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REVIEW ARTICLE

Industrial Wastewater Treatment by Biological Activated Carbon- A Review

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ABSTRACT

In the present article, the suitability biological activated carbon (BAC) prepared from low cost activated carbon for the treatment of wastewater has been reviewed. This paper has focused on the mechanism of the biological activated carbon (BAC) process. The efficiency of adsorption as well as biodegradation increased on BAC system in which suitable microorganism has immobilized on GAC. It is evident from literature survey of last 10-15 years that researchers have gained success to some extent in developing inexpensive and effective BAC system for water pollution control utilizing waste materials. i.e. waste turns into wealth. However, still there is a requirement to find out the practical utility of such developed BAC bioreactor on large scale.
Keywords: Wastewater treatment, Adsorption, Low cost adsorbents, Biological activated carbon (BAC), Bioreactor

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INTRODUCTION

Industrial wastewater is the discarded aqueous substance that results from the use of water in an industrial manufacturing process or the cleaning activities that take place along with that process. Untreated wastewater generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrient and toxic compounds. It thus entails environmental and health hazards and consequently must immediately be conveyed away from its generation sources and treated appropriately before final disposal. Currently there are many methods to treat wastewater including physical methods (Screening, Comminution, Flow equalization, Sedimentation, Flotation, Granular-medium filtration), chemical methods (Chemical precipitation, Adsorption, Disinfection, Dechlorination) and biological methods (Activated sludge process, Aerated lagoon, Trickling filters, Rotating biological contactors, Pond stabilization, Anaerobic digestion, Biological nutrient removal). Among these methods currently, Biological Activated Carbon (BAC) has been extensively studied by researchers as it offers potential advantages like low cost, bioregeneration and highly efficient in removing and/or biodegradation and recovering the pollutants.

Activated Carbon

Two important attributes of solid adsorbent are (a) extremely large surface area to volume ratio and (2) preferential affinity for certain components in liquid phase [1]. Activated carbon has both the features since it is an extremely porous carbon having a large surface area available for chemical reactions or adsorption and has strong affinity for attaching to itself most organics even at low concentrations. It is one of the most powerful adsorbent in the world. Treatment of wastewater with contaminants such as pesticides, aromatic compounds such as phenol, adsorbable organic halogens, non biodegradable organic compounds, color compounds, dyestuffs and halogenated organic compound will inhibit biological treatment. Many workers have tested activated carbon against inorganic pollutants such as cadmium [26, 34] and lead [22, 34], copper [II] [23], methylene blue [28], DOC [30] and organic pollutants such as phenol and its derivatives [40- 42, 44, 45]. Activated carbon prepared from *Parthenium* finds its successful application in removal of various constituents of wastewater such as p-Cresol from aqueous solution by adsorption [41], Ni (II) [20], Hg^{2+}, methylene blue, malachite green [29, 31] and Cd (II) [26].

The surface properties and regeneration characteristics of activated carbon depend upon both the initial material used to produce the carbon and the exact production procedure. Pores of activated carbon can be classified as macropores (> 25nm), mesopores (>1nm and < 25nm) and micropores (<1nm). Also AC can be size classified as powdered activated carbon, PAC, typical diameter of less than 0.074mm and granular activated carbon, GAC, typical diameter of greater than 0.1mm [1]. Generally, granular carbon from bituminous coal has small pore size, large surface area and the highest bulk density. Lignite carbon has the largest pore size, least surface area and the lowest bulk density [2].

Activated carbon removes organic compounds through the process of adsorption. Molecules in the water are attracted to the activated carbons surface. As the water passed through the attraction forces align the molecules onto layers (films) on the activated carbons surface. A number of factors alter the effectiveness of the activated carbon. These include, pore size, the amount of oxygen and hydrogen associated with the activated carbon, the composition and concentration of the contaminate, the temperature and pH of the water and the flow rate or time exposure of water to activated carbon.

The ability of activated carbon to adsorb pollutants is a function of both the characteristics and concentration of the pollutants and the temperature. Generally, the amount of material adsorbed is determined as a function of concentration at a constant temperature, and the resulting function is called an adsorption isotherm. The most common adsorption isotherm equations used in water and wastewater treatment are Freundlich isotherm and Langmuir isotherm. Activated Carbon is used for the treatment of pollutants within gaseous as well as liquid phases [8]. Many carbonaceous agricultural solid waste have been studied for the preparation and characterization of AC. Biomass like soya bean, peanut, pecan and walnut shells [21], Tamarind wood [34] coconut shells [22], coconut husk [36], ricebran [17], *Euphorbia rigida* [19], coirpith [23], cotton stalk [28] sawdust [20], cattle manure compost [12], durian shell [15], asphalt [10, 6], heavy oil fly ash and coal fly ash [10], chicken manure [11],palm shell [18] waste biomass sources (rice straw, wheat straw, wheat straw pellet, olive stones, pistachios shells, walnut shells, beech wood and hard coal [7] Bagasse fly ash [27] have been tested for the preparation of activated carbon.

Even though AC has high adsorption capacity but it can only maintains its adsorption for a short time after its available adsorption sites becomes exhausted with adsorbed pollutants. Besides this it is well known that AC is also act as a good support media for microbial growth. Thus an alternate to above problem is to attach biomass to AC that can effectively remove pollutants both by adsorption and biodegradation. BAC has more usable life.

Biologically activated carbon

As suggested by Zhang Xiaojian et al, BAC process can be defined as a combination of biodegradation and AC adsorption [43]. After adsorption capacity has been exhausted, the carbon particles will act like an ordinary biological medium and thus the reaction will be same in BAC bed reactor and the submerged biological filter; the only difference lies in the initial adsorption capacity of BAC [14]. Moreover BAC protects microorganisms from shear stress [5]. Choice of filter material is crucial in BAC systems. Thermally activated carbon columns are more efficient compared to the chemically activated one for DOC biodegradation**.** Biological activity inside the BAC columns extend the service life of GAC [38].

Kalkan et al., evaluate the effect of two different granular activated carbon (GAC) types (steam activated and chemically activated) on dissolved organic carbon (DOC) removal, nitrification and denitrification in BAC columns for wastewater reclamation/reuse purposes. The study demonstrates that a BAC system used for tertiary treatment of a secondary effluent, can remove organic carbon and total nitrogen to a significant extent. Dissolved organic carbon is more effectively removed by biological GAC showing better performance of biosorption in comparison of adsorption showing the practical use of BGAC in filtration [30].

One approach given by Buchanan et al., is to pretreat the natural organic matter by vaccum ultraviolet before it is passed through BAC column. According to them, this enhances the production of biologically degradable moieties as it breaks down the high molecular weight hydrophobic biodegradable moieties into more hydrophilic moieties. Immobilization of micro organisms by colonization on a porous material is a very promising approach to obtain high concentration of active biomass. It results in high biomass hold up as biofilm in AC which enables the process to be operated significantly at higher liquid throughputs and organic loading rate. Ong et al., immobilized azo dye degrading microbes in GAC through attachment by immersing the GAC into anaerobic bioreactor treating dye containing wastewater for more than 200 days and successfully mineralize CI Acid orange 7 [13]. AC acts as buffer to reduce the concentration of toxic chemicals during process operation. In BAC there is a decrease in bioreaction rate as the substrate is adsorbed by carbon making substrate concentration less in liquid phase. But it can be taken as favorable factor for the micro organisms if the high concentration of that substrate is toxic to biomass since micro organism lives on surface of AC and substrate is adsorbed by the carbon (Sutton & Mishra, 1994). The efficiency to remove cyanide by biologically activated granular AC was found better as compared to that of plain GAC. Simultaneous adsorption and biodegradation (SAB) process is more effective than adsorption and biodegradation alone [39]. Walker and Weatherleyb tested bacteria immobilized on granular activated carbon (GAC); bacteria immobilized on sand particles; GAC (with no biological activity) and free bacterial cell for the treatment of the simulated aqueous discharge comprising of a ternary solution of acid dyes from a carpet printing plant. BAC system exceeds the other combinations. For non biodegradable azo dyes, compared to conventional immobilized systems, increased biosorption was found in BAC systems. For biodegradable anthaquinone dyes, enhanced color removal was observed due to increase in substrate concentration at the granular surface found in BAC systems that results in higher dye utilization rates. Apart from liquid pollutants, gaseous pollutants such as gaseous H_2S can also be treated by immobilizing Thiomonas sp. on BAC [16].

Adsorption capacity of activated carbon

Several methods including Freundlich isotherm equation; by the amount of substrate that has been adsorbed in the carbon at different operation times and by testing the remaining fractional capacity which is a capacity between carbon in BAC column and virginal carbon at a selected equilibrium substrate concentration in liquid phase [14]. Deng et al., 2009 used the Langmuir isotherm, the Freundlich isotherm and the Temkin isotherm for getting the insight for both the properties of the surface and the mechanism of adsorption of the activated carbon prepared from cotton stalk by microwave assisted chemical activation and finds Langmuir isotherm fittest.

Biofilm attached to BAC

The density or thickness of micro organism attached to BAC is much smaller in comparison with traditional biological attached growth system such as trickling filter and rotating biological contractor. Bacteria forms a very thin Biofilm on BAC and do not usually form a uniform biofilm over the entire surface of the carbon particles. Warburg respirometer is used to measure the bioreaction properties in BAC if aerobic condition is provided to the system. Studies show that aerobic microorganism mainly live on the carbon particle surface and relatively few live in carbon pores [35, 8]. Chang and Rittman derive a mathematical description for the kinetics of Biofilm on AC using global orthogonal collocation method. Sequencing batch carbon reactor containing GAC Biofilm is tested for treatment of C.I Acid Orange 7 [14]. In 1970, Beer discussed the concept of using a Biological Fluidized Bioreactor (BFB) for denitrification of wastewater [9]. Combination of hydraulic model and Biofilm kinetics model can be used to formulate a process design for the AC based BFB reactor. Approximately 5 to 10 times greater biomass concentration is developed in a BFB using GAC media particles when compared with activated sludge bioreactor [8]. Patel et al., found fluidized bed reactor containing acetate fed granular activated carbon, an effective design for perchlorate reduction and exhibited first-order degradation kinetics.

CONCLUSION

Due to limitations in usage of activated carbon as adsorbent for wastewater treatment, biologically activated carbon (BAC) is introduced as a new approach for the researchers which are more advantageous and economical method. Regeneration of the capacity of activated carbon can be done either by using a pure culture isolate or mixed microbial consortium as per the requirement.

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