Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Spl Issue [3] 2022: 354-360

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD

REVIEW ARTICLE **OPEN ACCESS**

The Versatility of Activated Form of Carbon as an Environment-Friendly Adsorbent

Aishwarya Shivaji Mahangade[1] and. Atul. A. Phatak[2*]
Department of Pharmaceutics, P.E.Societiy's Modern College of Pharmacy, Affiliated to Savitribai Phule Pune University, Sector No. 21, Yamunanagar, Nigdi, Pune, Maharashtra 411044
Corresponding author's Email: atulapin@yahoo.com

ABSTRACT
Activated carbon black also known as Activated charcoal is a fine black powder that is made by burning biomass in a low oxygen environment which develops pores and increases its surface area. Activated carbon black is used in the food and pharmaceutical industry as a pH regulator, chelating agent, and antioxidant synergist. Activated carbon black is highly beneficial to reduce environmental pollution and eliminate contaminants. Even though there is limited clinical data available on the use of Activated carbon black in the medical field it is a promising natural ingredient that may be explored for various healthcare applications. The use of activated carbon black has increased in the last two decades. Its good adsorbing properties and cost-effective manufacturing process made activated carbon black a widely used adsorbent in industries. Manufacturing of activated carbon black from the lignocellulosic mass is the research field of interest in today's emerging research trend. In this review, the manufacturing process, a brief introduction to the adsorption mechanism, and applications of activated carbon black in life sciences are discussed.
KEYWORDS: Activated carbon black (ACB), Healthcare, Adsorbent, Pollutants, Pharmaceutical

Received 09.08.2022 Revised 26.09.2022 Accepted 05.12.2022

INTRODUCTION

The origin of activated carbon black (ACB) is linked to Ancient Egypt (1500 BC), when the Egyptians exploited its adsorption characteristics for water purification and medicinal purposes [1]. Around 420 BC Hippocrates was observed to be dusting powder charcoal into the wound to remove the odor. In ancient times Hindu societies were using charcoal as a filter to purify the water [2]. In 1773, Karl Wilhelm Scheele the Swedish chemist was the first to observe gas adsorption on charcoal. A few years ago, activated carbon black began to be used in the sugar industry factories as a decolorizing agent for syrup [2]. The implicit use of ACB was actually subsidized during the first World War, whereby ACB was used in a gas mask against poisonous gases. Respiratory defensive biases were developed as particular defensive tools against the use of poisonous gases during wars [2]. Activated carbon black is being utilized to clean pollutants, as a chemical purifier, as an electrode, as a medical tattoo, and as a nanocarrier in the pharmaceutical business.

TYPES OF ACTIVATED CARBON BLACK [3]:

Activated carbon black can be classified into three types, ACB granular form, ACB in pellets form, and ACB in powdered form depending on the manufacturing method and bead size. The granular alternating current has a relatively large size and small outer surface. Granular ACB is used in a variety of liquid and gas phase applications, depending on the aspect ratio. ACB pellets are usually synthesized from petroleum pitch with a diameter of 0.35-0.8mm. It shows its high mechanical strength and low dust content. Due to its spherical structure, it is commonly used in fluidized bed applications such as water filtration. Fine granules of 1 mm in size and averaging 0.15 to 0.25 mm in diameter are used to create powered AC.

MECHANISM OF ADSORPTION

There are four main mechanisms for adsorption [3]: (1) bulk transfer, (2) film diffusion, (3) pore diffusion, and (4) intraparticle diffusion. Bulk transfer is the instantaneous transit of adsorbate molecules in the solution phase. The hydrodynamic boundary in the film diffusion form transports the adsorbate molecules to the external surface of the adsorbent molecule. The transfer of adsorbate molecules into adsorbent pores reduces the overall adsorption rate. Adsorbate molecules are adsorbed to the surface of

pores and are also trapped inside the pores from the adsorbent's outer surface, a process known as intraparticle diffusion.

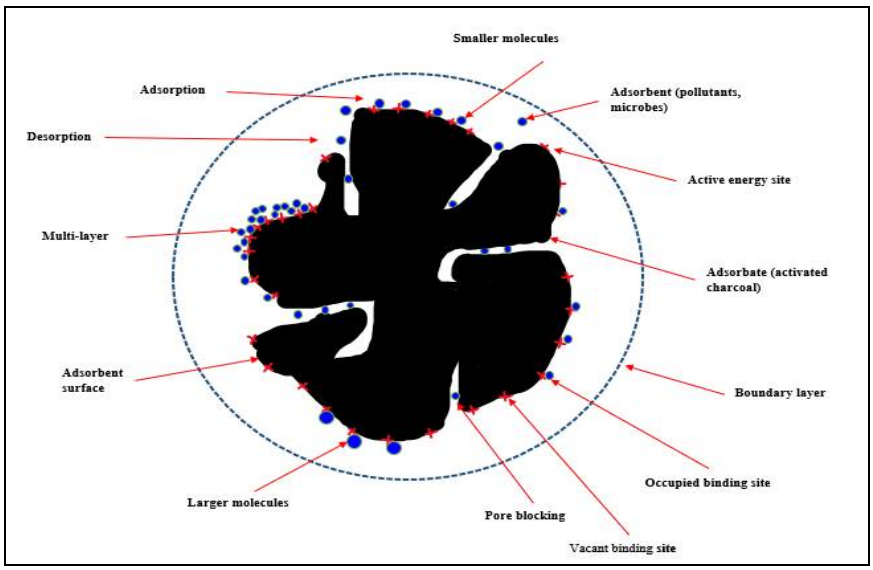

Figure.1: Mechanism of adsorption on activated carbon black

METHODS OF PREPARATION OF ACTIVATED CARBON BLACK:

1.Physical activation process: Physical activation process includes two basic physical steps, carbonization and activation.

Carbonization:

Carbonization is a process in which carbon materials such as biomass are heated in the absence of air to produce solid porous carbon. It is the destructive process of converting organic materials such as the remains of dead animals and plants into carbon. The raw material (biological source) undergoes thermal degradation in an inert environment at temperatures below 800^0C during the carbonization process [1]. Elements such as oxygen, hydrogen, nitrogen, and sulphur are removed from the source material during gasification, leaving biochar as a solid result [3].

Activation:

In order to completely create the pore structure, the carbon-rich material, or coal, must be activated. To do this, the coal is heated to a temperature between 800 and 900^0C while being exposed to air, co2, or water vapour [1]. The method used to create activated carbon can either be heat activation or chemical treatment, according to the origin of the raw material. Wet chemical techniques, which are basically one-step processes, and physical or gas-thermal processes, which are essentially two-step processes, are the two primary types of methods most frequently employed to generate activated carbon [1].

Chemical activation process:

In the chemical activation process, two steps are performed simultaneously, with the chemical activator mixing with the precursor as an oxidant and dehydrating agent, further heating the obtained carbon material under inert pressure. Commonly used chemicals as activators include zinc chloride ($ZnCl_2$), potassium hydroxide (KOH), phosphoric acid (H_3PO_4), and potassium carbonate (K_2CO_3) [4]. Research showed that the activated carbon black obtained from chemical process by using KOH has higher surface area (2878 m^2/gm) than prepared in steam pyrolysis process (2213 m^2/gm) [3].

Steam pyrolysis:

In this process, agricultural raw materials are heated in the temperature range of 500-700°C under a stream of pure steam, or in the higher temperature range of 700-800°C under a stream of steam [1]. Agricultural waste biomass such as tobacco stalks, rice husks, saws, banana husks, tropical wood waste, palm husks, corn cobs, coconut husks, hazelnut husks, jujube seeds, etc.used as an activation source for charcoal by biomass thermal decomposition [1].

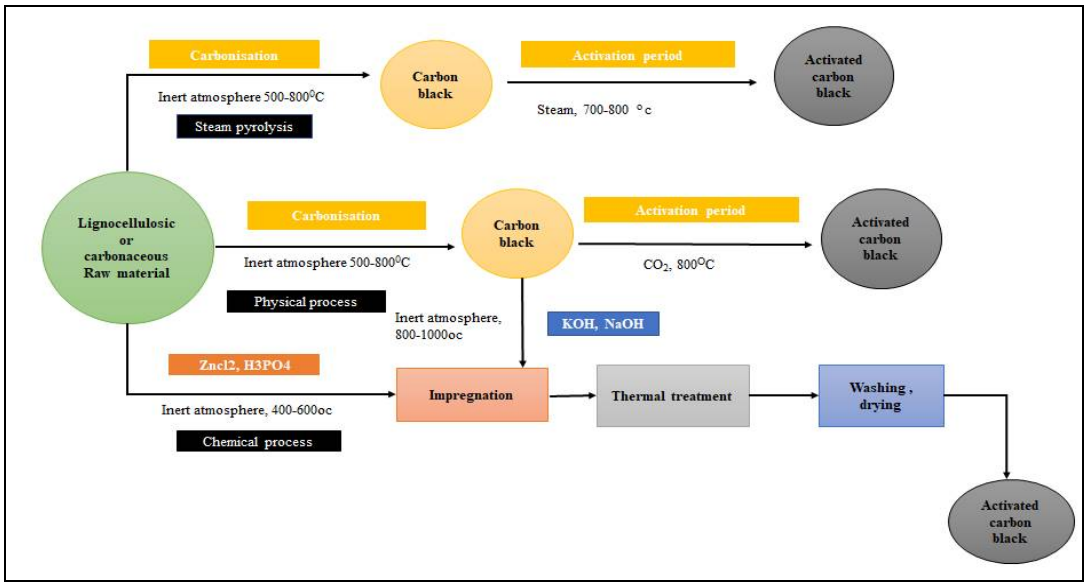

Figure .2: Process of manufacturing activated carbon black

TYPES OF PRECURSORS FOR ACTIVATED CARBON BLACK:

Carbonaceous natural materials are used as a precursor to producing activated carbon black. Different examples of precursors are listed in below table:

TABLE 1. List of biological material used as a precursor for manufacturing of activated carbon black

Sr No.	Precursor	Adsorbent	Maximum adsorption capacity	References
1.	**Coconut shell**	Phenol	23.745	[5]
2.	**Cocoa shell**	Diclofenac	63.47	[6]
3.	**Grape bagasse**	Cu (II)	43.47	[7]
4.	**Sucrose**	Methylene blue	707.20	[8]
5.	**Longan seed**	Cr (VI)	169.49	[9]
6.	**Walnut wood**	Pb(II)	58.823	[10]
7.	**Banana peel**	Malachite green	22.5	[11]
8.	**By-products from woody biomass**	Rhodamine B	189.83	[12]
9.	**Date seeds**	CO2	141.14	[13]
10.	**Potato peels**	Pb(II)	171	[14]
11.	**Fertilizer waste**	Pb(II)	1110.6	[15]
12.	**Apricot stone**	Cr(VI)	34.70	[16]
13.	**Rice Husk**	Cd(II)	2000.0	[17]
14.	**Orange peel**	Cd(II)	136.05	[18]
15.	**Wheat bran**	Cd(II	310.58	[19]
16.	**Mango peel**	Pb(II)	99.05	[20,21]
17.	**Tea waste**	Cu(II)	48.00	[22]

APPLICATIONS OF ACTIVATED CARBON IN HEALTHCARE:

1.Activated carbon black in Poisoning:

For a long time, activated carbon black has been used to treat acute poisoning and drug overdoses.Two recent studies have shown the potential importance of gastrointestinal activated carbon black in reducing the serum half-life of intravenous agents such as phenobarbital, theophylline, and digoxin [23]. Activated carbon black management has no real difficulties. It can be stirred in water until it has a thick soup-like consistency that children can entice to drink, taking no more time than finding and giving it to a child to drink. It is not a substitute for gastric lavage, but charcoal soup can be used to wash the liquid. When the wash is done, the last dose of charcoal broth remains in the stomach [23].

Hemoperfusion:

Hemadsorption, also known as hemoperfusion (HP), is a medical procedure used to purge the patient's blood of hazardous compounds. To remove harmful chemicals, huge quantities of the patient's anticoagulated blood must be run through an adsorbent material. The HP device usually consists of a polymer housing containing the sorbent particulate material through which the blood flows directly in a laminar flow [24].

Activated carbon black in Skin Care:

Activated carbon has the feature of adsorbing fat, darkish spots, and pollution connected to skin pores and skin. Activated Carbon Black is added to the beauty products of skin lightening creams. It is also commonly used in facial cleansers, pore-tightening patches, carbonated masks, and soaps. According to research, activated carbon-containing products can help with the treatment of seborrheic dermatitis, adult acne, wounds, and mild infections [25]. Additionally, psoriasis and eczema can be treated using its antibacterial and antifungal qualities.

Activated carbon black for Pharmaceutical Removal from waste water:

Pharmaceuticals are polluting waterways because of improper disposal and shortages in wastewater treatment plants. The effects of long-time period exposure in human beings are unknown however had been discovered in model organisms (i.e., fish), on reproduction, temper changes, and organ damage [26]. Adsorption of heavy metals and organic compounds like arsenic or iron is one of the traditional approaches used in purification [27]. Activated carbon black (ACB) is an effective adsorbent that is commonly used in drug removal like ibuprofen from water [28].

Activated black carbon Dressings on Chronic Wound Healing Results:

Activated carbon black is demonstrating its adsorptive influence on wound recovery. Activated Carbon Black is utilised to eliminate toxins from wounds and enhance wound healing, according to a case study on Actisorb [29]. In vitro studies have shown that activated carbon black may eliminate endotoxins and exotoxins from liquids [30]. Other test-tube experiments have demonstrated that activated carbon black eliminates 90 to 95 percent of this toxin when submerged in a media supplemented with Escherichia coli [30,31]. Silver is not liberated when it is integrated into the activated carbon matrix. .However, one test-tube study found that silver killed bacteria absorbed by activated carbon black, suggesting it would reduce the microbial load [32].

Activated carbon black in Dental Cleaning:

Use of Activated Carbon Black in dental products are beneficial for lowering yellow stains, for putting off acidic plaques, for remineralization of enamel and common development of oral health. to evaluate product efficacy and safety, controlled clinical studies and laboratory investigations are required[33].

Activated carbon black in Kidney disease and Pruritis:

Activated carbon black is widely used as an adsorbent in many fields, but there is little research regarding the preventive effect of medical charcoal on hyperphosphatemia and vascular calcification in stages 3–4 CKD patients with normal serum phosphorus and calcium levels [34]. Pruritis refers to the skin to the skin irritation and is common cause in renal failure. Pruritus in some dialysis patients is correlated with hyperphosphatemia, osteodystrophy, and increased serum parathyroid hormone. The clinical study showed that dialysis patients ingesting Activated Carbon Black have diminished perception of pruritus [35].

Activated carbon black used for the preservation of phototrophic and other sensitive bacteria:

Activated carbon black was found to protect photographic generated cultures from photooxidation by absorbing light and oxygen before to freeze-drying. This was done in order to preserve anaerobic phototrophic and other sensitive bacteria.. Mixture of activated carbon black (5% w/v) along with skim milk (20% w/v) and raffinose (5% w/v) or meso-inositol (5% w/v) in a suspending medium act as a protective agent for several anaerobic purple non-sulfur bacteria, Chromatiaceae, Ectothiorhodospiraceae and green sulfur bacteria were successfully preserved [36].

8.Activated carbon black in the treatment of hypercholesterolemia:

Preliminary studies have indicated that orally administered activated carbon black decreases the concentrations of LDL and total cholesterol in patients with primary hypercholesterolemia [37,38]. In some patients with renal insufficiency activated carbon black has reduced both total cholesterol and triglycerides [39], but in one preliminary report, it had no significant effect on serum lipids [40]. As different bile acids are avidly adsorbed in vitro by activated carbon black [41], the cholesterol-lowering effect of charcoal is probably due to their binding in the intestines, which leads to increased breakdown of cholesterol and to elevated plasma levels of its precursors.

The plant tissue culture and activated carbon black :

In tissue culture, activated carbon is frequently utilised to promote cell growth and development. It plays an important role in orchid seed germination, micropropagation, synthetic seed production, somatic embryogenesis, anther culture, rooting, shoot growth, tuber development, primary growth, etc.The effects of activated carbon black on formation may be primarily explained by its irreversible adsorption to inhibitory chemicals in culture media and the greatly decreased toxic metabolites, phenol secretion, and brown-colored secretion accumulation. [42].

Activated carbon black in breast cancer therapy:
Activated carbon black can be used as a black tattoo to localize the axillary lymph nodes in breast cancer patients undergoing neoadjuvant chemotherapy (NAC). Use of ultrasound technology activated carbon black has improved the efficiency by increasing high identification rate of lymph nodes in breast cancer treatment [43].

Activated carbon black as a Drug Nanocarrier:
Mesoporous Bamboo Carbon Nanoparticles (BCNPs) were created as smart Near Infrared light-responsive drug carriers for combined chemotherapy and PTT of the tumor. The BCNPs' wide surface area and high porosity significantly improved the efficiency of drug loading. Doxorubicin (DOX), used as an active ingredient, has been taken up by the BCNPs and may be released on demand in response to Near-infrared light stimulation. This mechanism results in a synergistic effect of BCNPs and DOX and reduced drug resistance of DOX in MCF-7 cancer cells [44].

CONCLUSION
Different carbon forms have many applications in human life to cure diseases and improve the lifestyle of human beings. As new technologies are getting involved in research methodology, applications of carbon black in healthcare are increasing. Apart from raw carbon, Graphene and Fullerene allotropes of black carbon are used as nanocarriers for drugs that is widely used in the pharmaceutical industry. From this review, it is clear that activated carbon black can be used as a good source in treatment as an adsorbent.

ACKNOWLEDGMENT
Dr. Atul. A. Phatak provided guidance for this work.

AUTHOR CONTRIBUTION STATEMENT
Dr. Atul. A. Phatak, designed the work and checked the complete manuscript, analyzed all data collected during the study. Aishwarya Mahangade, writing the original draft review and editing.

CONFLICT OF INTEREST:
Conflict of interest declared none.

REFERENCES
1. Tadda, M. A., Ahsan, A., Shitu, A., ElSergany, M., Arunkumar, T., Jose, B., Razzaque, M.A.& Daud, N. N. (2016). A review on activated carbon: process, application, and prospects. Journal of Advanced Civil Engineering Practice and Research., *2*(1):7-13.
2. EricL. (2010). Production, Characterization, and Applications of Activated carbon. University of Missouri., 1-55.https://doi.org/10.32469/10355/8078
3. Sharma, G., Sharma, S., Kumar, A., Lai, C. W., Naushad, M., Iqbal, J., & Stadler, F. J. (2022). Activated Carbon as Superadsorbent and Sustainable Material for Diverse Applications. Adsorption Science & Technology., 2022:1-21.
4. Lewoyehu M. (2021). Comprehensive review on synthesis and application of activated carbon from agricultural residues for the remediation of venomous pollutants in wastewater. Journal of Analytical and Applied Pyrolysis., 159:105279.
5. Hao, Z., Wang, C., Yan, Z., Jiang, H., & Xu, H. (2018). Magnetic particles modification of coconut shell-derived activated carbon and biochar for effective removal of phenol from water. Chemosphere., 211:962–969.
6. Saucier, C., Adebayo, M. A., Lima, E. C., Cataluña, R., Thue, P. S., Prola, L. D. T., Puchana-Rosero, M. J., Machado, F. M., Pavan, F. A., &Dotto, G. L. (2015). Microwave-assisted activated carbon from cocoa shell as adsorbent for removal of sodium diclofenac and nimesulide from aqueous effluents. Journal of Hazardous Materials., 289:18–27.
7. Demiral, H., &Güngör, C. (2016). Adsorption of copper(II) from aqueous solutions on activated carbon prepared from grape bagasse. Journal of Cleaner Production., 124:103–113.
8. Bedin, K. C., Martins, A. C., Cazetta, A. L., Pezoti, O., & Almeida, V. C. (2016). KOH-activated carbon prepared from sucrose spherical carbon: Adsorption equilibrium, kinetic and thermodynamic studies for Methylene Blue removal. Chemical Engineering Journal., 286:476–484.
9. Yang, J., Yu, M., & Chen, W. (2015). Adsorption of hexavalent chromium from aqueous solution by activated carbon prepared from longan seed: Kinetics, equilibrium and thermodynamics. Journal of Industrial and Engineering Chemistry., 21:414–422.
10. Ghaedi, M., Mazaheri, H., Khodadoust, S., Hajati, S., &Purkait, M. K. (2015). Application of central composite design for simultaneous removal of methylene blue and Pb2+ ions by walnut wood activated carbon. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy., 135:479–490.
11. Liew, R. K., Azwar, E., Yek, P. N. Y., Lim, X. Y., Cheng, C. K.,et.al. (2018). Microwave pyrolysis with KOH/NaOH mixture activation: a new approach to produce micro-mesoporous activated carbon for textile dye adsorption. Bioresource technology., 266:1-10.

12. Maneerung, T., Liew, J., Dai, Y., Kawi, S., Chong, C., & Wang, C. H. (2016). Activated carbon derived from carbon residue from biomass gasification and its application for dye adsorption: kinetics, isotherms and thermodynamic studies. Bioresource technology., 200:350-359.
13. Ogungbenro, A. E., Quang, D. V., Al-Ali, K. A., Vega, L. F., & Abu-Zahra, M. R. (2018). Physical synthesis and characterization of activated carbon from date seeds for CO2 capture. Journal of Environmental Chemical Engineering., 6(4):4245-4252.
14. Kyzas, G. Z., Bomis, G., Kosheleva, R. I., Efthimiadou, E. K., Favvas, E. P., Kostoglou, M., & Mitropoulos, A. C. (2019). Nanobubbles effect on heavy metal ions adsorption by activated carbon. Chemical Engineering Journal., 356:91-97.
15. Gupta, V. K., Srivastava, S. K., Mohan, D., & Sharma, S. (1998). Design parameters for fixed bed reactors of activated carbon developed from fertilizer waste for the removal of some heavy metal ions. Waste management., 17(8):517-522.
16. Kobya, M., Demirbas, E., Senturk, E., & Ince, M. (2005). Adsorption of heavy metal ions from aqueous solutions by activated carbon prepared from apricot stone. Bioresource technology., 96(13):1518-1521.
17. Ajmal, M., Rao, R. A. K., Anwar, S., Ahmad, J., & Ahmad, R. (2003). Adsorption studies on rice husk: removal and recovery of Cd (II) from wastewater. Bioresource technology., 86(2):147-149.
18. Sha, L., Xueyi, G., Ningchuan, F., &Qinghua, T. (2009). Adsorption of Cu2+ and Cd2+ from aqueous solution by mercapto-acetic acid modified orange peel. Colloids and Surfaces B: Biointerfaces., 73(1):10-14.
19. Nouri, L., &Hamdaoui, O. (2007). Ultrasonication-assisted sorption of cadmium from aqueous phase by wheat bran. The Journal of Physical Chemistry A., 111(34):8456-8463.
20. M. Iqbal, A. Saeed, I. Kalim., Characterization of adsorptive capacity and investigation of mechanism of Cu2+, Ni2+ and Zn2+ adsorption on mango peel waste from constituted metal solution and genuine electroplating effluent, Separation Science and Technology, 2009, 44(15):3770–3791.
21. Iqbal, M., Saeed, A., &Kalim, I. (2009). Characterization of adsorptive capacity and investigation of mechanism of Cu2+, Ni2+ and Zn2+ adsorption on mango peel waste from constituted metal solution and genuine electroplating effluent. Separation Science and Technology., 44(15):3770-3791.
22. Amarasinghe, B. M. W. P. K., & Williams, R. A. (2007). Tea waste as a low cost adsorbent for the removal of Cu and Pb from wastewater. Chemical engineering journal., 132(1-3):299-309.
23. Derlet, R. W., & Albertson, T. E. (1986). Activated charcoal—past, present and future. Western Journal of Medicine., 145(4):493.
24. Polaschegg, N. D., Ronco, C., & Soli, M. (2001). Characterization of flow-dynamic pattern in a new sorbent cartridge for combined hemoperfusion-hemodialysis. In Dialysis, Dialyzers and Sorbents., (133):154-165.
25. Finn, M., Giampietro, G., Mazyck, D., & Rodriguez, R. (2021). Activated Carbon for Pharmaceutical Removal at Point-of-Entry. Processes., 9(7):1091.
26. Mohindru, J. J., Garg, U. K., & Gupta, R. (2017). Coagulation-Flocculation Technologies for Arsenic removal -A Review. Asian Journal of Research in Chemistry., 10(3):405.
27. Phan, N. H., Rio, S., Faur, C., Le Coq, L., Le Cloirec, P., & Nguyen, T. H. (2006). Production of fibrous activated carbons from natural cellulose (jute, coconut) fibers for water treatment applications. Carbon., 44(12):2569–2577.
28. Kerihuel, J. C. (2010). Effect of activated charcoal dressings on healing outcomes of chronic wounds. Journal of Wound Care., 19(5):208–214.
29. Xiang-Nan, D., Zhen, N., Guo-Zheng, Z., &Zong-Ming, L. (1987). Effect of Activated Charcoal on Endotoxin Adsorption Part I. An in Vitro Study. Biomaterials, Artificial Cells and Artificial Organs, 15(1), 229–235.
30. Nolan, J. P., McDevitt, J. J., &Goldmann, G. S. (1975). Endotoxin Binding by Charged and Uncharged Resins. Experimental Biology and Medicine., 149(3):766–770.
31. Maitra, S. K., Yoshikawa, T. T., Guze, L. B., &Schotz, M. C. (1981). Properties of binding of Escherichia coli endotoxin to various matrices. Journal of Clinical Microbiology., 13(1):49–53.
32. Müller, G., Winkler, Y., & Kramer, A. (2003). Antibacterial activity and endotoxin-binding capacity of Actisorb® Silver 220. Journal of Hospital Infection., 53(3):211–214.
33. Brooks, J. K., Bashirelahi, N., & Reynolds, M. A. (2017). Charcoal and charcoal-based dentifrices. The Journal of the American Dental Association.,148(9):661–670.
34. Gao, Y., Wang, G., Li, Y., Lv, C., & Wang, Z. (2018). Effects of oral activated charcoal on hyperphosphatemia and vascular calcification in Chinese patients with stage 3–4 chronic kidney disease. Journal of Nephrology., 32(2):265–272.
35. Pederson, J. A. (1980). Relief of Idiopathic Generalized Pruritus in Dialysis Patients Treated with Activated Oral Charcoal. Annals of Internal Medicine. 93(3):446.
36. Malik, K. A. (1990). Use of activated charcoal for the preservation of anaerobic phototrophic and other sensitive bacteria by freeze-drying. Journal of Microbiological Methods., 12(2):117–124.
37. Neuvonen, P. J., Kuusisto, P., Vapaatalo, H., & Manninen, V. (1989). Activated charcoal in the treatment of hypercholesterolaemia: dose-response relationships and comparison with cholestyramine. European Journal of Clinical Pharmacology., 37(3):225–230.
38. Kuusisto, P., Vapaatalo, H., Manninen, V., Huttunen, J. K., &Neuvonen, P. J. (1986). Effect of activated charcoal on hypercholesterolaemia. Lancet (London, England)., 2(8503):366–367.
39. Friedman, E. A., Feinstein, E. I., Beyer, M. M., Galonsky, R. S., & Hirsch, S. R. (1978). Charcoal-induced lipid reduction in uremia. Kidney International Supplement., (8):S 170-6.

40. Hoekstra, J. B. L., &Erkelens, D. W. (1987). Effect of activated charcoal on hypercholesterolemia. The Lancet., 330(8556):455.
41. Krasopoulos, J. C., De Bari, V. A., & Needle, M. A. (1980). The adsorption of bile salts on activated carbon. Lipids., 15(5):365–370.
42. Thomas, T. D. (2008). The role of activated charcoal in plant tissue culture. Biotechnology Advances., 26(6):618–631.
43. Kim, W. H., Kim, H. J., Jung, J. H., Park, H. Y., Lee, J., Kim, W. W., Park, J. Y., Chae, Y. S., & Lee, S. J. (2017). Ultrasound-Guided Restaging and Localization of Axillary Lymph Nodes After Neoadjuvant Chemotherapy for Guidance of Axillary Surgery in Breast Cancer Patients: Experience with Activated Charcoal. Annals of Surgical Oncology., 25(2):494–500.
44. Dong X., Yin W, Yu J, Dou R, Bao T, & Zhang X,. (2016). Mesoporous Bamboo Charcoal Nanoparticles as a New Near-Infrared Responsive Drug Carrier for Imaging-Guided Chemotherapy/Photothermal Synergistic Therapy of Tumor. Advanced Healthcare Materials., 5(13):1627-1637.

CITATION OF THIS ARTICLE

Aishwarya Shivaji Mahangade and. Atul. A. Phatak. The Versatility of Activated Form of Carbon as an Environment-Friendly Adsorbent. Bull. Env. Pharmacol. Life Sci., Vol Spl Issue [3] 2022: 354-360