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SORBTION: A UNIVERSAL TECHNOLOGY FOR WATER PURFICATION

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Abstract. Amongst different water purification, sorption is the best one due to its unique features; especially universal and inexpensive. A large number of publications are appearing in the literature every year, confirming its importance. There is a great need to write a brief note on this method to keep aware of the researchers. The paper discusses the state-of-arts of the sorption process at batch and column levels. Some preliminary aspects are also discussed.

Keywords: *Water, sorption, batch processes, column operations.*

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1. Introduction

The universal solvent i.e. water is life-giving nectar on this blue glob. It is a God-given gift for all of us. But unfortunately, the overgrowth of population, much demand for industrial development and civilization have destroyed this gift. In appear to despise toward of this, secure drinking water isn't accessible in a number of portions of the world. The quality of water sources is breaking down exponentially because of their pollution. Both non-point and point sources are contributing a lot to water pollution. The most important is the overgrowth population, industrialization and development of our society. Consequently, there are someplace globally that have water unfit for drinking and recreation purposes. Water pollution is a serious matter as it, directly and indirectly, affected our lives (Ali, 2014; Hairom *et al*., 2021; Some *et al*., 2021). Therefore, we are very much serious about this issue (Liu *et al*., 2021; Dich *et al*., 1997).

More than a thousand pollutants have been identified in water including chemicals, viruses, bacteria and other pathogens. Metal ions are considered very serious as these are not biodegradable and may produce cancer (Brusick, 1993; Mattson & Mark, 1971; Cheremisinoff & Ellerbush, 1978; Parekh, 1988; Zahid, 1993; McNulty, 1984; Nemerow & Dasgupta, 1991; Faust & Aly, 1983; 1987). Besides, the viruses are also dangerous in the present situation where Corona is killing millions of people (Ali & Alharbi, 2020). Also, some organics are not biodegradable and may cause serious toxicity and cancer. The most notorious are pesticides, polynuclear hydrocarbons, fragrant hydrocarbons, phenols, biphenyls, plasticizers, ethers, fire retardants, etc. (Kallenborn *et al*., 2021). Hence, water purification and reusing contaminated are very much required and sorption may take care of it.

The most commonly used method for water purifications has been tested (Gupta *et al*., 1998; 1999; 2000). The foremost imperative methods are osmosis, electrodialysis, electrolysis membranes and sorption. But sorption is widespread in nature because it can be connected to the expulsion of solvent and insoluble pollutants and organic toxins with an evacuation effectiveness of 99%. At a community level, pollutants are purified from water by applying columns. The sorption can moreover be utilized for source decrease, recovery for consumable, community and other purposes. As a consequence, much work has been done on water purification by sorption. The present article describes the state-of-arts of the sorption process at batch and column levels. Some preliminary aspects are also discussed. The sorption is done in the following stages.

2. Experimental

2.1 Procedure

Sorption may be a surface wonder and is characterized as the augment in amount of a particular constituent at the interface or surface between two stages. Pollutants are sorbed on the surface of sorbents. The pollutants are called sorbates while solid materials are called sorbents. Sorption is controlled by temperature, the nature of the sorbate and sorbent, amount, temperature and particle size of sorbents. Besides, the presence of other species in water also affects the sorption process.

2.2 Sorbents preparation and characterization

In the starting activated carbon was used as sorbent but later on inexpensive sorbents from industrial and agricultural waste products have been prepared. But nowadays, researchers are making nanomaterials and using them as sorbents. Moreover, nanocomposites are more effective than normal sorbents. But there is a problem with these that still the toxicity could not be identified and, really, its risky to use nanomaterials. There are different methods of the preparation of these materials. In brief, these are prepared from different raw materials. Activated at high temperature then characterized by UV-Vis, FT-IR, XRD, SEM, TEM, BET, etc. methods. These are kept in a desiccator for further use.

2.3 Batch experiments

The sorbet and sorbets are mixed and shaken together at fixed temperatures and the remaining amount of pollutant is measured by specific techniques. We have to vary the initial amount of pollutants, then pH, then sorbent dose, then particle size. For the kinetic study, the experiments are done at different temperatures. The most common temperatures are 20, 24 and 30 ºC because these are the temperature of the natural water resources. The data is modeled through various models like Langmuir, Freundlich, Temkin, first and second-order reactions. The kinetics is determined by doing sorption at various temperatures. The commonly used models are given in the following tables.

Table 1. Langmuir, Freundlich, Temkin, Dubinin–Radushkevich adsorption models

Langmuir	Freundlich	Temkin	Dubinin–Radushkevich
Linear forms of the equations			
$\frac{1}{Q_e} = \frac{1}{Q_{max}} + \frac{1}{Q_{max} \cdot b} \cdot \frac{1}{C}$	$lgQ_e = \frac{1}{n} \cdot \lg C + \lg k$	$Q_e = B \cdot \ln K_T + B \cdot \ln C$	$\ln Q_e = \ln Q_{max} - K_{ad} \cdot \varepsilon^2$
Non-Linear forms of the equations			
$Q_e = Q_{max} \cdot \frac{b \cdot c}{1 + (b \cdot c)}$	$Q_e = k \cdot C^{1/n}$	$Q_e = B \cdot ln(K_T \cdot C)$	$Q_e = Q_{max} \cdot exp(-K_{ad} \cdot \varepsilon^2)$

Table 2. Models implemented to describe the adsorption kinetics and mechanism*

Model	Equation
Pseudo-first-order	$\lg(Q_e - Q_t) = \lg(Q_e) - \frac{k_1 \cdot t}{2{,}303}$
Pseudo-second-order	$\frac{1}{Q_t} = \frac{1}{k_2 \cdot Q_e^2} + \frac{1}{Q_e} \cdot t$
Elovich	$Q_t = \frac{1}{\beta} \cdot \ln(\alpha \cdot \beta) + \frac{1}{\beta} \cdot \ln(t)$
Intraparticle diffusion	$Q_t = k_{id} \cdot t^{0{,}5} + c$
Liquid film diffusion kinetic	$-\ln(1 - F) = k_{fd} \cdot t$

2.4 Column operations

Basically, batch mode is the evaluation of sorbent removal capacity in the laboratory. After developing the optimized batch conditions, these are transferred at a pilot scale in the laboratory. After this, the conditions are applied at a large scale for the community or industrial services. The big column is designed and through knowledge of Physics, Engineering and Chemistry are required. Therefore, such operations should be done with a group of different backgrounds. The experiments are done with a suitable sorbent. The fraction of water is collected and the saturation of the column is observed. After column saturation, the sorbent is taken out and recycled. The data obtained in column operation is tested by several models and the most important is Bohrat and Adam's model. This model is given as below.

$$t = (N_0/C_0)X - 1/C_0K\ ln\ (C_0/C_B - 1)$$

$t -$ service time, C_0 - initial adsorbate conc (mg/L), CB - break through conc, $K -$ adsn. rate constant (Lh/µg), $N_0 -$ adsn capacity (µg/L), X - bed depth (cm), V - linear flow velocity (cm^3/h).

3. Results and discussions

3.1. Recycling of sorbent

As you know that the preparation of sorbents is a costly affair and we cannot take away the used sorbents. Moreover, recycling is necessary for an inexpensive and effective method. Therefore, the used sorbents are recycled i.e. the sorbent pollutants

are removed from the sorbent. And then again the sorbents are used. Recycling depends on the type of pollutants. In the case of inorganic pollutants acids like hydrochloric, nitric acids are used. But in the case of organic pollutants, organic solvents are used. Sometimes, bases also work well. In this way, the pollutants are removed and the sorbent area gain activated at high temperature. Then they become ready for use in the next operation. The percentage removal capacity decreases after consecutive uses. Therefore, we stop recycling at a lower than ~80 removal capacity.

4. Conclusion

Sorption is a very important technique for water purification because of its inexpensiveness and good applications. Several sorbents have been used and tested to remove a variety of pollutants. Nowadays, nanomaterials are being used as sorbents but it is important to determine their toxicity before use. Also, the sorbent should have a good sorption capacity after recycling. It is important to mention that the batch method should be transferred at the pilot and industrial levels. Much work is required to make this technique freely amiable at a large scale in communities and industries.

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