Removal of heavy metal (phenol) by using various adsorbents

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Abstract : There are many methods such as adsorption, microbial degradation, chemical oxidation, precipitation, ion exchange and solvent extraction to remove phenols from aqueous solution. This paper presents review on removal of phenol by using various adsorbents like Ground nut shells, Peanut shells, cashew seed shells, leaf filter, Coconut shell carbon, silica gel ,activated alumina, polymeric resins, activated carbon, rice husk, zeolite, mango peels, tamarindus indica wood, Tea waste, hycinthe, date stone activated carbon, pineapple peels, sawdust. Effects of various parameter like pH, initial concentration, particle size have been studied by various researchers. In most of the cases Langmuir and Freundlich isotherm studies carried out by investigators.

Keywords - adsorbent, phenol, adsorption , isotherm, pH

I INTRODUCTION

Phenols are common contaminants in wastewater generated from oil, gasoline, coal, paper, textile, petroleum, petrochemicals, pharmaceuticals. They are considered one of the priority pollutants in wastewater because they are harmful to organisms even at low concentrations. Many phenols have been classified as hazardous pollutants because of their potential toxicity to human health. Human consumption of phenol contaminant water can cause severe pain leading to damage of the capillaries ultimately causing death. Their presence in water supplies is noticed as bad taste and odor. In the presence of chlorine in drinking water, phenols form chlorophenol, which has a medicinal taste and which is quite pronounced and objectionable so Environmental Protection Agency regulations call for lowering phenol content in wastewater to less than 1 mg/L. Adsorption is an effective separation process for treating industrial and domestic effluents.

2 TYPES OF ADSORBENTS

2.1 COCONUT SHELL CARBON

Sunil J.Kulkarnia ,Ravi W.Tapre et.al (1) have reported Adsorption of Phenol from Wastewater in Fluidized Bed Using Coconut Shell Activated Carbon used as an adsorbent. The adsorption is carried out in a fluidized bed. They studied effect of various parameters like concentration, fluid flow rate and adsorbent particle size. They observed that as the concentration increases the percent saturation of adsorbent increases. Also increase in fluid flow rate gives better adsorption in case of coconut shell activated carbon. They observed that percent saturation of adsorption decreases with increases in particle size of adsorbent. It was found that percentage saturation increases with increase in initial concentration of phenol and flow rate. Particle size also found to affect the adsorption operation. Preparation of high-surface-area activated carbons from coconut shell was tried by Zhonghua Hu et.al (2) Coconut shell has been converted to activated carbon through chemical activation with KOH. The removal capabilities were found to be 206, 267 and 257 mg/ g for phenol, 4-chlorophenol and 4- nitrophenol respectively.the properties of carbon produced were dependent on impregation ratio and activation temperature**.** Preparation of activated carbon from coconut husk Optimization study on removal of 2,4,6-trichlorophenol using response surface methodology was tried by I.A.W.Tan et.al (3). They studied effect of three activated carbon preparation variables which were the activation temperature, activation time and chemical impregnation ratio on the 2,4,6-TCP uptake and activated carbon yield. They found surfaces derived from the models KOH char impregnation ratio significant effect on 2,4,6-TCP uptake whereas activation temperature showed the most significant effect on activated carbon yield.

2.2 SAWDUST

Jadhav et.al (4) have carried out research on removal of phenol from wastewater using sawdust, polymerized sawdust and sawdust carbon. They investigated adsorption of phenol on sawdust, polymerized sawdust and sawdust carbon and the possible use of these adsorbents for the processing of phenolic wastewater. They studied various factors such as initial concentration, agitation speed, and amount of adsorbent, temperature and pH on the adsorption capacity. The percentage removal of phenol is observed to increase with the increase in initial concentration of phenol. With increase in temperature the adsorption of phenol decreases indicating exothermic nature of the reaction. Adsorption isothermal data could be interpreted by the Langmuir and Freundlich equations.

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Removal Of Phenol From Industrial Wastewater Using Sawdust have carried out by Ihsan Habib Dakhil (5). Sawdust used as an adsorbent for removal of phenol from wastewater. they studied effects of initial phenol concentration, adsorbent dosage, pH value and contact time on the adsorption process. the equilibrium isotherms Langmuir and Freundlich models were determined using the optimum conditions selected from the statistical design of experiments.

Sawdust as an adsorbent have carried out by Larous et.al (6). They observed that carbonized sawdust shows good adsorption capacity to remove phenol from wastewaters. They found adsorption of sawdust dependant on temperature, pH, initial concentration of adsorbate. Adsorption of phenol increases with increase in temperature then decreases. Freundlich and Langmuir adsorption models were studied.

2.3 RICE HUSK

Potential of Rice Husk and Rice Husk Ash for Phenol Removal in Aqueous Systems was tried by Mahvi et.al(7).they investigated ability of rice husk and rice husk ash to bind phenol as a function of pH and initial phenol concentration. Rice husk and rice husk ash adsorption capacity were strongly dependent on the pH of the solution. The sorption capacity was decreased with an increase in the pH and an increase in the initial phenol concentration. rice husk ash had a higher adsorption capacity (0.886 mg/g) for phenol. Freundlich and Langmuir adsorption models expressed the sorption phenomena of phenol to the rice husk and its ash. The adsorption of phenol onto both the sorbents follows first-order kinetics. They found that model parameters useful for fabrication and designing of wastewater treatment plants. They concluded that rice husk and its ash used as low-cost, natural and abundant sources for the removal of phenol.

Removal of Phenol from Aqueous Solutions using Rice Husk Ash was tried by Samah B. Daffalla et.al (8). They investigated feasibility of rice husk ash as adsorbent for removal of phenol from aqueous solution. They observed adsorption capacity of the sorbent was affected by burning time of rice husk, pH and initial phenol concentration. They concluded that that RHA300 was promising adsorbent for removing phenol from aqueous solution. Using RHA300 as adsorbent, the maximum uptake of phenol took place at pH 4. They also concluded that the sorption capacity of RHA300 increased from 0.96 to 45.2 mg g^{-1} when the initial phenol concentration was increased from 10 to 1000 mg l^{-1}.

Pushpa Jha (9) investigated rice-husk as an adsorbent for phenol removal. activated rice-husk char as sorbent for phenol sorption from effluents. They observed that at residual phenol concentration of 8000mg/l, sorption capacity of activated char is 150mg.of phenol/g of char. Equillibrium isotherm for sorption of phenol got fitted into Freundlich Isotherm.

2.4 TAMARINDUS INDICA WOOD

Removal of phenol from dilute aqueous solutions in a multistage bubble column adsorber using activated carbon prepared from Tamarindus indica wood was tried by Suneel kumar et.al (10).they carried out activated carbon prepared from Tamarindus indica wood by chemical activation of zinc chloride was used as the adsorbent for removal of phenol in a multistage bubble column adsorber. preparation and characterization of activated carbon showed that carbonization time and temperature are the two most important parameters that affect the quality of activated carbon. The maximum BET surface area and pore volume obtained at optimum conditions are 540 m3/g and 0.42 cm3/g. they found that the contact time, activated carbon loading, and superficial gas velocity are the three most important operating parameters that affect phenol removal. The equilibrium contact time and activated carbon loading for this system were found 160 min and 1 g/lit which were much lower compared to that of batch adsorption studies. They also found that the adsorption mechanism of phenol removal on activated carbon was physico-chemical adsorption. Effect of adsorbent dose, contact time, and superficial gas velocity enhances the removal efficiency.

2.5 DATA STONE

Mohamed L. et.al (11) have carried out research on preparation and characterization of an activated carbon from a date stones variety by physical activation with carbon dioxide .they investigated valorize a local byproduct of date stones (Ghars) as an adsorbent of a potent phenolic derivative compound 4-chlorophénol.

They found BET surface areas ranging from 502 to 604 m^2/g and a ratios of micropore volumes to the total pore volume ranging from 0.76 to 0.85. The obtained adsorption Capacity lies between 23.25 and 28.57mg/g.

They also found that variety of stone dates presents an interesting adsorptive proprieties and used as support in heterogeneous catalysis.

S.M. Anisuzzaman et.al (12) have carried out research on study on dynamic simulation of phenol adsorption in activated carbon packed bed column. They investigated that dynamic simulation of phenol adsorption within the packed bed column filled with activated carbon derived from dates' stones. The process parameters such as column length, inlet liquid flow rate, initial phenol concentration of feed liquid and characteristics of activated carbon for the small scale packed bed adsorption column were investigated based on the dynamic simulation results using

Aspen Adsorption V7.1 simulation program. They studied relationship between inlet liquid feed flow rate, breakthrough time and saturation time, relationship between initial phenol concentration, breakthrough time and saturation time, and relationship between packed bed column height, breakthrough time, saturation time, and C/Co ratio were studied.

2.6 ZEOLITE

Modeling the Removal of Phenol by Natural Zeolite in Batch and Continuous Adsorption Systems was tried by Shahlaa E. Ebrahim (13). natural zeolite for adsorbing phenol was investigated in fixed bed system. an experimental programme was designed and performed using different phenol concentrations, flow rates, bed depth and different solution temperatures. The experimental results obtained from varying concentration, flow rate and bed depth were compared with those obtained from theoretical formulation of the Homogenous Surface Diffusion Model which includes film mass transfer and surface diffusion coefficient.

2.7 SILICA GEL

Removal of phenol from aqueous solutions by adsorption was carried out by Roostaei N et.al (14.) They studied liquid-phase adsorption of phenol from water by silica gel, HiSiv 3000, activated alumina, activated carbon, Filtrasorb-400, and HiSiv 1000. Experiments were carried out for the analysis of adsorption equilibrium capacities and kinetics. Results of kinetic experiments indicated that HiSiv 1000 had the highest rate of adsorption among the adsorbents studied . They found particle size, temperature, and thermal regeneration on adsorption of phenol by HiSiv 1000. They also found from particle size experiments that adsorption capacity of HiSiv 1000 did not change by changing the particle size, but the rate of adsorption decreased considerably by increasing the particle size. They studied effect of temperature on adsorption by determining equilibrium isotherms for HiSiv 1000 at 25, 40, and 55 ^{0}C. The results showed that adsorption capacity decreased with increasing temperature. Thermal regeneration of HiSiv 1000 was performed at 360 ^{0}C. they observed that adsorption capacity of HiSiv 1000 did not change after 14 regeneration cycles. They concluded that adsorption capacities of activated carbon and Filtrasorb-400 were several times higher than that of HiSiv 1000.

2.8 TEA WASTE

Activated tea waste as a potential low-cost adsorbent for the removal of *p*-nitrophenol from wastewater was tried by m. ahmaruzzaman et.al (15). They investigated potential of activated tea waste (ATW) as a useful adsorbent for the removal of p-nitrophenol (p-NP) from aqueous systems. They studied effects of pH, contact time, and presence of anions. An increase in the pH to above neutrality resulted in a decrease in the p-NP adsorption capacity. The adsorption process reached equilibrium within 5 h of contact time. The Freundlich, Langmuir, Temkin, Dubunin–Radushkevich, and Redlich–Peterson adsorption models were used for mathematical description of the adsorption equilibrium, and they found that experimental data fitted very well to the Langmuir isotherm. They studied Batch adsorption based on the assumption of a pseudo-first-order, pseudo-second-order. The adsorption capacity of ATW for the removal of p-NP was found 142.85 mg•g−1. They found that efficiency of activated tea waste (ATW) as a low-cost adsorbent for treatment of wastewater containing p-NP.

Mohsin Kazmi et.al (16) research on removal of phenol from wastewater using activated waste tea leaves. They carried out treatment of phenol contaminated synthetic wastewater by Activated Waste Tea Leaves (AWTL). Phosphoric acid was used for the modification of waste tea leaves. They studied effects of initial pH, biosorbent dose, contact time, and initial phenol concentration on the phenol uptake from the synthetic solution. Kinetic modelling was performed using pseudo 1st and 2nd order kinetics. The Langmuir and Freundlich's Models were dertermine interpret the AWTL behaviour at various mass transfer gradients. They found that the optimum values for pH, biosorbent dose and contact time were 2.2 g/L and 180 minutes.

2.9 MANGO PEELS

Aditi Gupta et.al(17) have carried out research on removal of phenol from waste water using mango. They investigated on mango peel as an activated adsorbent used for the tertiary removal of phenol from aqueous solutions. The mango peel was activated with hydrochloric acid, sulphuric acid and phosphoric acid . Both H2SO4 and H3PO4 gave good results for the removal of phenol. better removal was achieved by H2SO4 activation. Adsorption of phenol was found increase with increase in agitation time and initial concentration of phenol. In case of pH, a pH of 7 was more favourable for the adsorption of phenol using mango peel activated by H2SO4 while a pH of 4 was better suited to removal by H3PO4 activation. They studied Equilibrium data of Langmuir and Freundlich which Langmuir isotherm model indicated single layer chemisorption. They found that kinetics of the adsorption process follow the pseudo-first-order kinetic model suggesting that pore diffusion was the rate limiting step. FTIR analysis was conducted on the prepared activated carbon before and after phenol adsorption.

Removal of Phenolic Pollutants from Water Utilizing Mangifera indica (Mango) Seed Waste and Cement Fixation was carried out by Amit Bhatnagar et.al (18).they found that process for the removal of two chlorophenols (2-chlorophenol and 2,4-dichlorophenol) from water using surface modified mango seed waste By Adsorption Process followed by cement fixation of the phenols-laden adsorbent. They studied modified mango seed adsorbent an efficient adsorption potential for chlorophenols removal from water. The maximum adsorption potential of modified mango seed adsorbent for 2-chlorophenol and 2,4-dichlorophenol was 40.6 and 72.3 mg g^{-1} at 25°C. After the adsorption studies, the phenol-laden adsorbent was immobilized in cement for its ultimate disposal. Leachates from the fixed phenols-laden adsorbent exhibit phenols concentrations lower than the drinking water standard.they concluded that potential utility of agricultural wastes as one of the most promising activated carbon precursors for phenols removal from water and wastewater and the safe disposal of phenol-laden adsorbent into cement by fixation process.

2.10 ACTIVATED CARBON

Adsorption for Phenol Removal by using activated carbon in batch and fluidized bed adsorption was studied by Sunil J. Kulkarni et.al (19).they investigated removal of phenol from synthetic effluent using batch adsorption and fluidized bed adsorption. In batch studies, they studied effects of adsorbent dose, pH, particle size on rate of adsorption and optimum parameters are identified. They observed that % decrease in phenol concentration increases with increase in adsorbent dose. With a reduction in particle size, initially step increase in % removal of phenol is observed and it was suitable for finer particles. In case of fluidized bed, they studied effect of concentration, fluid flow rate and adsorbent particle size. Increase in fluid flow rate gives better adsorption in case of activated carbon. They found particle size of 0.420 mm more beneficial.

Tapreet.al (20) have reported research on fluidized bed activated carbon adsorption for removal of phenol from wastewater. They investigated removal of phenol from waste water in a fluidized bed column using activated carbon as a adsorbent. They found % saturation increases with increase in initial concentration of phenol and flow rate. They also found Particle size affect the adsorption operation. The inlet concentration of phenol and flow rate have significant effect on the adsorption operation. They also investigated % saturation decreases with increase in particle size. The flow rate of 4.2 lpm yields maximum % saturation of 46 % and the maximum value of 72 %saturation yields at corresponding particle size of 0.420 mm..

Removal of phenol by powdered activated carbon adsorption was carried out by Yan Ma et.al (21).they found that adsorption performance of powdered activated carbon on phenol in aqueous solutions. They studied effects of PAC type, PAC dose, initial solution pH, temperature and pre-oxidation on the adsorption of phenol by PAC and establish the adsorption kinetics, thermodynamics and isothermal models. The found that PAC adsorption is an effective method to remove phenol from water. The adsorption rate of phenol by PAC was rapid and more than 80% phenol absorbed by PAC within the initial 10 min. They found adsorption process by pseudo second order adsorption kinetic model with rate constant 0.0313, 0.0305 and 0.0241 mg·μg^{-1}·min^{-1} with coal, coconut shell and bamboo charcoal..

2.11 FLY ASH

Use of coal fly ash for simultaneous co-adsorptive removal of phenol and cyanide from simulated coke wastewater was carried out by Agarwal et.al (22). They investigated process of simultaneous adsorption of phenol and cyanide from simulated coke wastewater onto acid treated coal fly ash was optimized at temperature, pH, adsorbent dose and initial concentration. Maximum removal of phenol (67%) and cyanide (82%) was achieved at a temperature of 30 °C, pH of 9 and adsorbent dose of 40 g L-1 at initial concentration of 200 mg L-1. They observed adsorption of phenol and cyanide onto fly ash is a favorable process with high capacity of fly ash as an adsorbent. They concluded that process carried out in continuous mode with real waste water from coke industry for the removal of phenol and cyanide quite efficiently.

Adsorption of Phenol from Aqueous Solution onto Fly Ash from a Thermal Power Plant was tried by Richa Sharan et al (23). They investigated phenol adsorption capacity of fly ash under adsorbent dosage, pH, varying phenol concentration and contact time. They studied at a phenol concentration of 100 mg/ℓ, the percentage removal of phenol was 95.69% at an optimum dosage of 7 g/ℓ fly ash. The effect of the initial phenol concentration indicated that the percentage phenol removal increased with increasing phenol concentration being a maximum (98.08%) at a phenol concentration of 700 mg/ℓ. The adsorption of phenol varied with the pH and was found maximum at a pH value of 8. They carried out isotherm showed that the adsorption of phenol onto fly ash was best described by the Langmuir isotherm relative to the Freundlich isotherm. Analysis of the kinetic data show that the kinetics of phenol adsorption closely follow the pseudo-second-order model.

A Kaushik et.al.(24) investigated potential of unburnt carbon fraction present in bagasse ash as an adsorbent for phenol. Chemical modification of the unburnt carbon from bagasse fly ash can be done by treatment with acids and hydrogen peroxide. The modification reduces the ash content and increases the surface area.ash is unburnt carbon can remove phenol from dilute streams and the performance can improved by chemical modification. At high phenol concentration, surface polymerization of phenol is suspected.

2.12 HYCINTHE

Adsorption of phenol from aqueous solution by water hyacinth ash was tried by M. T. Uddin et.al (25). the adsorption of phenol from aqueous solution was investigated using water hyacinth ash as an adsorbent. adsorption capacity of the adsorbent was affected by initial pH, initial phenol concentration, contact time and adsorbent dosage. They found that the amount of phenol adsorbed increased with increasing initial phenol concentration. They also found that the uptake of phenol took place at a pH in the range of 2.5-5. the adsorption of phenol decreased with increasing pH. They concluded that equilibrium data fitted very well in a Langmuir isotherm equation the monolayer sorption capacity of phenol onto water hyacinth ash with a monolayer sorption capacity of 30.49 mg/L.

3. CONCLUSION

In this paper some of adsorbents are used as low-cost, natural and abundant sources and also to remove harmful species such as heavy metal ions present in effluents for the removal of phenol.
some of adsorbents have as an inert atmosphere produces a highly porous carbon with a very high surface area. So such effective adsorbent can be an attractive option to eliminate waste materials..

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