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Research Article

UTILIZATION OF RICE HUSK AND LATERITE AS A LOW-COST ADSORBENT FOR HEAVY METAL REMOVAL THROUGH AQUEOUS SOLUTION

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ABSTRACT

Objective: Heavy metals are a major pollutant in marine, ground, industrial, and even treated wastewater. Metals are excessively released into the environment due to the natural processes and anthropogenic activities have created a major global concern regarding metal pollution. Hence, there is a strong need for economical and environment-friendly technology. The present study provides the solution for the problem in the form of laterite and rice husk.

Methods: The batch method was used to study the adsorption. The batch experiment was performed in two different conditions, stable and shaking.

Results: The obtained results from the batch experiment shown the ability of both the adsorbents in removing some heavy metals. Furthermore, it was found that the adsorption of metals by laterite decreases in order of chromium (Cr)>mercury (Hg)>Cadmium (Cd)>lead (Pb) and for rice husk, Hg>Cd>Cr>Pb. Rice husk was found more efficient for removal of Hg, Cd, and Pb. Laterite was more efficient than rice husk for removal of Cr.

Conclusion: Therefore, the adsorbents are efficient and cost effective in the treatment of heavy metal contaminated water.

Keywords: Wastewater, Heavy metals, Adsorption, Rice husk, Laterite.

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INTRODUCTION

Recent day's quality of water plays a key role in the health and hygiene of society. Environmental pollution is currently one of the most important issues facing humanity [1]. Water pollution by toxic heavy metals through the discharge of wastewater from industrial, agricultural, and domestic sectors is a worldwide problem and a major cause of concern for environmental researchers [2]. Industrial pollution is a major challenge in conserving water, as the contaminants are to be removed before releasing industrial effluent streams to the environment [3].

Heavy metal contamination in ground water is a serious problem in rural and urban India as groundwater is the main source that the community depends on for survival. Heavy metals are elements which have atomic density more than 5. Some toxic heavy metals, such as lead (Pb), cadmium (Cd), nickel, cobalt, chromium (Cr), arsenic, iron, and zinc, cause metal toxicity in living organisms [4]. The release of heavy metal has become a public health concern because of their tendency to accumulate in living organisms and by that they find their way into the human body causing various diseases and disorders [5]. The metals get bioaccumulated in the aquatic environment and tend to be biomagnified along the food chain [6]. All heavy metals are toxic and non-biodegradable and should be separated from wastewater.

The commonly used procedures for removing heavy metals from aqueous streams include chemical precipitation, coagulation, ion exchange, and reverse osmosis [7]. However, these methods have several disadvantages such as high reagent requirement, unpredictable metal ion removal, and generation of toxic sludge [8]. The most efficient and economically feasible process among them is adsorption [9]. Adsorption is very cheap, effective compared to other methods [10]. Natural material that is available in large quantities or certain waste from agricultural operations may have potential to be used as low-cost adsorbents as they represent unused resources, are widely available, and are environmentally friendly [11].

Adsorption is an effective purification and separation technique. Removal of heavy metals and other impurities by adsorption is an emerging field of research. The removal of heavy metals using low-cost adsorbent is found to be more encouraging in extended terms as there are several materials existing locally as natural materials which can be utilized as low-cost adsorbents.

METHODS

Collection and preparation of adsorbent

Laterite

The laterite rock was collected from the Ratnagiri district, crushed into the fine particles, and sieved through the sieve having mesh size <0.002 mm, to get geometric sizes, then the laterite is oven dried at 120°C for 24 h. It was stored in a container for further use.

Rice husk

Rice husk is a layer of cellulose protecting rice grain [12]. Rice husk was collected from the local rice mill and initially washed with distilled water to remove the impurities and then dried in a hot oven at 100°C for 24 h [13]. Prepared adsorbent was stored in the container for further use.

Adsorbate

Heavy metals were chosen in this study, are known for its eco-toxicological hazardous substances and their toxic effects have been of great interest for many years. The heavy metals tested in the present study are Cd, Cr, Pb and Hg. The heavy metal aqueous solution of 100 ppm of each metal was used.

Experimental setup

Batch method was used to study the adsorption [14]. Experiments were carried out in the 250 ml conical flasks. For studying the effect of adsorbent dosage, 100 ml aqueous solution of each selected metal and dosage varying from 1–3 g was mixed in each flask. A retention time of 3 h was maintained after which the solution was filtered through the Whatman filter paper 42 and tested for metal concentration.

Working conditions

The batch experiment was performed in two different conditions. The first condition was at room temperature for maintaining stable condition and another was at shaking condition for 120 rpm.

Analytical method

The final concentration of metals after providing 3 h treatment of adsorbent was determined by atomic absorption spectrophotometer [15]. The percentage of removal of heavy metals adsorption by the adsorbents was computed using the following formula [16]:

$$\text{Percentage removal}(\%) = \frac{Co - Cf}{Co} \times 100$$

Where,

Co = Initial concentration of adsorbate.

Cf = Final concentration of adsorbate.

RESULTS AND DISCUSSION

Effect of the adsorbent dosage

The study was carried out to determine the effect of adsorbent doses on the concentration of heavy metals. Various amounts of the adsorbents ranging from 1 g to 3 g were taken in 100 ml of aqueous solution in a conical flask for 3 h. These samples were filtered and analyzed. As per the results, it is observed that removal efficiency increases with respect to dosage (Figs.1 and 2). In the present study, 3 g per 100 ml is found to be the optimum dose with decrease in the concentration of heavy metals. In rice husk and laterite, it was found that higher doses lead to higher removal efficiency for each metal.

At constant, initial concentration (3 mg/l) and a constant time (48 h) removal of Hg (II) ions with respect to adsorbent dose were 100% [17]. However, the removal efficiency of the adsorbent generally improved with increasing dose [18]. From the results, it was observed that adsorption efficiency or metal uptake varies with the adsorbent dosage [19]. The adsorption dosage has a significant impact on the adsorption because it can influence the total surface area and binding site of adsorbents. The adsorbent dosage is significant factor in adsorption studies because it determines the capacity of adsorbent for a given initial concentration of metal ion solution [7].

Adsorption on rice husk

Rice husk has several characteristics that make it a potential adsorbent with binding sites capable of removing metal from aqueous solution [7]. Low-cost adsorbents from agricultural waste like rice husk were developed with various activation methods and tested for the removal of aqueous contaminants [20]. Rice husk is composed of 32.24% of cellulose, 21.34% of hemicelluloses, 21.44% of lignin, and 15.05% of mineral ash as well as high percentage of silica in its mineral ash, which is approximately 96.34% [21]. It was reported that modified rice husk is a potentially useful material for the removal of Cu and Pb from aqueous solution [22]. Rice husk has higher adsorption affinity for Cu compared to Zn and Fe [23]. It seems that rice husk has proven to be a promising material for removal of contaminants from wastewater, which is really an efficient and economic adsorbent that is effective for the treatment of different heavy metal pollutants from wastewater [24].

Maize cope and husk (493.7 mg/l) and sugarcane bagasse (sodium bicarbonate) (189 mg/g) were having maximum adsorption of heavy metals under industrial wastes [25]. Rice husk can be used to treat Cd in the form of either untreated or modified using different methods such as batch method and continuous flow method [26]. Rice husk capability to adsorb metallic ions is on the active group of CO-, OH-, Si-H, Si-O-Si, and Si-OH [27]. As per the result shown in Table 1, it is found that rice husk is showing high removal efficiency for the removal of Cr, Cd, Pb, and Hg heavy metals. It was found that the adsorption of metals by rice husk decreases in order of Hg>Cd>Cr>Pb (Figs. 1 and 2).

Adsorption on laterite

The laterite due to its porous structure can adsorb the water pollutant including the heavy metals efficiently. The experiment evaluated the heated laterite as a low-cost adsorbent for removal of arsenic (III) from aqueous solution [28]. All the analyzed samples show substantial reduction up to 50% in arsenic content after laterite treatment [29]. The adsorption of heavy metal in coarse grain size laterite and laterite granule is in the same order of effectiveness Ni>As>Pb [30]. As per the results shown in Table 1, it was found that laterite is an efficient adsorbent for the removal of heavy metals. It was found that the adsorption of metals by laterite decreases in order of Cr>Hg>Cd>Pb (Figs. 1 and 2).

Adsorption of Cr

The two common oxidation states of Cr observed in natural water are trivalent Cr(III) and hexavalent Cr(VI). The trivalent Cr is not a significant groundwater contaminant, whereas hexavalent Cr is approximately 100 times more toxic than trivalent Cr [31]. Inhalation of vapors containing Cr(VI) particles affects the respiratory system and causes lung cancer and chronic inflammation of the bronchioles and pulmonary fibrosis [32].

Table 1 shows the removal efficiency of laterite and rice husk for the Cr at stable and shaking condition respectively. As per the observations, the removal efficiency of laterite for the Cr in stable condition was 99.05%, 99.09%, and 99.13% for 1 g, 2 g, and 3 g of adsorbent, respectively. For the shaking condition, the removal efficiency of laterite was 99.07%, 99.11%, and 99.14% for 1 g, 2 g, and 3 g of adsorbent, respectively. As per the observations, the removal efficiency of rice husk for the Cr at stable condition was 93.45%, 95.12%, and 96.07% for 1 g, 2 g, and 3 g of adsorbent, respectively. For shaking condition, the removal efficiency

Table 1: Removal of heavy metals by use of laterite and rice husk at stable and shaking condition

Heavy metal	Quantity of adsorbent (g)	Removal efficiency of laterite (%)		Removal efficiency of rice husk (%)	
		Stable condition	Shaking condition	Stable condition	Shaking condition
Cr	1	98.74±0.497	97.85±1.916	93.63±0.370	94.69±0.420
	2	98.94±0.686	99.41±0.394	95.35±0.349	95.63±0.468
	3	99.32±0.305	99.33±0.328	96.33±0.460	97.63±0.347
Cd	1	77.55±0.431	78.47±0.452	93.61±0.459	94.20±0.219
	2	78.22±0.294	80.01±0.693	94.23±0.208	95.58±0.281
	3	80.24±0.232	82.20±0.182	95.49±0.345	97.03±0.284
Pb	1	61.17±0.144	62.17±0.172	72.31±3.804	74.50±0.426
	2	64.24±0.221	64.59±0.454	71.49±0.335	74.97±0.067
	3	65.37±0.275	65.05±0.074	73.58±0.429	75.17±0.139
Hg	1	84.06±0.103	85.38±0.372	99.16±0.227	99.42±0.302
	2	84.42±0.210	87.52±0.386	99.24±0.220	99.35±0.263
	3	86.19±0.181	88.07±0.117	99.19±0.260	99.45±0.244

Values represented as mean±SD (n=4)

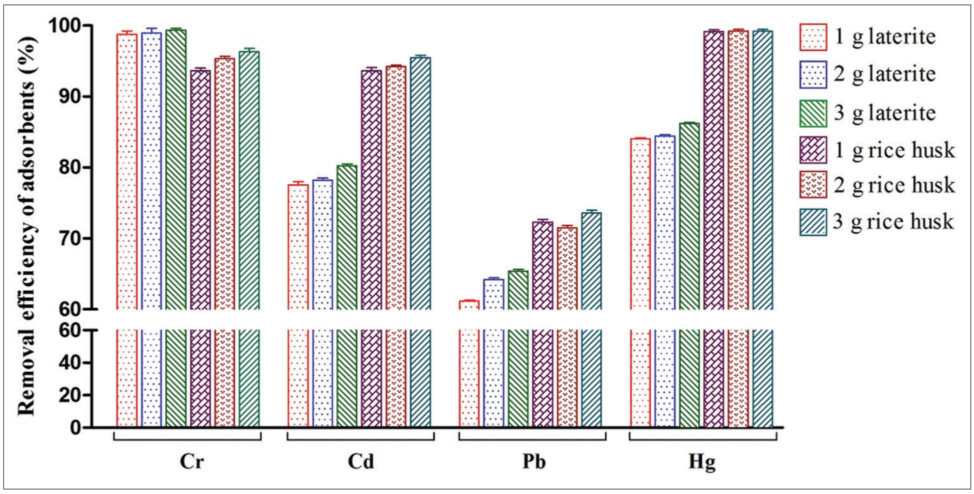

Fig. 1: Effect of adsorbent and its dosage in the removal of heavy metals at stable condition

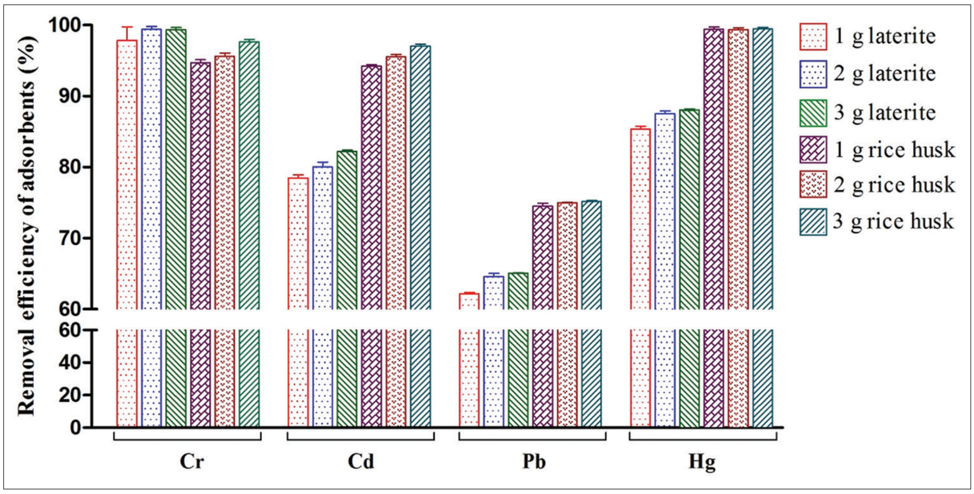

Fig. 2: Effect of adsorbent and its dosage in the removal of heavy metals at shaking condition

of rice husk was 94.66%, 95.97%, and 97.83% for 1 g, 2 g, and 3 g of adsorbent, respectively.

One of the studies investigated the biosorption characteristics of Cr(VI) on raw and modified palm branches [33]. Biosorption of Cr(VI) using fungal, algal, or bacterial biomass (growing, resting, and dead cells) and biological and agricultural waste materials has been recognized as a potential alternative to the existing conventional methods for detoxification of industrial wastewater [34]. Biomass could be considered a promising low-cost bioadsorbent for the removal of Cr(VI) from electroplating and galvanizing industry effluent [35].

Adsorption of Cd

Cd is a heavy metal which is highly toxic to the human, plant, and animal. A number of modified low-cost adsorbents have been projected as potential candidates for removal of Cd from aqueous solution [26]. Cd removal using fly ash varied from 25.21% to 73.54% of efficiency [22].

Table 1 shows the removal efficiency of laterite and rice husk for the Cd at stable and shaking condition, respectively. As per the observations, the removal efficiency of laterite for the Cd in stable condition was 77.76%, 78.09%, and 80.32% for 1 g, 2 g, and 3 g of adsorbent, respectively. For the shaking condition, the removal efficiency of laterite was 78.67%, 80.56%, and 82.43% for 1 g, 2 g, and 3 g of adsorbent, respectively. As per the observations, the removal efficiency of rice husk for the Cd at stable condition was 93.93%, 94.47%, and 95.64% for 1 g, 2 g, and 3 g of adsorbent, respectively. For the shaking condition, the removal efficiency of rice husk was 94.08%, 95.89%, and 97% for 1 g, 2 g, and 3 g of adsorbent, respectively. Moreover, desorption and reusability studies of the biomass of sesame waste showed that it could be considered as a sustainable and useful adsorbent for Cd(II) adsorption at the commercial level [36].

Adsorption of Pb

Table 1 shows the removal efficiency of laterite and rice husk for the Pb at stable and shaking condition, respectively. As per the observations, the removal efficiency of laterite for the Pb at stable condition was 61.22%, 64.33%, and 65.64% for 1 g, 2 g, and 3 g of adsorbent, respectively. For the shaking condition, the removal efficiency of laterite was 62.16%, 64.48%, and 65.07% for 1 g, 2 g, and 3 g of adsorbent, respectively. As per the observations, the removal efficiency of rice husk for the Hg at stable condition was 70.75%, 71.75%, and 73.95% for 1 g, 2 g, and 3 g of adsorbent, respectively. For shaking condition, the removal efficiency of rice husk was 74.64%, 75.02%, and 75.33% for 1 g, 2 g, and 3 g of adsorbent, respectively. The biochar of rice husk, wheat straw, and comcob demonstrated the Pb(II) adsorption capacity of 96.41%, 95.38%, and 96.92% [37]. The maximum percentage removal of Pb(II) ions was 93.36% and 94.8% with adsorbent rice husk and rice husk ash, respectively [38]. Rice husk was the most effective, for which the removal reached 98.15% of Pb at room temperature [11]. The study shown that the activated rice husk is an effective adsorbent for the removal of Pb(II) ions from aqueous solution [39].

Adsorption of Hg

Hg is widely used in industries which produce electrical equipment, paints, pesticides, pulp and paper, domestic thermometers, dental amalgams, and Hg vapor lamps [40]. It is a harmful contaminant as it can affect the central nervous system.

Table 1 shows the removal efficiency of laterite and rice husk for the Hg at stable and shaking condition, respectively. As per the observations, the removal efficiency of laterite for the Hg at stable condition was 84.03%, 84.43%, and 86.21% for 1 g, 2 g, and 3 g of adsorbent, respectively. For the shaking condition, the removal efficiency of laterite was 85.87%, 87.92%, and 88% for 1 g, 2 g, and 3 g of adsorbent, respectively.

As per the observations, the removal efficiency of rice husk for the Hg at stable condition was 99.49%, 99.5%, and 99.52% for 1 g, 2 g, and 3 g of adsorbent dosage, respectively. For the shaking condition, the removal efficiency of rice husk was 99.56%, 99.63%, and 99.69% for 1 g, 2 g, and 3 g of adsorbent dosage, respectively. It was found that the biomass of the fungus Mucor rouxii IM-80, Mucor rouxii mutant, Mucor sp1, and Mucor sp2 was very efficient at removing the Hg in solution (95.3%, 88.7%, 80.4%, and 78.3%, respectively) [41].

CONCLUSION

Aqueous solution of heavy metal was treated using low-cost adsorbents such as laterite and rice husk. The laterite and rice husk are efficient adsorbents for heavy metal removal. Heavy metal removal efficiency increases with the quantity from 1 g to 3 g of dosage. Three grams are optimum quantity for the removal of all the selected heavy metals. Rice husk is more efficient than laterite for removal of Pb Hg and Cd. Laterite is more efficient than rice husk for Cr removal only. In many industries, various methods are used for the removal of heavy metals from industrial effluent which requires high cost, manpower, equipment, chemical, etc. However, use of low-cost adsorbent for the removal of heavy metal is simple, low cost, and efficient. Hence, rice husk and laterite are low cost and potent adsorbent material for water treatment.

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