Fe-BIOCHAR COMPOSITE FOR THE REMOVAL OF DYE IN WASTEWATER USING ADSORPTION METHOD

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Abstract - *Use of various dyes in order to color the products is a common practice in textile industry. The presence of these dyes in water even at low concentrations is highly visible and undesirable. The biochar composite has become a hotspot as an adsorption material. It is an impurity adsorption material that shows promise and has prospective use in domains related to soil enhancement and sewage purification. This material can effectively remove the dye in wastewater. Using a spectrophotometer, kinetic studies and dye tests, the structural features and adsorption capabilities are studied. It was found that the biochar composite has a high specific surface area and pore volume. Compared to other adsorbents, this composite truly achieves the concept of "waste control by waste". Food waste derived biochar and Fe-Biochar composite are prepared by the pyrolysis process. The sequence of addition of ferric chloride differs for food waste derived biochar and Fe-biochar composites and the subsequent removal of Methyl orange dye and Congo red dye from wastewater.*

Key Words: Food waste derived biochar, Fe-biochar composite, pyrolysis process, adsorption, muffle furnace, magnetic stirrer.

1. INTRODUCTION

Environmental pollution has emerged as one of the unavoidable issues facing the world in recent years as a result of the advancement of industrial growth. The atmosphere, soil, and water are exposed to chemical reagents, biological materials, and certain solid or liquid industrial pollutants. Enormous quantities of pollutants are released into the river. Particularly considering in India, the increasing number of population led to development of many industries. Focusing on the textile industry, which is one of the most polluting industries in the world. 20% of all fresh water pollution is made by textile treatment and dying. At Haridwar, India, researchers tested the levels of metals in the soil and groundwater that are close to the textile and tannery businesses. According to the findings, the levels of all the metals, including chromium, iron, manganese, copper, lead, and cadmium, was higher than those considered safe by the World Health Organization (WHO). These can lead to a variety of issues for living things. Various toxic dyes are also released by the textile industries which are nothing but the main focus of this paper.

1.1 Dye-Usage of dye in textile industry

A dye is a material, either natural or artificial, used to color or alter the color of something. To chemically bind the dye's color to the fiber, dye is applied in an aqueous solution. As we all know, people have varied preferences, particularly when it comes to clothing, where they prefer various colors. Dye is employed in order to produce various colors. Methyl orange, Congo red, malachite green, crystal blue, and other colors are among the ones used. Fabrics are given specific colors by dyes when they are applied to them.

1.2 Release of dyes – Environmental impacts

After the application of dyes, they are lost to effluents and released into the water bodies. These dyes are not removed even after primary and secondary treatment. In the textile industry, different textile materials can be dyed using batch, continuous, and semi-continuous processes. These require different dyes, yarns, and fibres. Even though these dyes escape conventional water treatment and are released into the environment. Because dyes contain colour, they will tint the water when they are introduced into water bodies. Due to the properties of dye, they resist the biological degradation. The dyes seriously affect the transparency of water bodies and also their quality. This will eventually damage the aquatic life also.

Some dyes decrease the light penetration, which decreases the amount of oxygen in the water. Apart from natural dyes, azo dyes are mostly used in textile industries. These azo dyes can have toxic effects on the water and increase the levels of biochemical oxygen demand (BOD) and chemical oxygen demand (COD). If these dyes enter the human body, they will cause intestinal problems, liver problems, and many other harmful effects. Water that contains dye should be cleansed before being released into a water body. The impact of the textile industry on water can be devastating, but the good news is that there are ways to reduce its damage to the environment. Physical and chemical techniques, biological techniques, and sophisticated oxidation techniques such as flocculation, precipitation, and membrane separation technologies are currently the main ways to manage dye effluent. Adsorption among these systems has distinct benefits, such as absorbing the entire dye molecule and leaving no fragments in the effluent, and is also a cheap method for the removal of dye.

2. MATERIALS AND METHODOLOGY

2.1 Materials

Congo red ($C_3H_{22}N_6Na_2O_6S_2$), methyl orange (MO), ferric chloride ($Fecl_3$), Rice straw, Food waste, i.e., vegetable peels and fruit peels, Distilled water, Sodium hydroxide (NaOH).

2.2 Methodology

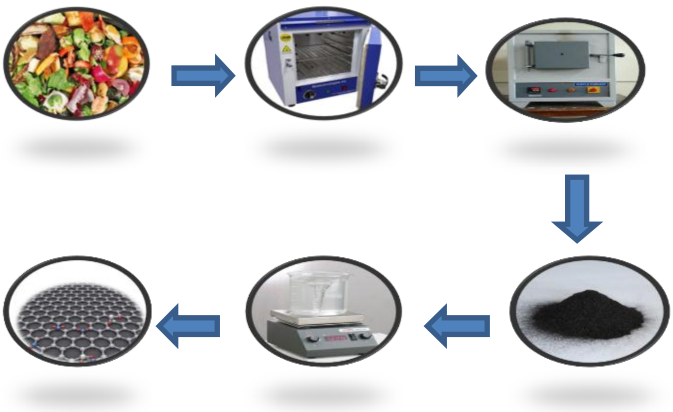


FIG-1 : Preparation of Fe-Biochar composite and Food waste derived biochar

2.3 Methods used

2.3.1 Pyrolysis

Pyrolysis is the heating of an organic substance like biomass without oxygen. Typically, biomass pyrolysis is carried out at or above 500 °C, which provides enough heat to break down the previously stated robust biopolymers. Because there is no oxygen, combustion cannot take place; instead, the biomass thermally breaks down into combustible gases and biochar.

2.3.2 Adsorption

The phenomenon of attracting and holding onto a substance's molecules on the surface of a liquid or a solid, resulting in a larger concentration of the molecules on the surface, is known as adsorption. When charcoal is dipped into a colored solution, the color of the solution fades as a result of the charcoal adsorbing the colored particles. Adsorption is the process by which the surface of another substance accumulates molecular, atomic, and discoloring ionic species of a first substance.

2.4 Preparation of Food waste derived biochar

Collect different types of food waste. The food waste can be any vegetable or fruit peel. Let the food waste dry in the oven at 102 degrees Celsius for 24 to 48 hours. After drying, the food waste loses its moisture content. Now, cut the food waste into fine pieces and keep it in a muffle furnace using crucibles at 500° Celsius for 1 hour. Now the finely cut piece turns into powder and forms biochar.

Take 100 ml of distilled water, add 5 g of biochar, and 0.5 g of $FeCl_3$, and stir continuously at 130 RPM for 2 hours using a magnetic stirrer. During stirring, add 1 mole of NaOH drop wise till the PH reaches 9 units. Filter the solution through a filter paper to separate the Fe-Biochar composite. Wash it with distilled water five times, which gives the Fe-Biochar composite. To get the biochar in a dry state, the biochar obtained is oven dried, which gives the biochar in powdered form.

FIG-2: Food waste after oven dried at 102^{θ} C

2.5 Preparation of Fe-Biochar composite

Take 10g of rice straw and chop it into small pieces. Now take 5% of 10g of ferric chloride and mix it thoroughly with the rice straw. Keep it in the muffle furnace for 30 min at 500° Celsius. Now grind it into fine powder.

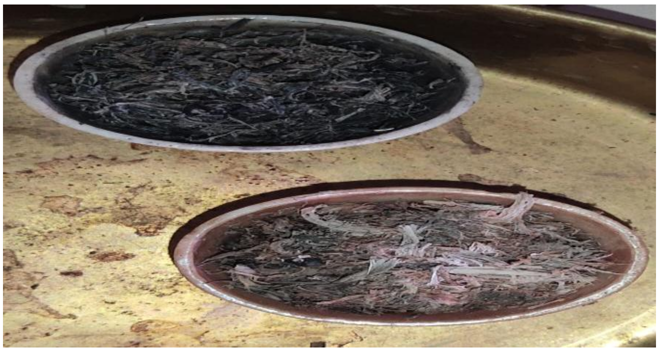


FIG-3: Fe-biochar composite after pyrolysis process

2.6 Characterization of Food waste derived biochar and Fe-biochar composite

Surface morphology information of Food waste derived biochar and Fe-biochar composite was obtained by scanning electron microscope.

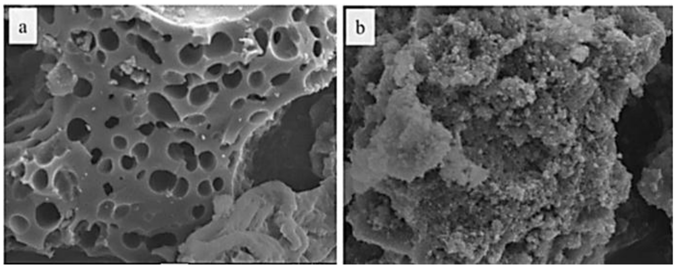
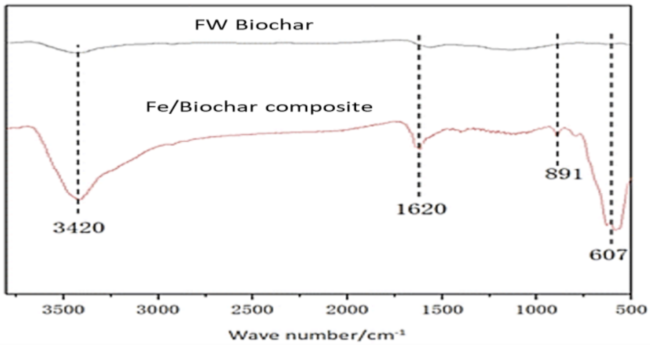
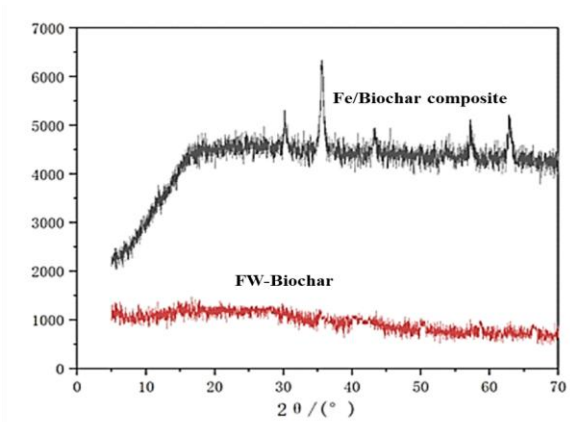


FIG 4: Scanning Electron Microscopic (SEM) image: (a) Food waste derived biochar and (b) Fe-biochar composite

FT-IR information of Food waste derived biochar and Fe-biochar composite was acquired using the FT-IR electro spectrometer.



GRAPH 1: FTIR Spectra: Food Waste (FW) derived biochar and Fe/Biochar composite



GRAPH 2: FTIR Spectra: Food Waste (FW) derived biochar and Fe/Biochar composite

2.7 Removal of dye

2.7.1 Methyl orange

Take 7.5 ml of methyl orange. Add up to 100ml of distilled water to the methyl orange solution to dilute it. Fe biochar should be weighed out and then added to the mixture. The same is true for biochar made from food waste. Stir the solution constantly for three hours using a magnetic stirrer. After that, filter the solution using filter paper and track the changes. Verify the solution's PH both before and after the experiment. Test other samples by increasing the amount of Fe biochar or the time spent on a magnetic stirrer until the dye is completely removed, or perhaps up to 70% of it. The same holds true for biochar made from food waste.

FIG-5: Methyl orange test samples

2.7.2 Congo red

Take 1g of Congo red and add it to 1000ml of distilled water. Now take 10 ml of the above solution and dilute it to 100ml.Weigh consecutive quantities of biochar and add it to the solution. The process is same as that of methyl orange the only difference is methyl orange is taken in liquid form while Congo red is taken in powdered form. Here in this project azo anionic dyes are tested.

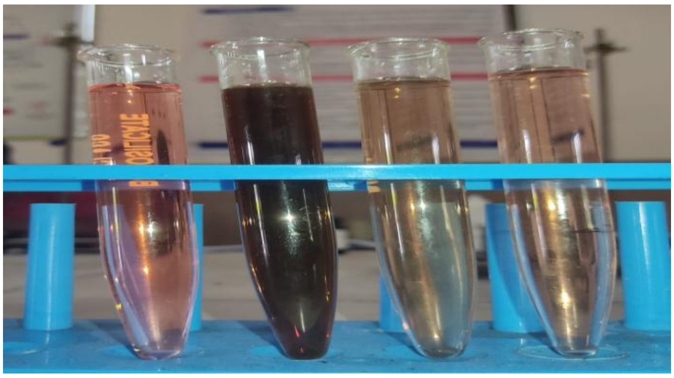


FIG-6: Congo red test samples

3. RESULTS

The total adsorption amount was calculated using the equation below:

$$q_e\ (mg/g) = \frac{C_0 - C_e}{m} \times V$$

Where C_0 and C_e are initial concentrations and equilibrium concentrations of CR and MO (mg L^{-1}), respectively; q_e is the equilibrium adsorption amount of adsorbent (mg g^{-1}); m and V are adsorption mass (g) and solution volume (L), respectively.

$$\text{Removal rate (\%)} = \frac{C_0 - C_e}{C_0} \times 100$$

Let us consider a sample, for a duration of 3 hours with an initial concentration (C_0) of 30 mg/L and using the adsorbent dose of 1 g/L, the maximum adsorption was calculated as follows:

C_0 = 30 mg/L

C_e = 6.5 mg/L

V = 0.5 L

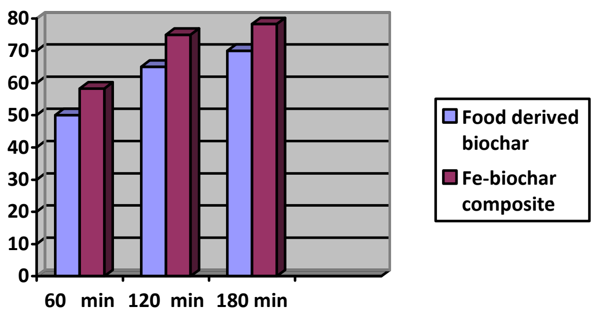
m = 0.5 g

$$q_e\ (mg/g) = \frac{(30 - 6.5)\ 0.5}{0.5}$$

$$= 23.5\ mg/L$$

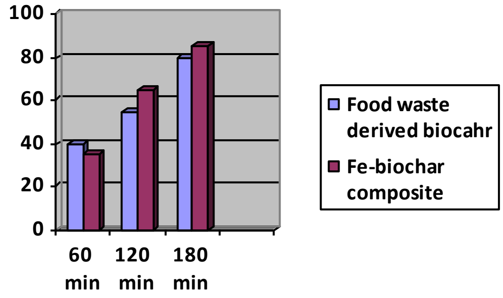
Removal (%) = 78.3 %

The below-mentioned graph is the result of the usage of Fe-biochar composite and Food waste derived biochar in the adsorption process for methyl orange dye.



GRAPH 3: Removal rate of Methyl orange using Fe-biochar composite and Food waste derived biochar

The below mentioned graph is the result of the usage of Fe-biochar composite and Food waste derived biochar in the adsorption process for Congo red dye.



GRAPH 4: Removal rate of Congo red using Fe-biochar composite and Food waste derived biochar

4. CONCLUSION

Comparing the 2 bio chars used above, Fe-biochar composites have a higher removal rate than food waste-derived biochar. The adsorption process used is effective in removal of azo anionic dye resulting in an average removal rate of 75%.

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