PHENOL REMOVAL USING NON-IONIC RESIN BED FROM INDUSTRIAL WASTE WATER

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Abstract

Experiments have been conducted to examine the liquid-phase adsorption of phenol from industrial waste water by Nonionic Resin Bed (XAD-4), a polystyrene-divinylbenzene resin without functional group, were carried out under different conditions. Experiments were carried out for the analysis of adsorption equilibrium capacities. Results of Laboratory experiments indicated that Non-ion Resin Bed had the highest rate of adsorption among the adsorbents studied and therefore more detailed studies were carried out with this adsorbent. The influence of particle size, temperature, and thermal regeneration on adsorption of phenol by Non-ion Resin Bed was evaluated. From particle size experiments it appeared that adsorption capacity of Resin Bed did not change by changing the particle size, but the rate of adsorption decreased with the quantity of Resin beds. The effect of temperature on adsorption was studied by determining equilibrium isotherms for Non-ion Resin Bed at 25 and 40°C. The results showed that adsorption capacity for Phenol by Non-ion resin bed was 99.8 %.it's also very effective for BOD and COD for the industrial waste water containing phenol.

1. Introduction

Phenol and its derivative are important aromatic compounds. The former is used extensively in the synthesis of organic product, such as phenolic-type resins, and occurs as a natural component in industrial wastes from the coal-gas, coal-coking, and petroleum industries, as well as in a wide variety of industrial wastes from processes involving the use of phenol as a raw material[1]. Many methods, such as oxidation, precipitation, adsorption, Pre-treatment with RO and solvent extraction have been used to remove phenolic materials from aqueous solutions. It was found that adsorption and oxidation processes were considered as possible treatment techniques. Even though activated carbon is the most frequently used adsorbent, some refractory organic compounds could also be concentrated and removed from aqueous solution via adsorption by macro reticular resins without ion exchange functional groups. That is, the attachment of the nonionic portion of the organic solute to the surface of the resin by van-der Waals interaction [8] .The Resin Bed separation of an organic solute from aqueous solutions is of interest from the point of view of its application for wastewater treatment and water pollution control. Membrane processes can be used to remove phenol from water, but they are not always successful. Therefore increasing attention is being paid to the study of various chemical and physical processes to accompany such separation systems. In general, depth filters, GAC, microfiltration and ultra filtration are used to reduce the pollution loading for RO systems [3]. If the efficiency of an Anion Resin Bed module for phenol removal is to be investigated, such pre-treatment methods must be considered. Thus, the objective of the following study is to investigate phenol removal by Adsorption by Non-ion Resin bed methods. The type and number of functional groups on benzene ring were also found important on the adsorption of phenol compounds. This paper discussed the adsorption behavior of phenol in aqueous solutions by XAD-4 resin. A conceptual model is established based on the elemental balances and equilibrium equations to describe the adsorption behavior and differentiate the extent of adsorption of various phenol species removed by XAD-4 resin under different experimental conditions.

2. Material and method

2.1 Experimental setup

The experiments were conducted on pilot-scale apparatus (Figure 1). XAD-4, a nonionic polymeric resin composed of polystyrene chains cross- linked with divinylbenzene, was used as the adsorbent for studying the adsorption behavior of various Phenols contain industrial waste water [11]. The medium size of the resin is 35–40 mesh or 0.02 micron. The specific surface area, average pore volume, and average pore diameter were determined to be $820m^3/g$, $0.81cm^2/g$, and 23.8 Å, respectively.

For the adsorption equilibrium experiments, predetermined amounts of XAD-4 resin were introduced into resin bed reactors filled with resin balls of known concentrations of phenol and the whole reaction setups were maintained at 30±5∘C. The solution pH was adjusted to desired level (between 3 and 11) by adding acidic or alkaline solutions to the collection tank .the waste water distribution continue on the resin balls. After 40-50 minutes of contact time for resin balls and phenol-containing waste water, the solution pH was recorded and the resin balls was allowed to pass remaining water from the percolated tray. The mesh size of that tray is less than 0.02 micron. The solution pH was recorded, and the concentrations of various phenols in the filtered samples were determined by measuring the absorption of specific wavelength with a UV-160A UV/visible spectrophotometer. Experiment performed for different resin balls quantity and found the best efficiency of waste water recovery.
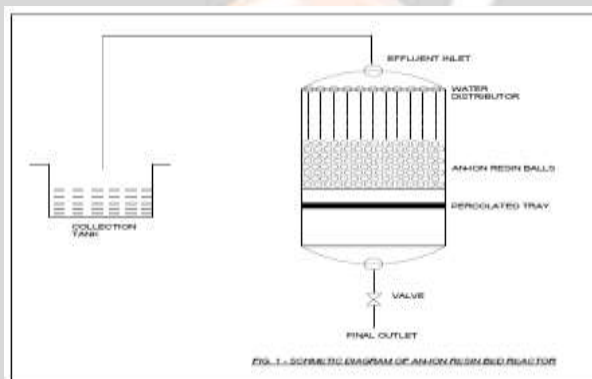

Figure: 1- Schematic Diagram of Non-Ion resin Bed   Reactor

2.2 Regenerating an ion-Exchange Resin

As stated earlier, an ion-exchange resin in industrial use is usually regenerated every 12 to 48 hours. Depending on the use of the resin, this can be done in several different ways, each with their own advantages and disadvantages depending on both chemical and economic factors [9].

Regeneration is important because reducing the regenerate level lowers water quality by allowing a small proportion of the ions which are being taken up by the resin to slip through without exchange. For example, with twin bed deionizers, incomplete regeneration of the cat-ion resin to the hydrogen form allows leakage of some sodium (the least held of the cat-ions commonly found in natural supplies) into water passing to the anion exchange vessel [6]. Consequently the water leaving the anion unit still contains this sodium in the form of sodium hydroxide solutions usually of pH 8 to 9. However, the excessive amounts of regenerate required for complete regeneration means that this is rarely practical. In practice a compromise is usually reached, and commonly resins are regenerated to about two thirds of the total capacity. In addition, for many uses total purification is not necessary. For example, the water with a pH of 8 to 9 mentioned earlier is highly suitable for use in boilers, as they require slightly alkaline water.

Some impurities such as silica can only be removed by a strongly basic resin. For example, dissolved silica is a major component of most water supplies. Normally it exists as a neutral polymer, and it becomes negatively charged only at high pH levels. This means that it can only be removed from water in the highly alkaline environment of a strong base resin in the hydroxyl form.

The exchange process is often made more efficient by introducing the regenerant at the bottom of the resin column and passing it upwards through the bed (counter current regeneration). This ensures that the resin at the bottom becomes more highly regenerated than that above it. Treated water leaving the column flowing downwards then comes in contact with this resin last and undergoes the highest possible degree of exchange.

2.3 *Advantages and Disadvantages in the use of Ion-Exchange Resins*

The advantages of ion exchange processes are the very low running costs. Very little energy is required, the regenerant chemicals are cheap and if well maintained resin beds can last for many years before replacement is needed. There are, however, a number of limitations which must be taken into account very carefully during the design stages. When these limitations itemized appear to represent a formidable list and the impression can be given that ion exchange methods might have too many short comings to useful in practice. However, this is not the case as the advantages mentioned above are very great and compensation can readily be made for most restrictions.

2.4 *Adsorption of organic matter*

One of the commonest problems results from the presence of organic matter in water supplies. Untreated water from industry and rivers usually contains dissolved organic material derived from decaying vegetation which imparts a light red or brown color [2]. These substances can become irreversibly adsorbed within the anion beads, reducing their exchange capacity and leading to a reduction in treated water quality. Removal of organics prior to de-mineralization is usually achieved by flocculation with alum or ferric salts followed by filtration which removes the metal hydroxide flock and the co-precipitated organic compounds. This treatment also removes any fine silt which represents another source of resin fouling. Both organic and iron fouled units can be chemically cleaned on site but complete removal of impurities is rare and resin performance usually suffers after fouling [7].

2.5 *Organic Contamination from the Resin*

The resins themselves can be a source of non-ionized organic contamination. New commercial grade resin often contains organics remaining after manufacture, while very old resin will shed organic fragments as the polymer structure opens up very slowly (de-cross linkage) [10]. Such contamination may be disregarded for many uses, but when removal is needed, the de-mineralised water can be passed through an ultra filtration membrane.

2.6 *Environmental Implications*

The waste water for disposal after regeneration contains all the minerals removed from the water plus salt from the spent re-generates. These are concentrated into a volume equivalent to 1-5% of the treated water throughput. Disposal is not usually a problem as the load on waste treatment systems is low compared with at from many other industrial processes.
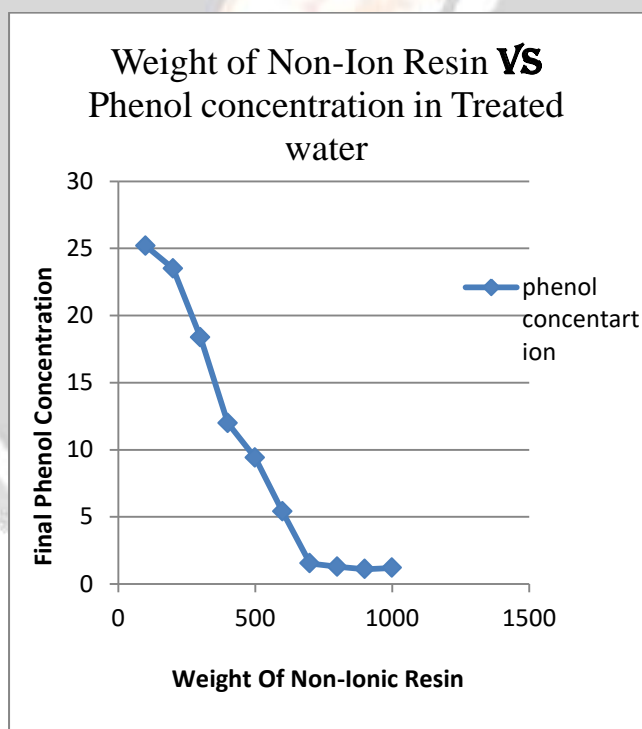
3. *Results and Discussion*

3.1 *Effect of initial concentration*

The effect of the initial phenol concentration on the removal efficiency is plotted in Fig. 1. In this study phenol concentration was varied between 1 to 107 mg/ L and the resins dosages were kept at 100 gm/L to 1000gm/L. Results show that phenol ions removal through resins is considerably influenced by its concentration in the feed stream. It was found that the phenol removal from 107 mg/L (Initial) from 1-3 mg/L phenol in the outlet stream, to 99.7 % for the highest assayed concentration under identical XAD-4 operating conditions in terms of recirculation time and temperature for the strong non -ion exchange resin. In this case, it can be ensured that XAD-4 was the predominant process responsible of the phenols ion removal since the increase in Resin Quantity in the outlet stream was directly proportional to the removal efficiency for each assayed initial concentration. Hence, the decrease in the removal percentage with the phenol concentration in the feed stream could be related to saturation of the XAD-4 resin.

Table 1: Result of Experiments.

Sr. No.	Weight of Non-Ion resin taken (gm)	Initial Phenol Concentration in W.W (mg/L)	Final Concentration Of Phenol treated water (mg/L)	Percentage Recovery (%)
1	100	90	25.2	67.32
2	200	107	23.5	81.85
3	300	97	18.36	79.19
4	400	99	11.99	87.12
5	500	101	9.4	91.50
6	600	102	5.4	96.49
7	700	98	1.53	96.50
8	800	99	1.287	97.72
9	900	100	1.1	98.90
10	1000	101	1.2	99.78

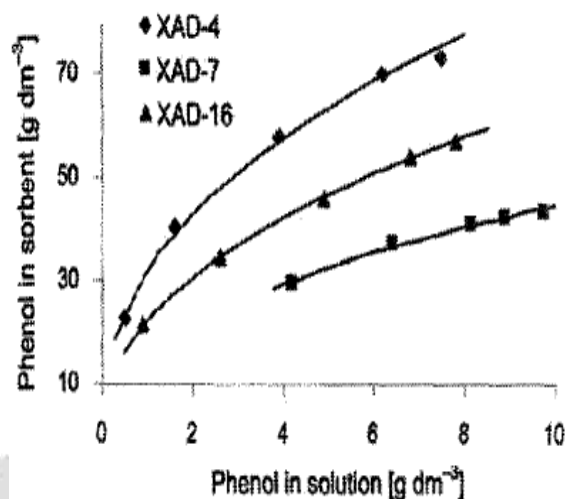**Figure: 2: Effect of Non-Ionic Resin to Phenol Concentration**

Figure: 3: Adsorption isotherms of phenol on the Amberlite resins of various grades.

3.2. Adsorption under dynamic conditions

Adsorption under dynamic conditions was performed in order to investigate properties of the chosen adsorbent Amberlite XAD-4 during adsorption and regeneration steps. The solutions modelling partially dephenolized wastes contained phenol (3-5 g.dm^{-3}) and sodium sulphate (30 g.dm^3). Four kinds of incombustible liquors were used to regenerate the resin bed. The breakthrough curve for the adsorption step enabled to estimate the volume of the eluate in the breakthrough point (V), which corresponded to the maximum volume of decontaminated eluate. On the other hand, the regeneration (elution) curve indicated the volume of a regenerant (VR) at which pollutant concentration decreased to a desired low value. This volume of regenerant was necessary to elute phenol out from the bed resin. The difference Delta V = V - VR was regarded as a measure of the efficiency of the regenerant used. The higher Delta value was, the more efficient the regenerate was.

The breakthrough and regeneration curves obtained at 368 K using water, sodium sulphate solution (30 g.dm-3) and treated model solution (with phenol concentration of 0.08 g.dm^{-3}) are presented in Fig. t0. Phenol concentration in the feed was equal 5 g.dm^{-3}. It was found that the highest volume of the treated waste (AV= 6 BV) was obtained when the adsorbent bed was regenerated with hot water. On the other hand sodium sulphate solution and treated model solution were the less efficient regenerants (AV approximately equal to 4 BV and 1 BV, respectively).
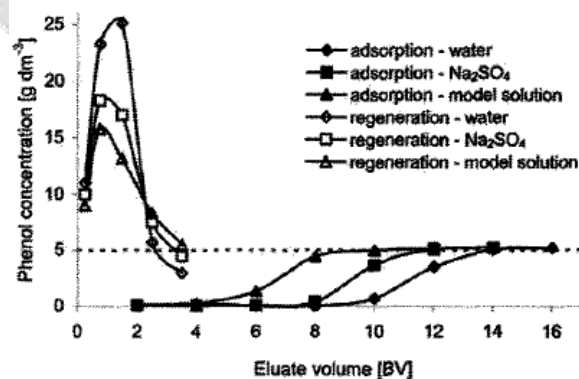

Figure: 4: The breakthrough curve for adsorption and the regeneration (elution) curve. The Amberlite XAD-4 bed regenerateda t 368 K using water, sodiums ulphate solution and treatedm odel solution.T he dashedl ine

indicatesp henol concentrationi n the feed (5 g.dm-3).T he eluate volume on the abscissa axis is expressed in the volume of resin bed (BV).

4. *Conclusions*

The phenol uptake by Non-ion exchange resin (XAD-4) has been investigated on the basis of the feed stream phenol concentration effect. The aim of this study was to examine the potential of these XAD-4 resins towards the removal of phenol. The phenol removal efficiency Increases considerably as the Resin Bed quantity increases. In this sense, the phenol removal efficiency increases from 67 % to 99.7 % for different quantity of phenol present in industrial waste water. In this case, it can be ensured that XAD-4 was the predominant process responsible of phenol removal. It can be assumed that the adsorption is the main responsible process for phenol removal through this resin.

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