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Green activated carbons from different waste materials for the removal of iron from real wastewater samples of Nag River, India

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ABSTRACT

Iron is essential virtually for every life form including humans, but our body has limited capacity to excrete iron, which means it can easily build up in organs like the liver, heart and pancreas. Therefore it is necessary to remove iron contamination, which can cause dangers to the human body. The present work is related with the preparation of green adsorbents using waste materials such as coconut shells, orange peels, sawdust and *C. procera* leaves so as to evaluate the cheapest and easiest means of iron removal. The Nag River water (India) was used as source of iron contaminated water. All the selected waste materials were carbonized in muffle furnace and activated using different agents such as HCl, HNO_3, and H_2SO_4. The results showed that all adsorbents have the potential capacity to remove iron, which further strongly increases after its activation. The most promising green adsorbents were found to be orange peels and the best activating agent was HCl. The order of iron removal from wastewater is: orange peels > coconut shells > sawdust > *C. procera* leaves. Similarly it was found that charcoal activated with HCl can remove around 77–90% iron followed by HNO_3 (70–80%) and H_2SO_4 (58–75%).

1. Introduction

Iron is important for every life form (including humans), where it is a key-factor of various proteins and enzymes, involved in the transport of oxygen and the regulation of cell growth and differentiation, among many other uses. One of the most important roles of iron is to provide hemoglobin. If you have too little iron, you may experience fatigue, decreased immunity or iron-deficiency anemia, which can be serious if left untreated. However, if you have more iron than your body needs to satisfy your hemoglobin requirement (for cell oxygenation), the excess becomes a dangerous surplus. This is an issue that deserves attention, as research examining iron levels in Americans shows that more people have iron levels that are considered too high, than levels that are deficient. In one study of more than 1000 people, only 3% were iron deficient, but 13% had iron overload.

Our body has a limited capacity to excrete iron, which means it can easily build up in organs like the liver, heart and pancreas. This is dangerous because iron is a potent oxidizer and can damage your body tissues contributing to serious health issues including: cirrhosis, liver cancer, cardiac arrhythmias, diabetes, Alzheimer's disease, bacterial and viral infections.

One of the main sources of excess iron in human body is through either consumption of vegetables and food stuffs congaing high amount of iron or through drinking iron containing water. As India is a farming based country most of the farmers are dependent on river water for its irrigation. Nag River is one of them, which is the easiest and cheapest source of irrigation water for farmers of this region. But the river serves as drainage for the city of Nagpur. Its ecosystem is extremely polluted by urban waste pollution from Nagpur. Nag River passes through the Nagpur city and is heavily polluted as many small and big industries discharge their wastewater (without any retreatment or partial treatment) into this river. Vegetable farming in Nagpur is mainly conducted by farmers with low socio-economic status cultivating small or marginal landholdings small farm holders. Chemical contamination from sources such as industries, vehicles and pesticides can affect the safety of food. Heavy metals are one of a range of important types of contaminants that can be found on the surface and in the tissue of fresh vegetables. Prolonged human consumption of unsafe concentrations of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical process in the human body.

The present work is related with the preparation of green adsorbents using waste materials such as (i) coconut shells, (ii) orange peels, *Calotropis* leaves and (iii) sawdust, so as to evaluate the cheapest and easiest means of iron removal and find an effective suitable low-cost adsorbent. Adsorption is considered to be one of the most applied processes in recent years for the decontamination of wastewaters [1–16]. This is

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attributed to its efficiency of removal from dilute solutions. Although the use of common materials (activated carbon [17], chitosan [18], zeolite, clay [19]) is still very popular due to the high adsorption capacity, but they are expensive. Thus, there is a growing demand to find relatively efficient, low-cost and easily available adsorbents. Researchers were oriented towards no expensive adsorbents. Nowadays, researchers apply the so-called "low-cost" or "zero-cost" materials as adsorbents in order to further reduce the cost of the process.

Activated carbons possess large surface area, as mentioned above and different surface functional groups, which include carboxyl, carbonyl, phenol, quinone, lactone and other groups bound to the edges of the graphite-like layers. Therefore, they are regarded as good adsorbents for the removal of heavy metal ions and other inorganic substances, as well as many organic compounds from liquid and gas phases [20]. Both surface chemistry and texture of carbons are affected by the nitrogen source and the type of oxygen functionalities preexisting on the surface [21,22]. Acid–base interactions were found to essentially govern the ammonia removal by modified activated carbons [23].

The Nag River water was used as source of iron contaminated water because the concentration of iron (Fe) and zinc (Zn) ions in waters of Nag River is very high compared to the World Health Organization/UN Food and Agriculture Organization (WHO/FAO) maximum permissive limits for Irrigation, while the concentrations of copper (Cu) and Mn (manganese) ions are slightly above the permissible limits as shown by researchers of Nagpur University on Nag River [24]. The prepared adsorbents were activated using different activating agents such as HCl, HNO_3 and H_2SO_4 to check the efficiency of adsorbents for its iron removal capacity by activation.

2. Materials and methods

2.1. Sampling and storage

The sampling was done as prescribed in IS 3025 (Part 1) [25]. The sampling bottles were cleaned thoroughly with aqueous solution HNO_3 (6 N), prior to the final rinsing with water. The wastewater samples were collected from five different villages: (i) Bharatwada, (ii) Pawangaon, (iii) Asoli, (iv) Mahalgaon and (v) Dighori of Nagpur District, which are located around the difference of 5 km of each other along the bank of Nag River (Nagpur). These villages were selected for study purposes, because all of them are situated along the Nag River and the vegetable farming in these areas is done by irrigating with Nag River water, which is highly polluted due to domestic wastewater and small scale industries effluents which is drain into this river (Fig. 1).

The samples were stored preferably in polypropylene bottles. For the determination of dissolved iron content, filtration through 0.45 μm membrane filter (at the time of sampling) was done (Fig. 2). The analysis of such samples was carried out during the day of sampling. For preservation, the samples were acidified with concentrated HNO_3. The acidified samples were stored for a few days (up to 5 days) in refrigerator.

2.2. Adsorbents

The green waste materials required for this research work were collected locally. Especially, coconut shells were collected from Famous Ganesh Temple of Nagpur (India), orange peels were supplied by a local juice shop, and *Calotropis procera* leaves were collected from plants growing locally. Wastes of coconut shell (denoted as COC), orange peel (denoted as (ORP), sawdust (denoted as SWD), and *C. procera* leaves (denoted as CALT) were cut into small sizes, washed and then dried for 24 h. Then, they were placed for carbonization in a Muffle Furnace (Bio Techniques India, Model No. BTI-40, India) at 500 °C for 2 h. The charred products were allowed to cool at room temperature for 12 h and then crushed and sieved (0.2 mm). For the activation of carbon samples, the chars were weighed and poured in different beakers containing known quantity of dilute HCl, HNO_3 and H_2SO_4. The content of the beakers was thoroughly mixed until a paste of each was formed. The pastes of the samples were then transferred to crucibles, which then placed in a Muffle furnace and heated at 500 °C for 2 h at a heating rate of 25 °C/min under nitrogen flow of 0.5 L/min. The activated samples were then cooled at room temperature, washed with distilled water to a pH of 6–7, and dried in an oven at 105 °C for three hours. The final products were sieved to same particle size kept in air tight

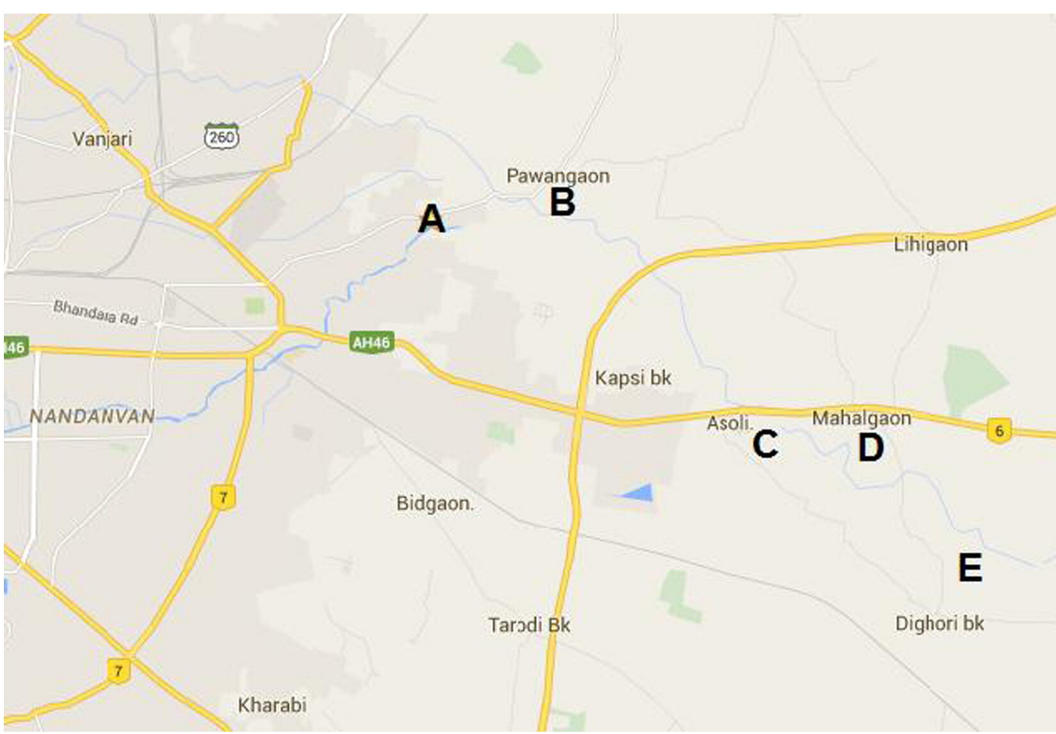

Fig. 1. Sampling location in villages near Nag River, India: (A) Bharatwada, (B) Pawangaon, (C) Asoli, (D) Mahalgaon and (E) Dighori.