Removal of Hexavalent Chromium by Adsorption using low-cost Adsorbents and Activated Carbon

Sangeeta[1], Rekha H B[2]

[1]PG Student, [2]Associate Professor, Civil Engineering Department, UVCE, Bangalore University, Bengaluru, Karnataka, India.

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Abstract - *The removal of heavy metal ions from water and wastewater has received a lot of attention. Although the methods that are most frequently used to treat contaminated water are adsorption ones. The current study's objective was to look into the viability of using low-cost natural-material adsorbents in these kinds of technological applications. The percentage removal of hexavalent chromium was evaluated under two process batch and column process. Batch adsorption was carried out with a variety of parameters, including pH, contact time, and adsorbent dose. Rice husk silica in the batch process eliminated a larger percentage of hexavalent chromium, or 64.25%, than rice husk and sawdust. We performed column adsorption with various flow rates and bed heights. Results show that rice husk silica removed 98.08% of the hexavalent chromium better than rice husk and sawdust under the best conditions, which were a lower flow rate (1 mL/min) and a higher bed height (15 cm). When batch and column studies are compared, column studies are favored over batch treatments. Comparing it with activated carbon it was seen to be around 98.32 % where the reduction using the above process shows reduction of 98.08% using the low-cost adsorbent. Thus, the rice husk silica in this study showed a good potential for the removal of hexavalent chromium in both batch and column process.*

Key Words: Rice husk silica, sawdust, hexavalent chromium, column adsorption, batch process, column process.

1.INTRODUCTION

Water being the significant resources of the biosphere as used in day today life, where after use the water is polluted leading to water contamination. Now this is a grave problem, in which wastewater comprising heavy metals continuously released into environment. In few ages, there is significantly upsurge in the ecological and global public health fear associated with aquatic pollution using these metals.

Out of ninety metals, ten metals such as Ni, Co, Mn, Zn, Cr, Cu, Se, Ti, and Sb are prime public concern as per World Health organization (WHO). These metals are available from earth's crust in very low concentration and found in their metallic, elemental form or chemical bounded with other inorganic materials like carbonate, sulphate, oxide or rock. Metal is considered as a one of the potential pollutants after dye, as it is lethal even at very low concentrations, last long effect, and persistent nature non-biodegradable. Due to their highly solubility in aquatic environments, heavy metals are spontaneously immersed by fishes and vegetables. When these metals are encounter human, they are penetrating our body by water, air, food or absorption through skin. (Himanshu Patel, 2020)

Chromium is a typical pollutant that is discharged into natural waters as a result of various industrial wastewaters. On the other hand, chromium-based catalysts are also typically used in a variety of chemical processes, such as selective hydrocarbons being oxidized. As per the World Health Organization (WHO), According to drinking water regulations, 0.05 ppm of total chromium is the highest permissible level. mgl−1. (Mojdeh Owlad, 2008) The metal chromium, which is the chromium (0) form, is used for making steel. Chromium (VI) and chromium (III) are used for chrome plating, dyes and pigments, leather tanning, and wood preserving. (Mojdeh Owlad, 2008)

Removal of Chromium (VI) ions from industrial wastewater is achieved principally by the application of several conventional processes such as reduction followed by chemical precipitation, absorption, activated carbon, electrochemical processes, ion exchange, biological operations, catalytic oxidation, and membrane processes. These methods require large amounts of chemical substances and energy, generation of toxic sludge, fouling, high capital and operational costs, expensive equipment requirement and efficient monitoring system, (Sivakumar, 2015). The need of safe and economical methods for the removal of heavy metal ions from contaminated water has developed interest towards the Adsorption process with low-cost adsorbents (Naba kumar, 2014).

2. MATERIALS AND METHEDOLOGY

The rice husk is a byproduct in rice mill. The rice husk is selected as one of the adsorbents for the removal of chromium. The rice husk is collected from the rice mill in Devadurga Raichur district. The sawdust is a byproduct of wood working operations in sawmill. The sawdust is also considered as adsorbent for the removal of chromium. The sawdust is collected from the sawmill in Devadurga Raichur district. Activated carbon is product from carbonaceous sources materials such as coconut, nutshells, coal and wood. All the chemicals used were analytical reagent grade.

Potassium dichromate was used for preparation of stock solutions. Hydrochloric acid and sodium hydroxide were used to adjust the solution pH. Formaldehyde was used for preparation of adsorbent. Diphenyl carbazide was used for determination of chromium as per standard methods for the examination of water and wastewater. Distilled water was used throughout the experimental studies.

2. 1 ADSORBENT PREPARATION

To create a homogenous combination, the rice husk that was taken from the rice mill was combined. Then, to remove mud and filth, a homogeneous combination of rice husk was thoroughly washed with tap water. 100 g of the thoroughly cleaned rice husk were mixed with 1 litre of 1.0 M HCl, and the mixture was then heated for two hours to 100 °C. The treated rice husk was rinsed in tap water to remove any last residues of HCl acid after the 2-hour reaction. It was then dried for 24 hours at 130 °C in the oven. Rice husk ash, which is black in color, was made during this time period from rice husks. To get silica, the rice husk ash was additionally roasted for 6 hours at a temperature of 650 °C. (Shivakumar et al 2015).

A rice mill provided the rice husk. 500 grammes of rice husk were washed in water several times, dried at 60 degrees for 24 to 48 hours, and then kept at room temperature for further research. To fit through a 1 mm filter, rice husk was crushed. As depicted in fig. 3.2, (Sobhanardakani et al. 2013).

The sawdust used in this experiment was collected from a local sawmill and dried in sunlight until almost all the moisture evaporated. It was ground to a fine powder and sieved to 125–250_m size. Sawdust contained water-soluble compounds like tannin, which gave brown color to the effluents during the treatment. Chemical treatment with formaldehyde led to polymerization of the compounds responsible for colorization. Sawdust (50 g) was washed repeatedly with distilled water and subsequently dried for 24 h at 233K to washout the coloring materials. To improve upon the physical characteristics further, it was treated with 1% formaldehyde in the ratio of 1:4 (sawdust: formaldehyde, w/v) and 100 ml of 0.2N H_2SO_4. It was heated with cover-over hotplate at 323K for 6 h with occasional stirring. The product was cooled and washed several times with distilled water and finally dried at 333K to eliminate all toxicity due to the presence of formaldehyde. (Saroj Baral et al, 2006)

2. 2 METHOD USED FOR ADSORPTION PROCESS FOR CHROMIUM (VI) REMOVAL

Batch process and fixed column bed process were used for adsorption process. The experiment was carried out in the Environmental Laboratory of Civil Engineering Department, UVCE, Bangalore University Jnanabharathi campus, 560056.

In Batch Process a pre-determined amount of adsorbent is mixed with the sample, stirred for a certain time and subsequently separated by filtration.

An uninterrupted flow of chromium (VI) solution was passed to the columns by gravity. The discharge from the column is collected in a container below and analyzed for the chromium (VI) concentration.

3 RESULTS AND DISCUSSION

The contact time has an influence in the removal process as it can be observed that at a certain time the adsorption process is higher and after this time there is reduction in the adsorption of the metal. This was probably due to the availability of a larger surface area over this stage of the adsorption process. However, as the number of available surface adsorption sites diminished, the uptake rate was controlled by the rate at which the adsorbate was transported from the exterior to the interior sites of the adsorbent particles (Shivakumar et al, 2015).

The effect of dosage is important as increase in dosage increases the removal percent this may occur due to the fact that the higher dose of adsorbents in the solution provides the greater availability of exchangeable sites for the ions. This result also suggests that after a certain dose of adsorbent, the equilibrium conditions reached the number of ions bound to the adsorbent and the number of free ions in the solution remain constant even with further addition of the dose of adsorbent (Sobhanardakani et al, 2013).

The effect of pH is important as increased in pH from 1 to 4 increases the removal percentage later further increase from 5 to 8 leads to decrease in removal percentage because at low pH hydrogen was not allowing the ion to adhere with binding sites, at high pH becomes basic released more hydroxyl groups making basic as a result ion was not adhering into binding sites (Ahmed El Nemr et al, 2007).

Table -1: Removal percent of chromium by Batch and Fixed Bed Column process for rice husk silica, rice husk, saw dust, activated carbon

Adsorbent	**Rice husk silica**	**Rice husk**	**Saw dust**	**Activated carbon**
Batch process	64.25%	52.65%	57.85%	82.65%
Column process	98.08%	95.95%	96.35%	98.32%

The flow rate has an influence in the column process where it is inversely proportional to the removal. Because when the flow rate increases which leads to lowered time of contact between the adsorbent and the chromium solution. (Sobhy yakout et al, 2019)

The bed height also has a greater influence in the column process where grater the bed height the removal is greater. This is due to the availability of specific surface area. (Tedi Hudaya et al, 2018)

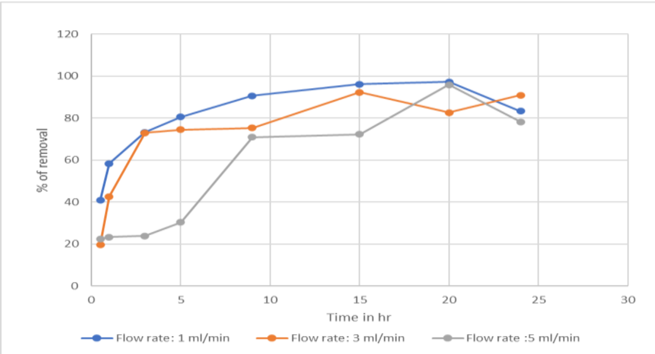

Chart -1: Effect of Flowrate: on rice husk silica with Flow rate 1,3,5 ml/min in removal of chromium (VI)

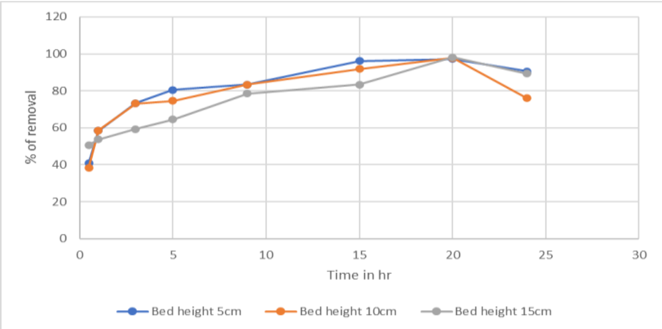

Chart -2: Effect of Bed height: on rice husk silica with Bed height 5, 10, 15cm in removal of chromium (VI)

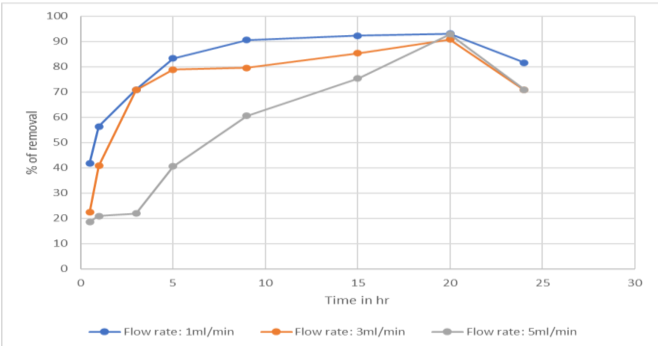

Chart -3: Effect of Flowrate: on rice husk with Flow rate 1,3,5 ml/min in removal of chromium (VI)

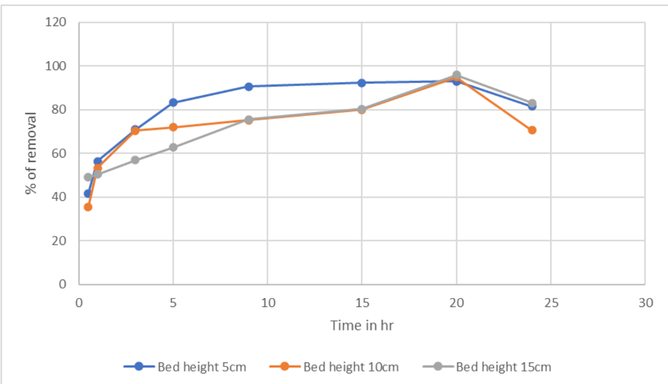

Chart -4: Effect of Bed height: on rice husk with Bed height 5, 10, 15cm in removal of chromium (VI)

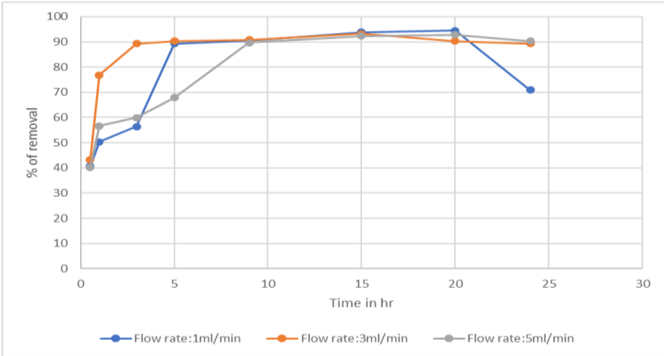

Chart -5: Effect of Flowrate: on Sawdust with Flow rate 1,3,5 ml/min in removal of chromium (VI)

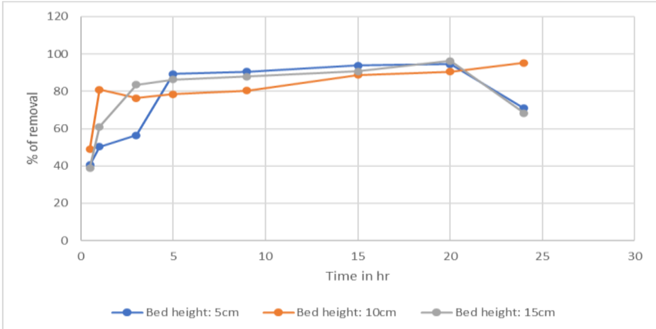

Chart -6: Effect of Bed height: on Sawdust with Bed height 5, 10, 15cm in removal of chromium (VI)

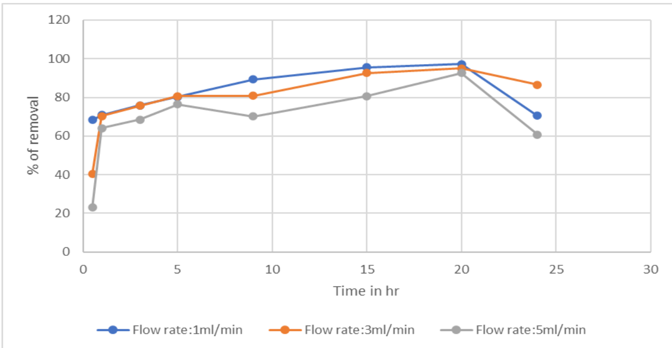

Chart -7: Effect of Flowrate: on Activated carbon with Flow rate 1,3,5 ml/min in removal of chromium (VI)

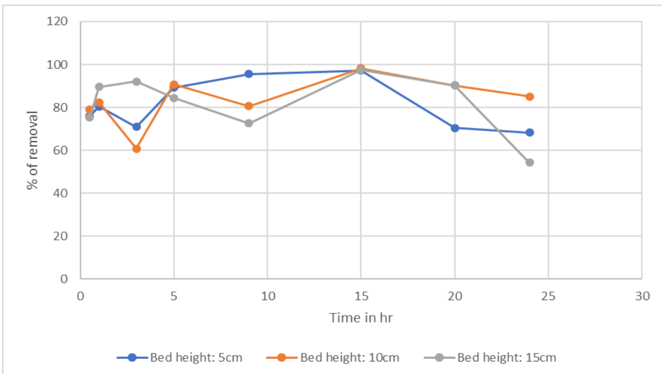

Chart -8: Effect of Bed height: on Activated carbon with Bed height 5, 10, 15cm in removal of chromium (VI)

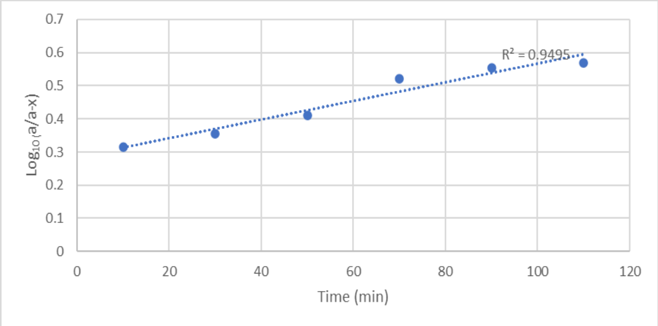

Chart -9: Reaction rate constant of chromium (VI) adsorption for rice husk silica

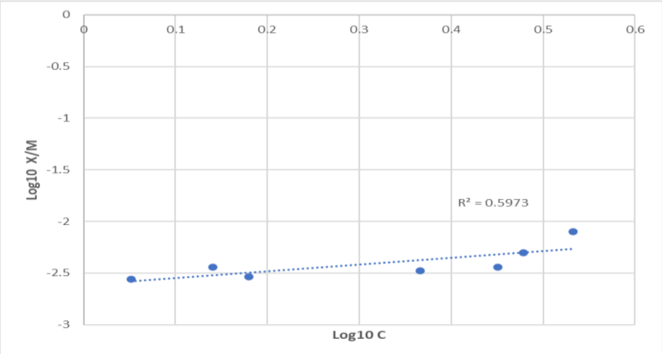

Chart -10: Plot of Freundlich Isotherm

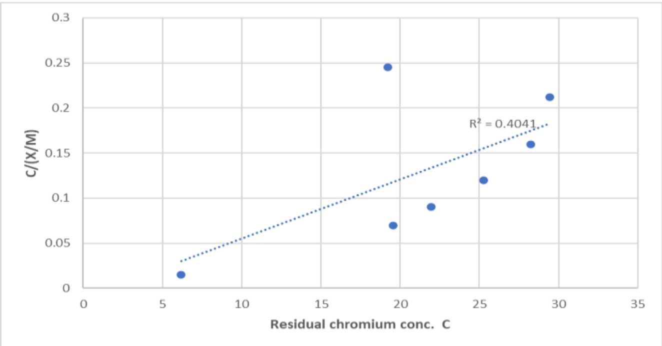

Chart -11: Plot of Langmuir Isotherm

4. CONCLUSIONS

BATCH PROCESS

1. Rice husk silica removal efficiency was 64.25%, with optimum condition being 90min contact time, 2gm dosage and pH 4.
2. Rice husk removal efficiency was 52.65%, with optimum condition being 90min contact time, 2gm dosage and pH 5.
3. Sawdust removal efficiency was 57.85%, with optimum condition being 50min contact time, 2.5gm dosage and pH 3.
4. Activated carbon removal efficiency was 82.65%, with optimum condition being 70min contact time, 2gm dosage and pH 2.

COLUMN STUDY

1. Rice husk silica the removal efficiency was 98.08% for 1mL/min with 15cm bed height.
2. Rice husks the removal efficiency was 95.95% for 1mL/min with 15cm bed height.
3. Saw dust the removal efficiency was 96.35% for 1mL/min with 15cm bed height.
4. Activate carbon the removal efficiency was 98.32% for 1mL/min with 15cm

On comparing both the batch and fixed bed column process the column process gave higher removal of chromium. The rate of adsorption of chromium (VI) obeys first order rate equation. The result fallows Freundlich isotherm indicating single layer adsorption of chromium (VI) and proves to be a favorable adsorption. But it does not obey the Langmuir isotherm.

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