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Ranitidine hydrochloride sorption onto superheated steam activated biochar derived from mung bean husk in fixed bed column

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ABSTRACT

The present investigation highlights the sorption of ranitidine hydrochloride (RH) from aqueous solution onto superheated steam activated mung bean husk derived biochar (SMBB) in fixed bed column. The SMBB were well characterized by Brunauer–Emmett–Teller (BET) surface area analyzer, Fourier transform IR spectroscopy (FTIR), scanning electron microscope (SEM), point of zero charge (pH_{PZC}) and X-ray diffractory (XRD). The influence of various parameters viz. bed depths (1, 2, and 3 cm), RH initial concentrations (100, 150, and 200 mg/L), and volumetric flow rates (2.0, 4.0, and 6.0 ml/min) on the performance of the breakthrough curve was studied. The highest adsorptive capacity of sorbent was observed to be 12 mg/g using bed height 3 cm, flow rate 2 ml/min and inlet RH concentration 200 mg/L. The breakthrough time was found to increase with increase in bed depth, and decrease with increase in initial concentration and volumetric flow rate. Among all the kinetic models examined, Yoon–Nelson model was found to be most suitable for simulation of the breakthrough curve of RH uptake on SMBB in fixed bed column. The study revealed that SMBB could be a potential sorbent for efficient removal of RH in fixed-bed adsorption column.

1. Introduction

Over the past few decades, researchers has turn out to be progressively worried about the potential public health effect of new ecological contaminants originated from industrial, agricultural and human activities [5]. These newly found emerging pollutants are the substances that were previously undetected or had not been considered as a risk [42]. It includes prescription and non-prescription human and veterinary pharmaceutical compounds and personal care products (PPCPs). They are pervasively exposed into water and introduced in aquatic environment, for example, surface water, waste water from drug manufactures, spillover, etc [19,20]. The significant concern of widespread pharmaceuticals is that it causes unfavorable and chronic impacts including antibiotic resistance and antagonizing hormones to humans, even at extremely low concentration levels [37]. Nonetheless, little is thought about the event, destiny, synergistic, and long haul impacts of these contaminations and their metabolites taking after their end-utilization as they pose a potential risk for future drinking water resources [6].

Ranitidine hydrochloride (RH) is a H_2 receptor antagonist that is generally utilized for short-term gastric treatment and duodenal ulcers, Zollinger–Ellison syndrome, reflux esophagitis, high intestinal bleeding etc. It is chemically a furan derivative, with a nitroenamine urea polar group and dimethylamine group enhancing the basic character of its heterocyclic moiety. It is produced in tons every year and effortlessly consolidated in unconstrained component of environmental contamination, particularly in urban zones [8]. After being excreted through urine and feces, parent compounds or metabolites of ranitidine reach the sewage system, as wastewater treatment plant can not remove them completely [14], are ended up in surface water mainly in river.

It is worth-mentioning that conventional wastewater treatments are not viable to eliminate and/or to degrade the majority of these pharmaceuticals compounds. They are somewhat dispensed with, along these lines leftover amounts stay in treated water, and have been found to aggregate in drinking (tap) water [17].

Several methods such as adsorption [32], ozonation and advanced oxidation processes [18,33] and membrane filtration [43], have been reported to expel PPCPs from water of different qualities. Among these methods, adsorption processes have been

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proved to be superior over other techniques for drinking water treatment plants (DWTPs) on account of its simplicity of design and operation, cost effectiveness and insensitiveness of toxic substances [39]. Different adsorbents, for example, activated carbon, clay, alumina, silica, mesoporous silica, functionalized mesoporous silica, zeolite, and metal–organic frameworks have been utilized for evacuation of pharmaceuticals as a part of water treatment process [9,10,16,25,27,29,26]. However, the success of a sorptive removal of contaminants from aqueous solution greatly depends upon efficacy of sorbent material. In this regard, agricultural waste materials particularly which are cheap, effortlessly accessible, available, and delivered overall, could be an attractive option for its use as precursor in manufacturing engineered biochar towards remediation of undesirable compounds from wastewater. Diverse sorts of horticultural waste utilized for serving this purpose are: sugarcane biomass, peanut husk and so on [21,34]. Mung bean, the seeds of *Vigna radiate* is local from the Indian subcontinent, and it is a standout amongst the most imperative grain legumes in South Asia [28]. Around 90% of world's mung bean is produced in Asia, and India is the top maker of this crop. Mung bean husk (MBH) is cultivated in 4.2 million hector territory with the yearly limit of 1.3 million tones creation in 2008 [28]. This bean husk, an agro by product that is created amid processing of mung bean by legume seed splitting process, has been utilized as an effective precursor in developing adsorbent for RH removal. The change of a waste material into a valuable commodity towards the removal of a potential contaminant is by all accounts an attractive way in monetary and ecological perspective.

Till date, most of the adsorption studies for the treatment of contaminant-laden wastewater have been reported to be performed in batch operation. The data obtained during batch adsorption is not sufficient to provide accurate scale-up data required in the design of adsorption columns. Therefore, studies of column adsorption systems are required, in which column breakthrough curves are determined, and that is useful for determination of the operating life span of the fixed adsorbent bed. The present study is the first case where sorptive removal of ranitidine hydrochloride has been investigated in fixed bed column reactor using mung bean husk derived steam active biochar as an adsorbent. Moreover, different error function analysis has been done among the different model to analyze the model giving least error for measuring the adsorptive capacity of the adsorbent.

Therefore, the objectives of this study are: (1) to evaluate practical applicability of the activated biochar developed from steam activated mung bean husk biochar for the removal of RH from aqueous solution in column operations.; (2) to investigate the influence of important design parameters such as initial RH concentration, flow rate of fluid and column bed height on RH removal, and to analyze the obtained breakthrough curves using different adsorption column models and (3) to make a comparative study of six different error functions in minimizing the error distribution between the experimental and predicted adsorptive capacity by using different column models.

2. Materials and methods

2.1. Material

In the present study all chemicals used were of analytical reagent grade. The ranitidine hydrochloride was purchased from Sigma–Aldrich, India. The physicochemical properties of ranitidine hydrochloride are depicted in Table 1. Drug solution was prepared by doubly distilled water obtained from Merck Millipore water system (Merck, Germany).

2.2. Adsorbent preparation

The mung bean husk was used as raw material for indigenous preparation of activated biochar and was purchased from a local shop in Durgapur, India. The MBH was washed with bi-distilled water for several times and dried them under intense sunlight to obtain the preferred precursor. The raw material was then carbonized in a spherical-shelled muffle furnace at 550 °C for 1 hour maintaining a heating rate of of 55 °C/15 min. The carbonized char was activated at 650 °C by passing superheated steam at 1.5 kg/cm^2 pressure into furnace chamber. The activated biochar was then cooled down to room temperature in desiccator and used for the experiment.

2.3. Characterization of adsorbent

Scanning electron microscopy (SEM) analysis was carried out to investigate the surface textures and the development of pore of sorbent material. Adsorption of nitrogen at a temperature of 77 K prompts a purported adsorption isotherm, once in a while alluded to as BET isotherm, which is basically measured over permeable materials. The Brunauer–Emmett–Teller (BET) surface area analyzer (Quantachrome NOVA 2200C, USA) was utilized to quantify the surface area and total pore volume of the prepared carbonized char and steam activated biochar. Furthermore the surface chemistry of the adsorbent the pH of the point of zero charge (pH_{pzc}) was also measured. X-ray diffraction patterns of the adsorbent were collected on a PANalytical X'pert pro model diffractometer.

Table 1
Physico-chemical characteristics of ranitidine hydrochloride.

I.U.P.A.C name	(E)-1-*N*′-[2-[[5-[(dimethylamino) methyl]furan-2-yl]methylsulfanyl]ethyl]-1-*N*-methyl-2-nitroethene-1,1-diamine;hydrochloride
Solubility	Freely soluble in water
CAS number	66357-59-3
Empirical formula	$C_{13}H_{23}ClN_4O_3S$
Molecular weight	350.86472 g/mol
Molecular structure