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Paper Study on Column Adsorption

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Preface

Pollution due to lead contamination in the water stream has become a serious problem nowadays. Lead poisoning causes several types of damage to human health such as kidney, nervous system, liver, and brain damage that can lead to death. Major sources from where the lead is discharging are mining wastes, chemical industries, lead acid storage batteries, and ceramic and glass industries. Environmental Protection Agency (EPA) has given some standard for drinking water which is 0.05 mg/L.

Therefore, in order to reduce the harmful effect of lead contamination in the environment, it is necessary to treat the lead contaminated wastewater before discharge. Many types of treatment system like ion exchange, coagulation, chemical precipitation, membrane filtration, electrodeposition, solvent extraction, and adsorption have been proposed for lead removal from the lead contaminated wastewater. Among all the methods for removal of lead ion adsorption is apparently the most efficient method, due to its simplicity, higher removal capacity, and low operating cost. Numerous adsorbents like green coconut shells, wheat bran, cortex fruit wastes, agave bagasse, and modified Agarics Bosporus have been used to remove the lead ion from aqueous solutions. Most of the adsorption experiment is limited to batch experiments which do not give accurate scale-up data that can be used for large scale of treatment.

The objective of this study was to evaluate the performance of the chemically carbonized rubber wood sawdust (CRSD) column for the removal of lead ion from the lead contaminated waste stream. Dynamic behaviour of fixed-bed column was described in terms of breakthrough curve. As part of this study, effects of bed depth, flow rate, and initial feed concentration on the performance of lead adsorption onto CRSD were investigated. Different models such as Thomas, Yoon-Nelson, and Adams-Bohart models were used to compare the experimental data.

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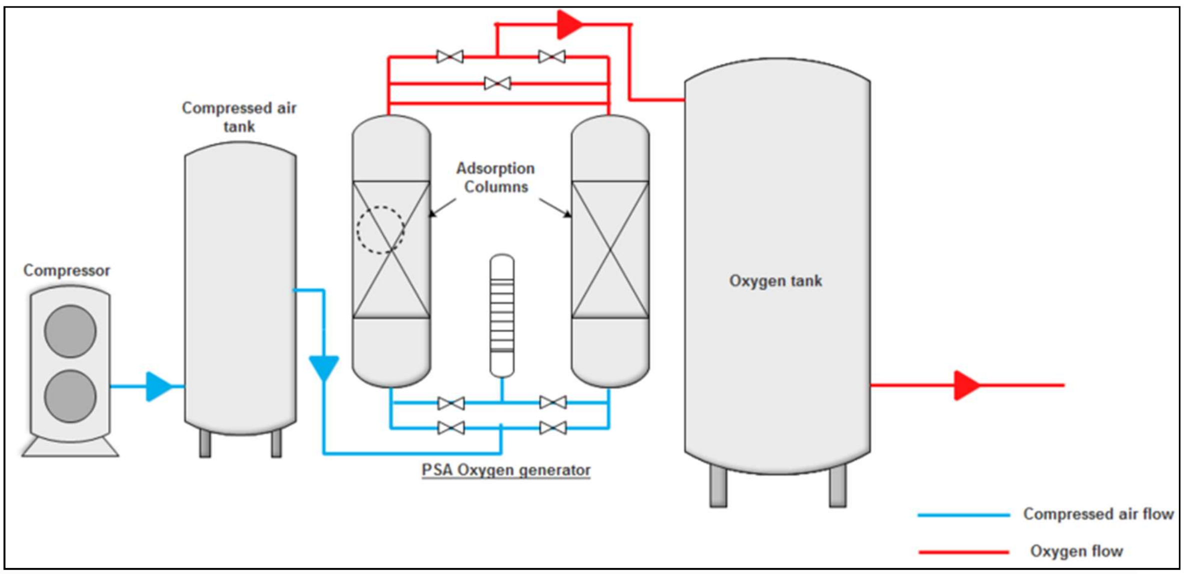
Introduction

The “adsorption” was suggested by Bois-Reymond but given into the world by Kayser, which is defined as an increasing concentration of a specific compound at the surface of interface of the two phases. These specific compounds are transporting from one phase to another and thereafter adhered into surface. It is considered to be a complex phenomenon and depends mostly on the surface chemistry or nature of the sorbent, sorbate and the system conditions in between the two phases. It is the most inexpensive and efficient process for treatment of water or wastewater; therefore, it has been widely used for the removal of solutes from solutions and harmful chemicals from environment. It required less investment in terms of the initial cost and land, simple design, no other toxic effect and superior removal of organic waste constituent, compared to the other conventional treatment in water pollution control.



In adsorption process, there is higher concentration of materials at the surface or interface between the two phases, it is called interphase accumulation. The substance which is being adsorbed on the surface of another substance is called adsorbate. The substance, present in bulk, on the surface of which adsorption is taking place is called adsorbent. The interface may be liquid–liquid, liquid–solid, gas–liquid or gas–solid. Of these types of adsorption, only liquid–solid adsorption is widely used in water and wastewater treatment. Following four steps are considered, in which solute (adsorbate) is moved toward the interface layer and attached into adsorbent-

1. **Advective transport:** solute particles are moved from bulk solutions onto immobile film layer by means of advective flow or axial dispersion or diffusion.

2. **Film transfer**: solute particle is penetrated and attached in immobile water film layer.

3. **Mass transfer**: attachment of solute particle onto the surface of the adsorbent

4. **Intraparticle diffusion:** Movement of solute into the pores of adsorbent

Mainly two types of adsorption are occurred. Physical sorption is occurred due to weak Van der Waals attraction forces. This sorption is reversible in nature with low enthalpy values, about 20 kJ/mol. Here, wear attractive forces are available between adsorbed molecules and the solid surface weak in nature. Therefore, adsorbed molecules are liberated to travel over the surface, as these molecules are not stuck to a particle side on the adsorbent surface. The electrostatic forces include dipole–dipole interactions, dispersion interactions and hydrogen bonding available among the adsorbate–adsorbent in physical sorption. When there is a net separation of positive and negative charges within a molecule, it is said to have a dipole moment.

Whereas, chemical bonding between sorbate and sorbent molecule takes place in chemisorption. Therefore, this sorption is irreversible in nature and has high enthalpy of sorption than physical sorption 200 kJ/mol. Stronger electrostatic forces such as covalent or electrostatic chemical bond play a vital role in attraction between sorbent and sorbate. This bond is shorter in bond length and has higher bond energy.

The adsorbent is broadly divided into three classes:

1. **Synthetic adsorbent**: Various porous materials are synthesized in laboratory using different processes, which have high adsorption capacities. Disadvantage is that this process of manufacturing is comparatively costly.

2. **Natural adsorbent**: Natural materials like plant root, leaf and agricultural waste are dried, crushed, sieved, again washed with distilled water and used as adsorbent for treatment of real as well as synthetic wastewater. This process is cheap, but adsorption capacity is comparatively low.

3. **Semi-synthetic adsorbent:** Natural materials undergo chemical as well as physical activation to develop highly porous surface. The major advantages of this adsorbent include: low cost, high efficiency, minimization of chemical or biological sludge, no additional nutrient

requirement and regeneration of absorbent and possibility of metal recovery.

The properties of the adsorbent are identified by different analytical techniques such as Fourier transform infrared spectroscopy (FT-IR), scanning electron microscopy (SEM), X-ray diffraction (XRD), porosity, pore diameter, pore volume and surface area analysis. FT-IR technique determines the chemical composition by investigating the function group. SEM investigates the morphology of adsorbent. XRD provides information on the crystallographic structure of the material.

An adsorbate is any substance that has undergone adsorption on the surface. In environmental chemistry, adsorbate is considered as pollutant or compounds contributing to the pollution, which adhered in porous adsorbent and easily removed. The various types of water pollutants can be classified into following major categories:

1. Organic pollutant, which includes oxygen demanding waste, oil, sewage and agricultural waste, synthetic organic waste, disease causing wastes

2. Inorganic pollutant, which contains inorganic salts, mineral acids, finely divided metal compounds, trace metals, etc.

3. Sediments, which are soil and minerals particles that are washed away from land by flood waters.

4. Thermal pollution, in which higher temperature is considered as pollutant.

5. Radioactive pollutants are pollutants that have a radiological hazard, its sources might be natural, accidental release of radio contaminant, historical releases due to military tests and/or historical discharge

Each pollutant has different adverse effect. These pollutants are hazardous into mankind, aquatic life and other ecological constitutions.

Process Parameter for Column Study

Most of the adsorption studies were conducted on synthetic wastewater as adsorbate, in which metal or dye solution is prepared and treated with adsorbent. Effect of various process parameters like the initial adsorbate concentration, flow rate of adsorbate in column, bed height of column, pH of adsorbate, particle size of adsorbent and temperature of system were performed and breakthrough and exhaust points were measured. All these parameters are importance for evaluating the efficiency of adsorbent in a continuous treatment process of effluents on the pilot or industrial scale.

1. **Initial adsorbate concentration (IAC):** Breakthrough and exhaustion points are occurred earlier with increasing influent concentration. And thereafter breakpoint time decreased with increasing the inlet concentration.

2. **Flow rate of adsorbate (FRA):** Breakthrough points generally occur faster with higher flow rate. Saturation of breakthrough time is increased significantly with a decrease in the flow rate.

3. **Bed height of column (BHC):** Breakthrough and exhaustion times are slower with increasing bed depth. Also, it was found that the volume of effluent treated increased with increasing the bed depth.

4. **pH of adsorbate (pH):** In some case, highest removals are found at acidic pH and maximum removals of some adsorbate are found at alkaline pH.

5. **Particle size of adsorbent (PSA)**: Breakthrough and exhaustion times are slower with increasing particle size of adsorbent. Maximum particle size is favoured to get better adsorption capacity. But, moderate flow rate is preferred for industrial applications.

6. **Temperature (*T*):** Breakthrough and exhaustion times are slower with increasing temperature of system. But, adsorption capacity decreases with the increasing temperature.

Out of these parameters, initial adsorbate concentration, bed height and flow rate are most feasible parameters, as most of researchers are recently working on these parameters and utilized to remove various types of pollutants like dyes, metal, hazardous waste, etc. using natural and synthetic adsorbents.

Adsorption of Metal and Ion

Earth's crust is constituent of metal and other parts, but random human activities have significantly changed their geochemical cycles and biochemical balance. This results in accumulation of metals in plant parts having secondary metabolites, which is responsible for a particular pharmacological activity. Prolonged exposure to heavy metals such as cadmium, copper, lead, nickel and zinc can cause deleterious health effects in humans. Various scientists have being tried to remove metals and its ions using adsorptive column treatment.

Comparison of batch and column treatment for removal of nickel(II) and copper(II) using chemically modified *Cucurbita moschata* was exploited, which indicated column treatment is more feasible than batch process. Series of synthetic solutions of cadmium(II), copper(II), lead(II) and zinc(II) were prepared and tried to remove using chemically modified multi-metal-binding biosorbent (MMBB) in packed bed column.

Adsorption of Dye

Dyes usually have a synthetic origin and complex aromatic molecular structures which make them more stable and more difficult to biodegrade. Degradation of dyes is typically a slow process. The removal of color is needed to be considered in the disposal of textile wastewater obstruction of penetration of dissolved due to aesthetic deterioration as well as the oxygen and sunlight into water bodies, which seriously affects aquatic life. Besides, the dye precursors and degradation products are proven carcinogenic and mutagenic in nature. Consumption of dye-polluted water can cause allergy reactions, dermatitis, skin irritation, cancer and mutation both in babies and matures.

Some of the die removal using column adsorption studies can be depicted in the following tabular form:

Dye adsorbate	Adsorbent	Operation parameters	Column isotherm investigated	Thomas maximum adsorption capacity
Malachite green (MG)	NaOH-modified rice husk	pH, initial concentration, flow rate and bed height	Thomas Model, Bed Depth Service Time Model, Adam and Bohart Model and Yoon-Nelson Model	101.31 mg/g
Methylene blue	Waste watermelon rind	Initial concentration, flow rate and bed height	TM, BDST and ABM	113.5 mg/g
Acid yellow 17	Tamarind seed powder	Initial concentration, flow rate, pH and bed height	TM, YHM, BDST and ABM	978.5 mg/g
Methylene blue	Pine cone	Initial concentration, flow rate and bed height	TM, BDST and YNM	55.68 mg/g
Methylene blue	NaOH-modified rice husk	Flow rate and bed height	TM, BDST and YNM	101.3 mg/g
Malachite green (MG)	NaOH-modified rice husk	pH, initial concentration, flow rate and bed height	TM, BDST, ABM and YNM	101.31 mg/g
Allura red AC, tartrazine and sunset yellow FCF	Glass bead-coated chitosan	pH and bed height	TM, BDST and YNM	29.8, 75.1 and 65.6 mg/g
Methyl blue	Biochar and Kaolin	Initial concentration, flow rate and bed height	TM, BDST and YNM	20.06 mg/g

Challenges for Utilisation

1. As industry is always demanded for low cost, lower discharge, environmental friendly, easily available material usage and least spacious for effluent treatment plant, and most of plant consists of biological treatment as a tertiary treatment due to its vast feasibility; the main disadvantages of any adsorption are that the high price of treatment and difficult regeneration. It also produced solid waste of exhausted adsorbent.

2. Column adsorption studies are considered as better adsorption due to reasonable advantages, but challenge for column adsorption is that as fluid is passed through the fixed bed of solid adsorbents, initially transfer of adsorbate from the feed fluid occurs at the bed entrance. As feed fluid is continuously passed toward the column, MTZ progressively move through the bed once the adsorbent in a region becomes saturated with the adsorbate molecules. After particle time duration, the adsorbent particles upstream or downstream of the MTZ do not participate in the mass-transfer processes, and thus, adsorption process of removing the adsorbate (pollutants) is congested. Thereafter adsorbent must be replaced or regenerated. Fixed-bed column adsorption has facing other problems of poor temperature controller, undesirable heat gradients, un-wanted chemical reactions, channelling and difficult to clean.

3. For proper industrial prospective, series of column should be attached for better adsorption results. Other factors such as column containing multiple adsorbents, numerous adsorbate system and also their appropriate ratio are to be considered.

4. All the experiments are being accomplished using synthetic wastewater of metal, dye and other contaminations including pharmaceutical products in the continuous fixed-bed column studies by various researchers. But, real industrial like textile, dyeing, electroplating, tanning, paper, etc. effluent must be considered for the removal of components contributing the COD, BOD, colour and other parameters. Furthermore, regeneration studies and desorption step modelling must be conducted.

Quick Highlights and Conclusion

1. Column (or fixed-bed) system consists of a adsorbent in which adsorbate is continuously flowed through a bed of adsorbent at constant rate.

2. It is very easy and cheap technique.

3. It is used for higher quantity of wastewater having higher pollution load.

4. It is also widely used for industrial purpose, because the adsorbate is continuously in contact with a given quantity of fresh adsorbent in fixed-bed column system.

5. The problems associated with this sorption are adsorbent attrition, feed channelling, and non-uniform flow of adsorbent particles.

6. Forceful interaction is conducted in continuous fixed-bed systems to reduce space and time. As a result, it is difficult to carry out a priori design and optimization of fixed-bed columns without a quantitative approach.

We conclude that fixed-bed column studies for removal of various contaminations from synthetic wastewater are still in the very infancy. This project comprised of adsorption, its types and mechanism, types of adsorbent, adsorbate and adsorption study. Column study is better, easy, simple, economical and feasible for industrial for removal of various contaminations including dye, metal and other hazardous waste. Numerous process parameters are known to have important influence on this phenomenon: initial concentration of adsorbate, flow rate, bed height, pH, particle size of adsorbent and temperature.

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