Results and Discussion

Figure 3. Effect of bio adsorbent treatment on the water quality parameters of clay suspension

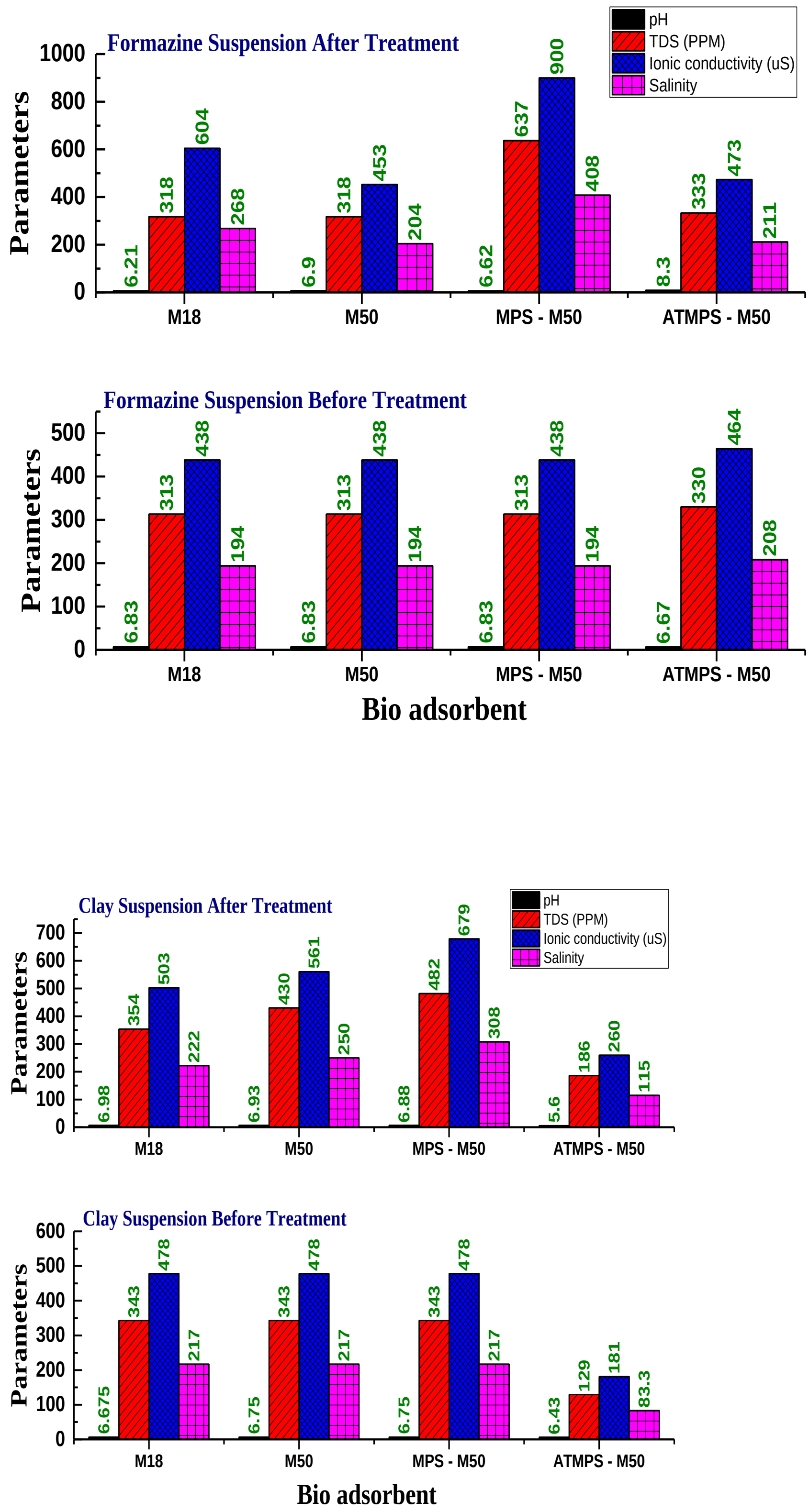
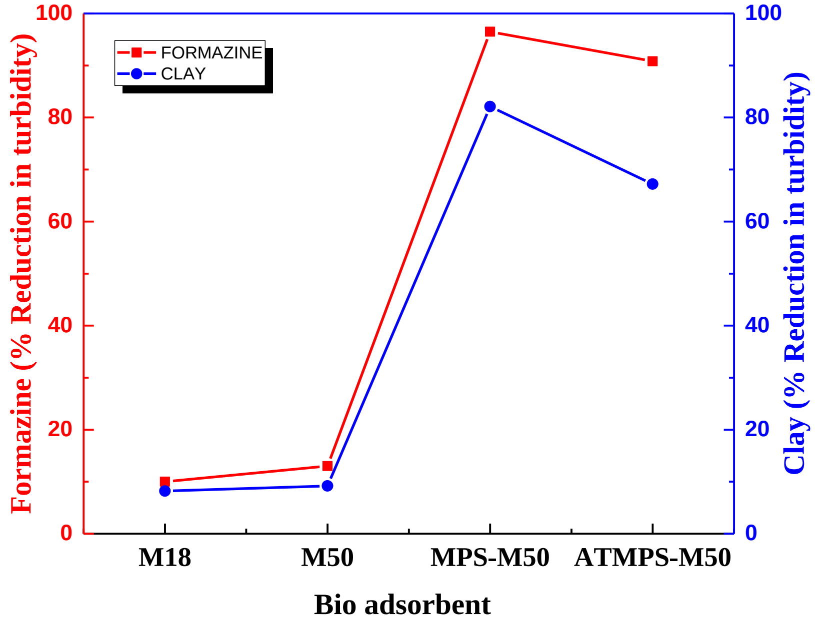


Figure 4. Percent reduction in turbidity by the application of bio adsorbents in chemical and natural suspensions



Biosorption involves a combination of several mechanisms such as electrostatic attraction, complexation, ion exchange, covalent forces, van der Waals forces, surface adsorption, and microstructure sequestration[8]. Water quality parameters like, pH, TDS, salinity, ionic conductivity and turbidity were measured before and after bio adsorbent treatment of formazine and clay suspension separately using various adsorbents distinguished by size and surface treatment. **Table.1** displays the broad summary of the effect of bio adsorbents on water quality parameters in chemical and natural suspensions before and after the surface treatment. Comparing M-18 and M-50 samples, it can be observed that the turbidity reduction capacity of M-50 sample is better than the M-18 sample. This can be an attribute of small size effect. Smaller particle size samples have larger surface area and therefore can adsorb more impurity elements than the bigger size particles[8], [49]. This is clearly visible in the obtained results. Thus, to further increase the impurity adhesion capabilities of the M-50 sample, surface modification of the sample was performed by microwave pyrolysis and acid treatment. Effect of bio adsorbents treatment on water quality parameters of formazine and clay suspensions before and after the treatment, are shown in **Figure.2 and Figure.3**, respectively. For all sets of experiments, adsorbent treatment contributed mostly towards increase in parameters like pH, TDS, ionic conductivity and salinity[50] but decrease in turbidity of the suspension[42].Treatment of formazine suspension as well as clay suspension with different bioadsorbent resulted into little increase in the pH value[42] except when acid treated bioadsorbent was used. Increase in the pH, TDS, ionic conductivity and salinity can be accounted for partial dissociation of surface groups and possible interaction between adsorbent and constituents of suspension [51]. Bioadsorbent contains cell wall polymers including many chemical groups such as hydroxyl, carbonyl, carboxyl, sulfhydryl, thioether, sulfonate, amine, imine, amide, imidazole, phosphonate[8].

The bio adsorbents M-18 and M-50 showed a little increase in the values of water quality parameters after treatment (6%-28%) and only slight reduction of turbidity (8.2% - 13%) **(Table.2)**. In case of sample prepared by microwave pyrolysis, all the major water quality parameters showed good increment (28%-110%) with significant turbidity reduction (82%-96%)[18]. Adsorbent can release ions by dissociation of surface groups [51]. This indicates availability of greater number of adsorption sights and increased ion exchange during the treatment process. In the latter case conductivity will increase when released ions have higher mobility than those taken up. When ATMPS-M50 adsorbent was applied to formazine suspension, the water quality parameters did not increase significantly (1-2%) but turbidity was reduced by 90% [45]. In case of same adsorbent treated with clay suspension, water quality parameters were increased by 38-45% but turbidity was reduced only by 67%.

Figure.4 shows the percent reduction of turbidity in chemical and natural suspensions by the effect of bio adsorbent samples. Significant reduction in turbidity was observed in both the suspensions when adsorbent MPS-M50 was used. This can be accounted for the activated carbon present in the sample[51]– [53], which resulted into turbidity reduction up to 96.5% in case of chemical suspension and 82% in case of natural suspension[9].

Conclusion

The potential of bio adsorbent samples of various sizes to reduce the turbidity of chemical and natural suspensions was studied in depth using peanut shell waste. Turbidity reduction was found to be more effective with tiny bio adsorbent materials. According to the results, the adsorbent treatment resulted in an increase in water quality indicators such as pH, TDS, ionic conductivity, and salinity, as well as a decrease in suspended turbidity. In the case of chemical suspension, the application of bio adsorbent generated through microwave pyrolysis resulted in a considerable reduction in turbidity of up to 96.5 percent and 82 percent in the case of natural suspension. This method is scalable and can be used to treat large amounts of water. Carbon filters can be made and utilized not just to treat natural water from sources such as rivers, wells, and ponds, but also to treat waste water.

Competing interests

The authors declare no competing interests.

REFERENCES

A. G. Capodaglio, “Integrated, decentralized wastewater management for resource recovery in rural and peri-urban areas,” Resources, vol. 6, no. 22, p. 6020022, 2017, doi: 10.3390/resources6020022.

M. Salgot and M. Folch, “Wastewater treatment and water reuse,” Current Opinion in Environmental Science and Health, vol. 2, pp. 64–74, 2018, doi: 10.1016/j.coesh.2018.03.005.

Z. Kakar, S. M. Shah, and M. A. Khan, “Scarcity of water resources in rural area of Quetta District; Challenges and preparedness,” IOP Conference Series: Materials Science and Engineering, vol. 414, no. 1, p. 012013, 2018, doi: 10.1088/1757-899X/414/1/012013.

L. A. Djehdian, C. M. Chini, L. Marston, M. Konar, and A. S. Stillwell, “Exposure of urban food–energy–water (FEW) systems to water scarcity,” Sustainable Cities and Society, vol. 50, no. May, p. 101621, 2019, doi: 10.1016/j.scs.2019.101621.

K. Frost and I. Hua, “Quantifying spatiotemporal impacts of the interaction of water scarcity and water use by the global semiconductor manufacturing industry,” Water Resources and Industry, vol. 22, p. 100115, 2019, doi: 10.1016/j.wri.2019.100115.

V. K. Chaturvedi, A. Kushwaha, S. Maurya, N. Tabassum, H. Chaurasia, and M. P. Singh, “Wastewater Treatment Through Nanotechnology: Role and Prospects,” in Restoration of Wetland Ecosystem: A Trajectory Towards a Sustainable Environment, A. K. Upadhyay, R. Singh, and D. P. Singh, Eds. Springer Nature Singapore Pte Ltd., 2020, pp. 227–247. doi: 10.1007/978-981-13-7665-8.

S. Firdous et al., “The performance of microbial fuel cells treating vegetable oil industrial wastewater,” Environmental Technology and Innovation, vol. 10, pp. 143–151, 2018, doi: 10.1016/j.eti.2018.02.006.

A. A. Beni and A. Esmaeili, Biosorption, an efficient method for removing heavy metals from industrial effluents: A Review, vol. 17. Elsevier B.V., 2020. doi: 10.1016/j.eti.2019.100503.

M. T. Santos, J. F. Puna, A. M. Barreiros, and M. Matos, “Agricultural wastes for wastewater treatment,” Conference: 4th International Conference on Sustainable Solid Waste Management, pp. 1–11, 2016.

S. Jangkorn, S. Kuhakaew, S. Theantanoo, H. Klinla-or, and T. Sriwiriyarat, “Evaluation of reusing alum sludge for the coagulation of industrial wastewater containing mixed anionic surfactants,” Journal of Environmental Sciences, vol. 23, no. 4, pp. 587–594, 2011, doi: 10.1016/S1001-0742(10)60524-4.

C. S. Patil et al., “Waste tea residue as a low cost adsorbent for removal of hydralazine hydrochloride pharmaceutical pollutant from aqueous media: An environmental remediation,” Journal of Cleaner Production, vol. 206, no. January, pp. 407–418, 2019, doi: 10.1016/j.jclepro.2018.09.140.

K. Pyrzynska, “Removal of cadmium from wastewaters with low-cost adsorbents,” Journal of Environmental Chemical Engineering, vol. 7, no. 1, p. 102795, 2019, doi: 10.1016/j.jece.2018.11.040.

G. Crini and E. Lichtfouse, “Advantages and disadvantages of techniques used for wastewater treatment,” Environmental Chemistry Letters, vol. 17, no. 1, pp. 145–155, 2019, doi: 10.1007/s10311-018-0785-9.

L. F. Cusioli, H. B. Quesada, A. L. de Brito Portela Castro, R. G. Gomes, and R. Bergamasco, “Development of a new low-cost adsorbent functionalized with iron nanoparticles for removal of metformin from contaminated water,” Chemosphere, vol. 247, p. 125852, 2020, doi: 10.1016/j.chemosphere.2020.125852.

É. Fekete, B. Lengyel, T. Cserfalvi, and T. Pajkossy, “Electrochemical dissolution of aluminium in electrocoagulation experiments,” Journal of Solid State Electrochemistry, vol. 20, no. 11, pp. 3107–3114, 2016, doi: 10.1007/s10008-016-3195-6.

M. Sillanpää, M. C. Ncibi, A. Matilainen, and M. Vepsäläinen, “Removal of natural organic matter in drinking water treatment by coagulation: A comprehensive review,” Chemosphere, vol. 190, pp. 54–71, 2018, doi: 10.1016/j.chemosphere.2017.09.113.

J. C. Te Lin, C. Y. Wu, Y. L. Chu, and W. J. Huang, “Effects of high turbidity seawater on removal of boron and transparent exopolymer particles by chemical oxo-precipitation,” Journal of the Taiwan Institute of Chemical Engineers, vol. 94, pp. 109–118, Jan. 2019, doi: 10.1016/j.jtice.2018.02.012.

S. Wongcharee, V. Aravinthan, and L. Erdei, “Removal of natural organic matter and ammonia from dam water by enhanced coagulation combined with adsorption on powdered composite nano-adsorbent,” Environmental Technology and Innovation, vol. 17, no. February, p. 100557, 2020, doi: 10.1016/j.eti.2019.100557.

W. il Park, S. Jeong, S. J. Im, and A. Jang, “High turbidity water treatment by ceramic microfiltration membrane: Fouling identification and process optimization,” Environmental Technology and Innovation, vol. 17, no. December, p. 100578, 2020, doi: 10.1016/j.eti.2019.100578.

M. S. Anantha et al., “Comparison of the photocatalytic, adsorption and electrochemical methods for the removal of cationic dyes from aqueous solutions,” Environmental Technology and Innovation, vol. 17, no. February, p. 100612, 2020, doi: 10.1016/j.eti.2020.100612.

V. K. Chaturvedi, A. Kushwaha, S. Maurya, N. Tabassum, H. Chaurasia, and M. P. Singh, “Wastewater Treatment Through Nanotechnology: Role and Prospects,” in Restoration of Wetland Ecosystem: A

Trajectory Towards a Sustainable Environment, A. K. Upadhyay, R. Singh, and D. P. Singh, Eds. Springer Nature Singapore Pte Ltd., 2020, pp. 227–247. doi: 10.1007/978-981-13-7665-8.

S. Jangkorn, S. Kuhakaew, S. Theantanoo, H. Klinla-or, and T. Sriwiriyarat, “Evaluation of reusing alum sludge for the coagulation of industrial wastewater containing mixed anionic surfactants,” Journal of Environmental Sciences, vol. 23, no. 4, pp. 587–594, 2011, doi: 10.1016/S1001-0742(10)60524-4.

P. J. Panikulam, N. Yasri, and E. P. L. Roberts, “Electrocoagulation using an oscillating anode for kaolin removal,” Journal of Environmental Chemical Engineering, vol. 6, no. 2, pp. 2785–2793, 2018, doi: 10.1016/j.jece.2018.04.020.

H. K. Agbovi and L. D. Wilson, “Design of amphoteric chitosan flocculants for phosphate and turbidity removal in wastewater,” Carbohydrate Polymers, vol. 189, pp. 360–370, 2018, doi: 10.1016/j.carbpol.2018.02.024.

A. Jafari, M. Ghaderpoori, B. Kamarehi, and Z. Shakarami, “Removal of stabilized functionalized CNTs from aqueous solutions using chemical coagulants and Moringa oleifera seed extract,” International Journal of Environmental Science and Technology, vol. 17, pp. 777–788, May 2019, doi: 10.1007/s13762-019-02395-3.

B. W. N. Grehs et al., “Removal of microorganisms and antibiotic resistance genes from treated urban wastewater: A comparison between aluminium sulphate and tannin coagulants,” Water Research, vol. 166, p. 115056, Sep. 2019, doi: 10.1016/j.watres.2019.115056.

D. Cruz, M. Pimentel, A. C. Russo, and W. Cabral, “Charge Neutralization Mechanism Efficiency in Water with High Color Turbidity Ratio Using Aluminium Sulfate and Flocculation Index,” Water, vol. 12, no. 572, pp. 1–17, 2020, doi: 10.3390/w12020572.

J. Ren, N. Li, H. Wei, A. Li, and H. Yang, “Efficient removal of phosphorus from turbid water using chemical sedimentation by FeCl3 in conjunction with a starch-based flocculant,” Water Research, vol. 170, p. 115361, 2020, doi: 10.1016/j.watres.2019.115361.

J. Ma, X. Fu, W. Xia, K. Fu, and Y. Liao, “Flocculation of a High-Turbidity Kaolin Suspension Using Hydrophobic Modified Quaternary Ammonium Salt Polyacrylamide,” Processes, vol. 7, no. 2, p. 108, 2019, doi: 10.3390/pr7020108.

Z. Zhang, H. Chen, W. Wu, W. Pang, and G. Yan, “Efficient removal of Alizarin Red S from aqueous solution by polyethyleneimine functionalized magnetic carbon nanotubes,” Bioresource Technology, vol. 293, no. August, p. 122100, 2019, doi: 10.1016/j.biortech.2019.122100.

B. Ramavandi, “Treatment of water turbidity and bacteria by using a coagulant extracted from Plantago ovata,” Water Resources and Industry, vol. 6, pp. 36–50, 2014, doi: 10.1016/j.wri.2014.07.001.

R. Nilsson, “Residual Aluminium Concentration in Drinking Water After Treatment with Aluminium or Iron Salts,” Chemical Water and Wastewater Treatment, pp. 399–410, 1990, doi: 10.1007/978-3-642-76093-8_26.

A. M. Simpson, W. Hatton, and M. Brockbank, “Aluminium, its use and control, in potable water,” Environmental Technology Letters, vol. 9, pp. 907–916, 1988, doi: 10.1080/09593338809384650.

L. Tomljenovic, “Aluminum and Alzheimer’s disease: After a century of controversy, is there a plausible link?,” Journal of Alzheimer’s Disease, vol. 23, no. 4, pp. 567–598, 2011, doi: 10.3233/JAD-2010-101494.

I. Krupińska, “Aluminium drinking water treatment residuals and their toxic impact on human health,” Molecules, vol. 25, no. 3, p. 641, 2020, doi: 10.3390/molecules25030641.

I. Krupinska, E. Pluciennik-Koropczuk, and S. Gagala, “Residual Aluminium in Water Intended for Human Consumption,” CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS, vol. 29, no. 4, pp. 248–256, 2019.

N. Fathima, U. Baig, S. Asthana, and D. Sirisha, “Removal of Turbidity of Waste Water by Adsorption Technology,” International Journal of Innovative Research in Science, Engineering and Technology, vol. 5, no. 11, pp. 20010–20016, 2016, doi: 10.15680/IJIRSET.2016.0511066.

H. SINGH, N. K. SINGH, and D. K. KARDAM, “Economic analysis of groundnut crop in Jaipur district of Rajasthan,” Agriculture Update, vol. 9, no. 1, pp. 59–63, 2014.

M. Lokeshwari and C. Nanjunda Swamy, “Waste to wealth - Agriculture solid waste management study,” Pollution Research, vol. 29, no. 3, pp. 513–517, 2010.

I. Fatimah, B. N. Huda, I. L. Yusuf, and B. Hartono, “Enhanced adsorption capacity of peanut shell toward rhodamine b via sodium dodecyl sulfate modification,” Rasayan Journal of Chemistry, vol. 11, no. 3, pp. 1166–1176, 2018, doi: 10.31788/RJC.2018.1134021.

H. Wu et al., “Synthesis of activated carbon from peanut shell as dye adsorbents for wastewater treatment,” Adsorption Science and Technology, vol. 37, no. 1–2, pp. 34–48, 2019, doi: 10.1177/0263617418807856.

S. Singh, “Turbidity Removal from Water by Use of Different Additive Materials,” International Journal of Scientific Engineering and Science, vol. 1, no. 10, pp. 55–57, 2017.

G. S. Kainth, “Removal of Turbidity from Water using Low-Cost Adsorbents,” National Institute of Technology, Rourkela, 2015.

P. R. Wani and S. B. Patil, “Treatment of Dairy Waste Water by Using Groundnut Shell as Low Cost Adsorbant,” International Journal of Innovative Research in Science, Engineering and Technology (An, vol. 6, no. 7, pp. 14941–14948, 2017, doi: 10.15680/IJIRSET.2017.0607353.

R. S. T.Aarti Sowmya, E.Gayavajitha, R.Kanimozhi, “REMOVAL OF TOXIC METALS FROM INDUSTRIAL WASTE WATER USING GROUNDNUT SHELL,” International Journal of Pure and Applied Mathematics, vol. 119, no. 15, pp. 629–634, 2018.

M. A. Nkansah, M. Donkoh, O. Akoto, and J. H. Ephraim, “Preliminary Studies on the Use of Sawdust and Peanut Shell Powder as Adsorbents for Phosphorus Removal from Water,” Emerging Science Journal, vol. 3, no. 1, p. 33, 2019, doi: 10.28991/esj-2019-01166.

C. Jeyaseelan and K. Chauhan, “Removal of Congo Red from Aqueous Solution Using Groundnut Shells,” Journal of Basic and Applied Engineering Research, vol. 2, no. 11, pp. 910–914, 2015.

M. Yao, J. Nan, and T. Chen, “Effect of particle size distribution on turbidity under various water quality levels during flocculation processes,” Desalination, vol. 354, pp. 116–124, 2014, doi: 10.1016/j.desal.2014.09.029.

N. Khatri, K. Kishore, and A. Sharma, “Enhanced Energy Saving in Wastewater Treatment Plant using Dissolved Oxygen Control and Hydrocyclone,” Environmental Technology & Innovation, vol. 18, p. 100678, 2020, doi: 10.1016/j.eti.2020.100678.

B. O. O and S. A. Y, “Adsorption and Equilibrium Studies of Textile Effluent Treatment with Activated Snail Shell Carbon,” IOSR Journal of Environmental Science, Toxicology & Food Technology, vol. 12, no. 4, pp. 26–33, 2018, doi: 10.9790/2402-1204012633.

A. Bhatnagar and M. Sillanpää, "Utilization of agro-industrial and municipal waste materials as potential adsorbents for water treatment-A review," Chemical Engineering Journal, vol. 157, no. 2–3, pp. 277–296, 2010, doi: 10.1016/j.cej.2010.01.007.

D. Mohan, A. Sarswat, Y. S. Ok, and C. U. Pittman, "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.