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Isotherm and Kinetics of Phenol Removal by Adsorption- A Review

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Abstract:

Phenol is one of the major pollutant in wastewater. Various methods are available for phenol removal, both biological and non biological. Phenol removal by adsorption is widely studied area of investigation. The kinetics and isotherm studies are major part of studies carried out in this regard. These studies are important with respect to adsorption capacity, loading and time. The current review aims at presenting the summery of the research carried out in order to investigate isotherm and kinetics. It was observed during this review that in most of the investigations solute uptake kinetics was second order in nature and Langmuir isotherm was better fitted to the data.

Keywords:

adsorption, models, kinetics, removal, isotherms.

Introduction

Phenol is introduced in the wastewater by various industries such as resin, plastic, yarn, petrochemical, coal, ceramic, glue, iron, steel, aluminum, leather, food process and etc. Phenol imparts bad taste to water. It is also potential human carcinogen and is of considerable health concern, even at low concentration. The maximum allowance of phenol in drinking water is 0.002 mg/L according to World Health Organization (WHO).Various methos for phenol removal includes biologic filtration by ultrasound waves, photocatalistic destruction, membranous filtration, enzymatic filtration, and extraction by solvent, chemical oxidation, light oxidation, photochemical destruction and wet oxidation.Adsorption is widely studied method because of its applicability, simplicity and cost effectiveness. The studies of isotherm and kinetics are important in this research. The present review aims and summerizing the investigation in this field with respect to the methodology and findings of these investigations.

Isotherms and Kinetics of Phenol Removal

Gholizadeh et. al. carried out comparative studies on kinetic and isotherm of adsorption and biosorption processes in the removal of phenolic compounds from aqueous solutions(1).They developed a cheap technology for treatment of phenol and its derivatives. They used rice bran ash (RBA) and biomass of brown algae, Cystoseiraindica for phenol removal. These were compared against granular activated carbon (GAC).It was observed that the efficiency of GAC was higher than those of other adsorbents for all of the phenolic compounds.The second order equation fitted the equilibrium data.Abdelwahaba and Amin carried out Kinetics, isotherm and thermodynamic studies for adsorption of phenol from aqueous solutions by Luffa cylindrica fibers(2). They applied Langmuir, Freundlich, Tempkin and Dubinin–Radushkevich isotherm models for the data. It was observed that the Langmuir isotherm fits the data. The adsorption was second order in nature. The process was also found to be exothermic.

Bohli et.al carried out research on Kinetics and Equilibrium of Phenol Removal from Aqueous Solution by using the activated Carbon from Olive Stones(3). They prepared Activated carbon from olive stones by chemical activation with orthphosphoric acid (H_3PO_4). It was observed that the first order kinetic model does not correctly fit the experimental data for different initial concentration and particle sizes. The second order equation gave satisfactory fit for solute uptake. Langmuir isotherm model, with a maximum monolayer adsorption capacity of about 58.8 mg/g described the isotherm satisfactorily.Subha and Namasivayam carried out Kinetics and isotherm studies for the adsorption of phenol using low cost micro porous $ZnCl_2$ activated coir pith carbon(4).They investigated the potential of $ZnCl_2$ activated coir pith carbon for adsorption of phenol from aqueous solution. They tested the adsorption kinetics for first order, second order, and Bangham's model and also evaluated rate constants of kinetic models.Also Langmuir, Freundlich, Dubinin-Radushkevich, and Temkin isotherm models were analysed. Their study indicated that physical process was involved in the removal of phenol. They observed that negative value of ΔG^0 indicated the spontaneity of the adsorption process. Alkaram et. al. studied the removal of phenol from aqueous solutions by adsorption using surfactant modified bentonite,kaolinite(5).They used two surfactant of hexadecyltrimethylammonium bromide and phenyltrimethylammonium bromide (PTMA) to modify natural Bentonite (BC) and kaolinite (KC). It was observed that the adsorption capacity increased with increasing temperature indicating endothermic adsorption. The adsorption patterns data were correlated well by Langmuir and Freundlich isotherm models.The kinetics was pseudo second order.Mondal et.al. carried out Artificial Neural Network model and isotherm Study to predict the removal efficiency of phenol(6). Orange peel ash (OPA) adsorbent was used for effective uptake of phenol from aqueous solution. Langmuir isotherm model explained phenol uptake.Kinetics followed Pseudo-second-order kinetic model. The Back Propagation Algorithm (BPA) was found to be the best algorithm with a minimum mean squared error (MSE) for training 0.00528.Equilibrium and kinetic studies of phenol sorption by chitosan coated montmorillonite were carried out by Yan and Quan(7). They observed that the second order equation model provided the best correlation with the experimental results.Kinetic and isotherm study on phenol removal by using activated carbon prepared from coffee residue was done by Khenniche and Aissani(8). They also studied the effect of impregnation ratio of (zinc chloride/coffee residue) on the adsorbent. Phenol experimental data was perfectly described by the Langmuir model and second order kinetics was observed.Gholizadeh et.al. investigated removal efficiency, adsorption kinetics and isotherms of phenolic compounds from aqueous solution using rice bran ash(9). They burned rice brans at temperature of 400 ºC (RBA-400)for 2 h in a muffle furnace.Then it was powered and used.It was observed that Langmuir isotherm gave better fits than the other isotherms for adsorption of Phenol and the maximum uptake capacity for phenol Was 5.903 mg/g. Pseudo second order model suited better than other models for the adsorption.Studies on kinetic and thermodynamic models for the removal of amino-phenol (dye) from aqueous solutions using groundnut (Arachis hypogea) shells as the biomass was carried out by Asiagwu et.al.(10).They found that the variance, R^2 for both isotherms were 0.996 and 0.994 respectively, indicating excellent agreement with data. It was also observed that pseudo-second order gave a better kinetic description of the adsorption process. It was also observed that the process was not spontaneous.Batch and column studies for phenol removal were carried out by Kulkarni and Kaware(11).They used ground nut shell activated carbon for the purpose. It was observed that the solute uptake followed Lanmuir isotherm. Also the phenol uptake was described more closely by second order kinetics.Kulkarni and Kaware also carried out the phenol removal by leaf litter(12). The optimum pH from the investigation was found to be 7. The solute uptake agreed with both Langmuir and Fruendlich isotherms.Agarwal et.al. Carried out quilibrium, kinetic and thermodynamic studies of simultaneous co-adsorptive removal of phenol and cyanide using chitosan(13).Their kinetic studies revealed that the chemisorptions was involved in removal mechanism. The uptake of solute followed pseudo second order model. They fitted data for multicomponent adsorption of phenol and cyanide onto chitosan to different multicomponent isotherm models i.e. Non-modified Langmuir, Modified Langmuir, Extended Langmuir and Extended Freundlich. These multicomponent models used the constants from single component models. They used Marquardt's percent standard deviation (MPSD) for the validation of both equilibrium and kinetic models. Better results were obtained by Extended Freundlich model with lowest MPSD's of 12.78 for phenol and 6.47 for cyanide.Kulkarni carried out review on fixed bed removal of phenol(14).The batch and column results were in agreement as per the review. The solute uptake was second order in nature.Sengupta and Balomajumder carried out research on on the potential of biosorbent, Corn husk leaves, for the co-removal of phenol and cyanide from coke waste water by simultaneous adsorption and biodegradation(15). They analysed the simultaneous adsorption and biodegradation equilibrium data for phenol and cyanide on corn husk leaves using Solver function of Microsoft excel 2010. Modified Langmuir Isotherm showed best the simultaneous adsorption and biodegradation of cyanide.Equilibrium, Kinetic and thermodynamic studies on phenol sorption to clay were carried out by Nayak et.al(16). Langmuir isotherm was followed by solute uptake and the second order rate law was followed.Priyanka et.al carried out the investigation aimed at determination of the potential application of adsorbent prepared from coconut fiber for the removal of organic water pollutants(17).The adsorption was endothermic in nature.Pseudo second order model fitted better to the solute uptake and Langmuir isotherm model adequately fitted to the adsorption data.Ekpete et.al. investigated the potential of a powdered commercial activated carbon to assess its possible use as an adsorbent for the removal of phenol and chlorophenol from waste water(18). They fitted the data from the initial concentrations to Langmuir and Freundlich equilibrium adsorption isotherms.Langnuir isotherm described the uptake better.Fly ash and Guava leaves were used for phenol removal by Sharada(19). Their data followed Langmuir isotherm and the solute uptake was explained by first order kinetics.

Houari et.al. investigated static sorption of phenol and 4-nitrophenol onto composite geomaterials based on Montmorillonite, Activated Carbon and Cement(20).Langmuir isotherm fitted the data. The adsorption was second order in nature.Subramanyam and Ashutosh investigated adsorption isotherm modeling of phenol onto natural soils(21). They analysed experimental data using fourteen isotherm models, ranging from single-parametric model to multi-parametric models (up to 5 parameters) of the system.With increase in degree of freedom the accuracy of model increased.According to their study, Temkin isotherm model, Langmuir-Freundlich isotherm model and Fritz-Schlunder model as well as Baudu model were found to be the best fit models amongst the two-parametric models, three parametric models and four parametric isotherms modeling, respectively.According to them , higher parametric models were better options for their modeling in comparison to lower parametric models.Zarei et.al carried out studies on Moringa Peregrina tree shell ash as an adsorbent for phenol removal(22). Langmuir model was better fit with R^2 value of 0.9833.

Conclusion

The isotherm and kinetic studies are very important part of adsorption experiments. The research carried out suggests that the isotherm and kinetics depends on the adsorbents used for the removal. Multiparameter models gives better results than single parameter models. In most of the cases , the Langmuir isotherm was followed by the solute uptake process. Also the kinetics was second order except few exceptions.

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