Development and Characterization of Antibacterial Activated Carbon Composite of Zinc and Oxide for Water Filtration as an Industrial Application

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Abstract. A scientific approach has been adopted in this research work to develop an antibacterial composite material by synthesizing the zinc and oxide together along with activated composite of carbon. NH_3, H_2O_2, ZnO, AC and H_2O were used in this context. Embedded together to convert the zinc oxide to activated carbon. The 2.5 g of zinc oxide along with 45 mL of ammonia mixed with 4 mL of H_2O_2. After that 250 g of activated carbon along with precursor solution was soaked for a period of 3 h. Immediately, after soaking the solution was kept for drying at room temperature for a period of 12 h. After drying, the product was sintered in the sintering furnace at a temp: of 248 °K (120 °C) for a soaking period of 2 h. The morphology was analyzed with the help of XRD and SEM. The XRD peaks clearly shows the zinc oxide and activated carbon product and also the SEM micrographs reveal the porous structure of the composite of ZnO activated carbon. It is concluded that the antibacterial activated carbon composite of zinc and oxide was successfully developed and can be used for water filtration.

Keywords: composite, activated carbon, zinc oxide, water filtration, XRD, SEM etc.

Introduction

The water pollution has been the major global issue in the past years. According to WHO (World Health Organization) impure water, less hygiene and sanitation are the main causes of death with estimate deaths of 871,000 in 2012 (WHO, 2015). These deaths have mostly been observed in lesser income societies and usually within the children age period of 5 years. Even around 6,600,000,000 people have been using better drinkable water sources according to the research of 2015, but the coverage of those services to safely provide the drinking water has been quite low with an estimation of 67% metropolitan areas and 21% in pastoral regions. (Azizullah *et al*., 2011). It has been estimated that about 1/3 of the inhabitants does not have the ingress to improved sanitation (free from germs) means around 946,000,000 population who performed open excretory products. (Sumrit *et al*., 2015; Zhang *et al*., 2011). It was estimated that 108 thousand deaths occurred due to involuntary poisoning. In the low middle income countries like Pakistan insecticides, kerosene, chemicals for household and CO (carbon monoxide) are all one of the main causes of this unintentional poisoning. (Ali *et al*., 2017; Wisner *et al*., 2006). In developed countries the material involved for the poisoning contain CO (carbon monoxide), medicines and personal care items in the home. Therefore, the need for the water purification should be the top most priority for ensuring the safety of public drinking water. (Lu *et al*., 2015; Wiesner *et al*., 2006). Deployment of activated carbon (AC) in the filtration of water has been one of the keen interests of scientists and researchers because of its high surface area and its micro porous structure. (Shahid *et al*., 2019; Kumar, 2015). Activated carbon has been found greatly effective in removing the impurities in contaminated water. It is also known as an excellent absorbent for the nano or micro scale for the organic contaminants. But there is a limit for its use for the purification process. (Shahid *et al*., 2019; Ohira *et al*., 2016; Varaprasad *et al*., 2016). That is because the impurities which are adsorbed in activated carbon promote the fast growth of micro-organisms inside the activated carbon which results in secondary micro-organism contamination and reduces the life or activated carbon for water purification.

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(Cloudier *et al.*, 2015; Bei, 2011; Stamenov *et al.*, 2002). Some researchers have conducted that it is possible to impregnate the metallic particles into AC (activated carbon) which can be used to eliminate the microbes. Metals such as silver and zinc Nano particles have been found effective when used with activated carbon for bacteria elimination purposes. (Ali *et al.*, 2018; Gaashani *et al.*, 2013; Ali *et al.*, 2012; Padmavathy and Vijayaraghavan, 2008; Ali and Gupta, 2006). The reason for the use of ZnO-AC (zinc oxide activated carbon) in this project is because of the low cost and the ease of production which could result as a promising solution for the water purification problem in Pakistan. One of the drawbacks of activated carbon is a short service life this is due to the contaminants which can be filled in the adsorbing pores of activated carbon. (Osman and Mustafa, 2018; Menaka and Subiya, 2016; Zhiyuan *et al.*, 2016). Similarly one of the drawbacks of ZnO is that its large amount in human body is hazardous. (Ghorbanifar *et al.*, 2015). Therefore, we aspire to increase the service life of activated carbon and reduce the quantity of ZnO as possible with the highest service efficiency. (Alidad *et al.*, 2019; Kyunghwan and Hwang, 2014). The antibacterial property of zinc oxide activated carbon is applied to determine the ability of material to work against the bacteria. This sample is specifically work against the *E-coli* bacteria which can be killed by the presence of ZnO which are rested into the pores of activated carbon. When *E-coli* contaminated water is passed through the ZnO-AC then it will be trapped into the pores of activated carbon and can be killed by zinc oxide. (Bao *et al.*, 2012; Aboul and Ali, 2011).

Materials and Methods

The chemicals and experimental materials that were employed for synthesizing in this research and experimental work were buy from the local market. The complete description has been shown in the Table 1.

The materials and chemicals mentioned in the Table 1 were collected and embedded together to convert the zinc oxide to activated carbon. The 2.5 g of zinc oxide along with 45mL of ammonia mixed with 4mL of H_2O_2. After that 250g of activated carbon along with precursor solution was soaked for a period of three hours. Immediately, after soaking the solution was kept for drying at room temperature for a period of 12 h. After drying, the product was sintered in the sintering furnace at a temp: of 248 °K (120°C) for a soaking period of 120 min. The whole process cycle can be visualized in Fig. 1.

In this method the impregnation of ZnO nano-particle can occur by dissolving zinc sulphate in distilled water. This solution can be made in an Erlenmeyer flask. Then hexa methylene tetra amine can be added to this solution and the pH. can be maintain add hydro chloric acid HCl and sodium hydroxide (NaOH). Then we add activated carbon to this solution which is followed by continuous stirring in a shaking incubator at 70 °C for 24 h. After that it is filtered and dried at the temperature of 70 °C for 24 h. The solution is shown in Fig. 2.

The antimicrobial property of ZnO-AC can be determined by the following two methods.

Spread plate method. This is the method which is used to determine the bacteria in the culture or in the solution. It is an easier method to determine the quantity of Bacteria.
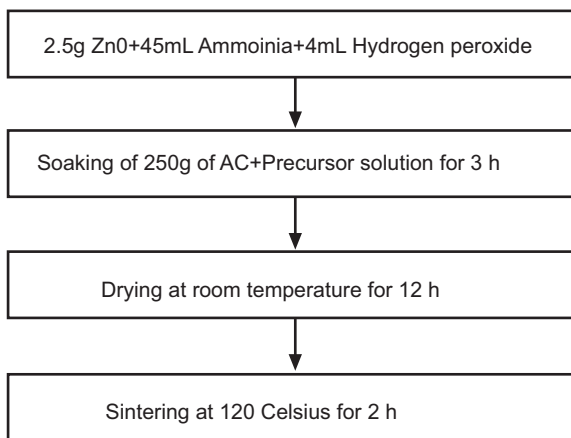
Table 1. List of chemicals used to develop the ZnO-activated carbon composite

Chemical name	Formula	Company name	Concentration
Ammonia solution	NH_3	Merck, Germany	40%
Hydrogen peroxide	H_2O_2	Merck, Germany	37%
Zinc oxide	ZnO	Industrial Grade	-
Activated carbon	AC	Industrial Grade	-
Deionized water	H_2O	Industrial Grade	100%

Fig. 1. Synthesize process flow chart of forming the solution.

Principle of spread plate technique. In this method a sterile spreader is used having smooth surface made of metal or glass. A small amount of liqu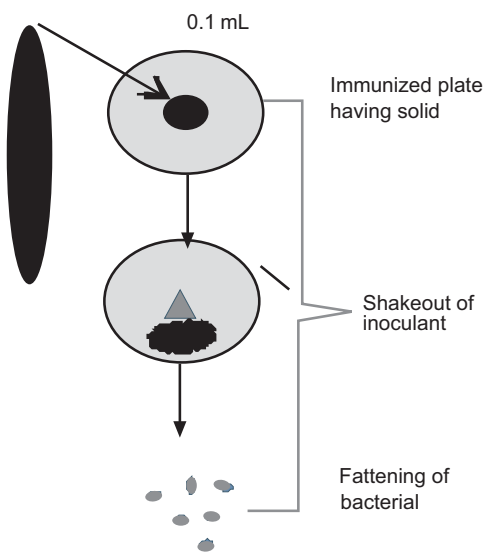id can spread over the plate. Then this surface can be dry so that the agar can absorb the bacteria. A quantitative colonies of bacteria can be formed on the plate which can be distributed evenly.

The Fig. 3. indicates the bacteria development using the spread plate method. A liquid sample activated carbon composite was spread on the plate to distinguish and isolate the bacteria for easy counting in numbers the bacteria in solution. The visibility and randomly distributed colonies of bacteria are now easy countable. The quantity and score of isolated bacteria are shown also shown in table form in each XRD peaks results.

Results and Discussions

To confirm that ZnO and activated carbon were successfully developed, an XRD analysis was taken as shown in Fig. 4 and Fig. 5. The peaks in the Fig. 4 in which carbon has a high peak and score can confirms that it is the product of carbon known as activated carbon. The peaks in the Fig. 5 and the score shows that this material can contain a high percentage of zinc and oxygen which can make a compound of zinc oxide.

After individually development of ZnO and activated carbon and confirmed by the ERD peaks shown in Fig. 4 and 5, an antimicrobial zinc oxide-activated carbon composite was analyzed in the similar method by XRD machine. The peaks of the composite are shown in Fig. 6.

The Fig. 6 shows that the high percentage of carbon that confirms the activated carbon. The ammonia evolves from our product so it is beneficial for us having a small
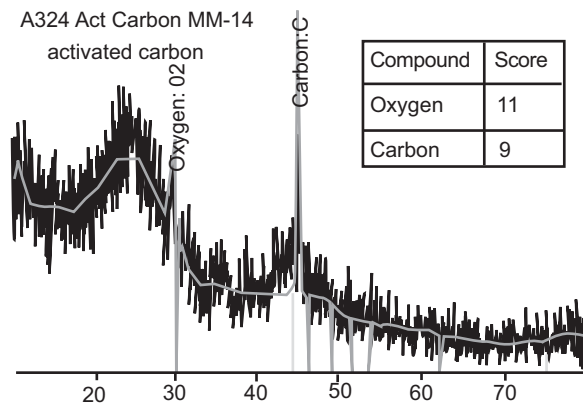

Powder of ZnO.

Powder of activated carbon.

Fig. 2. Powder of ZnO, powder of activated carbon.

0.1 mL

Immunized plate having solid

Shakeout of inoculant

Fattening of bacterial

Fig. 3. Plate count technique.

A324 Act Carbon MM-14

activated carbon

Oxygen: 02

Carbon:C

Compound	Score
Oxygen	11
Carbon	9

Fig. 4. Peaks of activated carbon indicates the presence of carbon.

score. The product also contains high percentage of oxygen. But this time the zinc oxide is remain in the product and does not make any other compound with other species. So, we have some sufficient amount of zinc oxide.

This Fig. 7a indicates the presence of activated carbon because such a carbon can called activated carbon having high porosities in which a species can be rested. The Fig. 7b can show that it also contain ZnO which can rested in these pores and act against the *E-coli* Bacteria to remove it from water.
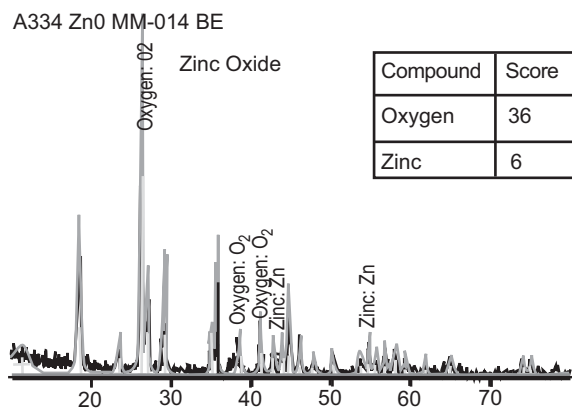

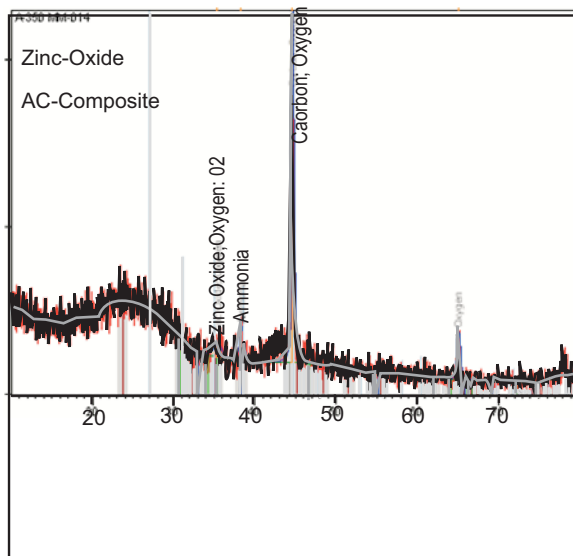**Fig. 5.** Peaks of ZnO indicates the presence of zinc oxide.

Fig. 6. XRD peaks shows the antimicrobial zinc oxide-activated carbon composite
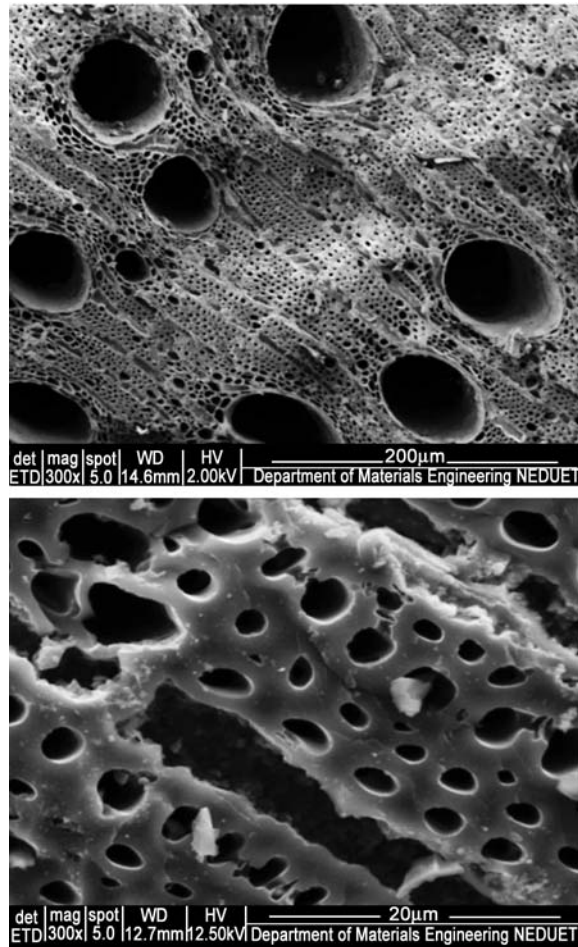

Fig. 7. SEM micrographs of ZnO and activated carbon composite.

Conclusion

In this research work it was successfully synthesis activated carbon and zinc oxide composite. The conformity of successfully synthesizing this composite product was done by the tools used for characterization such as X-ray diffraction (XRD) in addition of Scanning Electron Microscope (SEM). Three samples was developed and prepared in which sample "3" was the best one because the traces of ZnO were found in XRD pattern and have a peak around $35°$. Moreover, ZnO have a score of "14" which confirms the traces of zinc oxide. Scanning Electron Microscope (SEM) images also provided confirmation for the presence of ZnO and formation of ZnO-AC composite.

Future work. It is recommended and suggested to develop or culture the *E-coli* bacterial and a water filter. Water which is to be tested may be passed through this

filter and then check the bacteria killed, minimized or eliminated completely.

Acknowledgement

Conflict of Interest. The authors declare no conflict of interest.

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