Ravi Verma, 2025, 13:4
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology

An Open Access Journal

Chemical Impregnation Methods Optimized For Spent Activated Carbon Regeneration

Ravi Verma[1], Manish Choudhary[2]

[1,2] Central Institute of Petrochemical Engineering & Technology, (CIPET) Lucknow, India

Abstract- **One efficient method for recovering the adsorptive capacity of spent activated carbon is to regenerate it through chemical impregnation. To regenerate the carbon and eliminate adsorbed pollutants, the spent activated carbon is treated with specific chemicals. The purpose of this study was to examine the properties of the regenerated activated carbon to determine whether it might be used in water purification applications. Spent activated carbon was gathered from the water purification unit's spent activated carbon cartridge. It is easily accessible and contains more carbon. At the ideal activation period, 1N KOH was used to activate the wasted carbon. The elemental analysis of spent activated carbon both before and after activation is the focus of this work. Scanning Electron Microscope (SEM), CHNS (elemental analysis), and significant index iodine number studies were used in this work. The goal of the current project is to investigate the regeneration of spent activated carbon. Regenerated carbon has been found to have well-developed pores and activation sites.**

Keywords: Purification of Water, Activated SAC, Recycling, Regeneration.

I. INTRODUCTION

Nowadays, activated carbon is utilized in many different industries, including the food and beverage, cosmetic, wastewater treatment, and pharmaceutical sectors. It is possible to renew activated carbon. to remove the adsorbed contaminants and partially replenish its adsorption capacity[1]. Landfilling, burning, and reactivation. Spent active carbon can currently be disposed of in three different methods. Since powdered active carbon is the least priced alternative, around 95% of it ends up in landfills, while roughly 70% of granular active carbon is reactivated. The ongoing usage and disposal of powdered activated carbon is a resource and waste management challenge that requires appropriate handling. Consequently, reactivating spent activated carbon is a sustainable approach; nevertheless, reactivating carbon is not affordable [2]. Another useful strategy to lessen secondary pollution and preserve natural resources is the regeneration and reuse of spent activated carbon (SAC) [3]. Many methods of regeneration have been reported, including solvent regeneration, biological regeneration, microwave regeneration, electrochemical regeneration, and thermal desorption using liquid water under subcritical circumstances [4]. However, one very efficient method of enhancing the pore structure of activated carbon is chemical activation. Activated carbon is made with exceptional properties by treating raw materials with the right chemical activators at the right temperatures. Activator substances like sulfuric acid (H_2SO_4), potassium hydroxide (KOH), potassium carbonate (K_2CO_3), phosphoric acid (H_3PO_4) are used to create exceptionally high-quality activated carbon. Optimizing the chemical activation process is essential to guaranteeing the economic viability of activated carbon [5], [6].

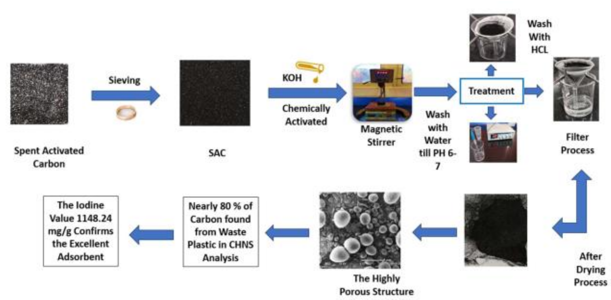

Figure. 1. Process flow of Spent activated carbon.

Being a microcrystalline substance with a large surface area and porosity, activated carbon works incredibly well as an adsorbent [7]. There will undoubtedly be differences depending on the kind of raw materials used. The raw materials, temperature, and type of activation used can also affect the activated carbon's surface area [8]. Because it encourages the formation of a porous structure, low-temperature carbonization is perfect for creating effective activated carbon [9]. Because it alters the structure of graphite and increases its adsorption capacity, hydrochloric acid is one of the best activation agents [10]. The source material and processing technique used determine the amount of activated carbon [11].

A sustainable method to remediation in wastewater purification can be achieved through the use of carbon-based materials. SAC is regenerated and activated in the current work using chemical treatment techniques. The carbon content, char production, and activated carbon characteristics are revealed through characterization

II.EXPERIMENTAL

Materials

The following material is used as follows

Chemicals Used- In the present work, the following chemicals were used. The sources of the chemicals and their acronyms used are given in Table I.

Table I: List of chemicals used and their sources

Sr. No.	Chemicals	Acronym	Source
1	Spent Activated Carbon	SAC	Cartridge from RO system
2	Potassium Hydroxide	KOH	Central Drug House, New Delhi
3	Hydrochloric acid	HCl	Central Drug House, New Delhi
4	Potassium iodide	KI	Loba Chemie Pvt Ltd
5	Iodine	I	Central Drug House, New Delhi
6	Potassium iodate	KIO_3	Thermo Fisher Scientific India Pvt Ltd
7	Starch solution	$(C_6H_{10}O_5)n$	SD Fine Chemicals (SDFCL)
8	Sodium thiosulphate	$Na_2S_2O_3$	Loba Chemie Pvt Ltd

Preparation for Regenerated Spent Activated Carbon

activated carbon is spent activated carbon that has not been regenerated.

Raw Material Collection

From the RO system's activated carbon cartridge, spent activated carbon was gathered as a raw material. SAC was kept in bags. (Fig. 2).

Figure. 2. SAC sample.

Drying of Spent Activated Carbon (SAC)

The SAC samples were placed in trays. Initially, these trays were dried in an oven set to 80 degrees Celsius for 15 minutes.

Sieving

To eliminate the bigger particles and attain a uniform particle size, the Spent Activated Carbon (SAC) samples were sieved through 200 and 100-grade mesh (Fig. 3). The creation of fine activated carbon particles, which is necessary for appropriate distribution in the matrix, depends on sieving.

Figure. 3. Sieving.

Impregnation

After gathering the char in a beaker, it was treated with KOH solution at different 5:1 impregnation ratio.

Magnetic Stirrer Process

For two hours, the beaker was activated by setting it on a magnetic stirrer.

Washing and Drying

After an hour of rinsing with 1N diluted HCL, the resulting regenerated spent activated carbon was repeatedly carefully cleaned with distilled water until the sample's pH reached 6-7. Before being stored in desiccators, the resulting regenerated Spent Activated Carbon (SAC) was dried for four hours at 110 °C in an oven. (Fig. 4a,b).

Figure. 4(a) pH value

Figure. 4. (b) SAC sample after washing.

III. METHODS

The activated carbon samples from the RO system's activated carbon cartridge were studied for the percentage of the yield of spent activated carbon, CHNS elemental analysis, Iodine number, and SEM (Scanning Electron Microscope).

Percentage of the Yield

For the spent activated carbon, the percentage of yield is an important parameter. The amount that was produced from the dried precursor can be calculated by using the formula. Eq. (1) [12].

$$\text{Yield \%} = 100\text{x} \frac{\text{Weight of activated carbon produced (g)}}{\text{Weight of dried precursor used (g)}} \tag{1}$$

CHNS Elemental Analyzer

The CHNS elemental analyzer is used to find and determine the percentages of carbon (C), hydrogen (H), nitrogen (N), and sulphur (S) in a sample. Elemental analysis on developed samples was recorded by CHNSO Elemental Analyser, Elementar (Unicube), from CIPET-IPT Lucknow. Characteristics of char and developed activated carbon have been studied to analyze the Carbon (C), Hydrogen (H), Nitrogen (N), and Sulphur (S) % percentages in all our samples.

Iodine Number

An established procedure for figuring out the iodine number of activated carbon is provided by the ASTM D 4607-94 test technique. The amount of iodine in milligrams that one gram of activated carbon absorbs under specific test conditions is known as the iodine number. The SI unit mg/g is used to represent it. Using a 1% starch solution as an indicator, the technique uses an iodometric titration to titrate alkaline iodine (0.1N) against sodium thiosulfate (0.1N). First, a blank reading is taken, and then an activated carbon reading is taken [13], [14].

Scanning Electron Microscope (SEM)

To determine the surface characteristics and morphological structure, a scanning electron microscope (SEM) is utilized. The Scanning Electron Microscope (SEM) Jeol- KM 6000 plus) From CIPET-IPT Lucknow was used to capture the morphological pictures of the generated samples. To examine the morphological changes in each of our samples, characteristics of char and produced activated carbon have been examined.

IV. RESULTS AND DISCUSSION

Percentage of Yield of Activated Carbon

After spent activation carbon for chemical impregnation, activated carbon was created. To create the activated carbon, several impregnation ratios have been carried out in accordance with the

5:1 impregnation with KOH solution. Table II displays the samples' yield percentage results.

Table II. Yield of activated carbon.

Sr. No.	Ratio of KOH/Char	Char wt.(gm.)	After activation with the KOH process, AC wt.(gm.)	After drying (gm.)	Yield % of AC
1	5:1	1.0	0.97	0.96	96 %

CHNS Analysis

The existence of carbon, hydrogen, nitrogen, and sulfur in organic matter and other materials is verified using the CHNS elemental analyzer. Table III presents the findings of this investigation. It was discovered that the raw material SAC without regeneration had a carbon content of 74.55%. The carbon content of the chemically regenerated SAC sample was found to be 79.84 %. The results of the high carbon content indicate that it can be used to prepare activated carbon.[15]

Table III. CHNS Analysis

CHNS Elemental Analysis					
Sr. No.	Ratios	C %	H %	N %	S %
1	SAC	74.55	3.21	0.58	0.56
2	5:1 SAC	79.84	2.27	0.43	0.71

Iodine Number of Activated Carbon

The iodine number value for the spent activated carbon is observed at 346.72 mg/g. The value of iodine number for our SAC samples with chemical impregnation has been shown in Table IV.

Table IV. Iodine number of activated carbon

Plastic waste wrappers	Ratio	Weight of AC (gm.)	Iodine Number (mg/g)
Without a regenerated SAC	5:1	0.5	346.72
Spent Activated Carbon	5:1	0.5	1148.24

The activated carbon's iodine number, which indicates its adsorption ability, typically ranges from 500 to 1200 mg/g, making it an excellent adsorbent [16].

Scanning Electron Microscope (SEM)

Figure-5a displays a SEM of Spent Activated Carbon (SAC) without regeneration, while Figure- 5b displays images following chemical activation by KOH impregnation ratios of 5:1. A broad outer surface with irregular cracks and pores that appear throughout the activation stage is revealed by the gradual increase in pore development during the conversion of carbon to activated carbon. A network of interconnected spaces and pores may be seen across the samples in SEM pictures. The distribution of voids showed that the samples' morphology was homogeneous, which is ideal for reliable application performance. The SEM pictures of the samples show bright regions that indicate carbon-rich zones.

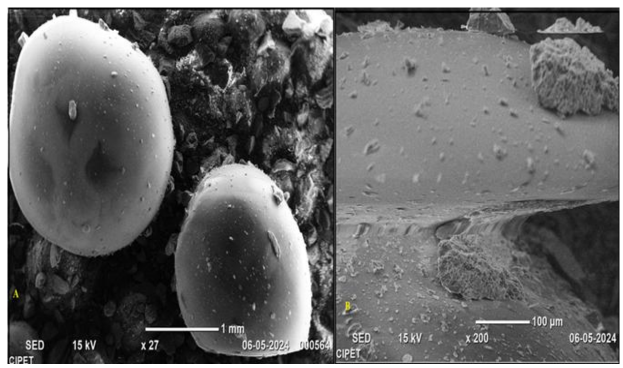

Figure. 5. SEM analysis (a) 5:1 without regeneration (b) 5:1 SAC impregnated with KOH.

V.CONCLUSION

The current study used a chemical treatment process methodology to regenerate spent activated carbon. Approx nearly 80 % of carbon was reported in the samples, and the CHNS value confirms the carbon percentage in activated carbon. The 5:1 ratio's obtained iodine value of 1148.24 mg/g confirms the creation of activated carbon with this impregnation ratio and shows the adsorption potential. The network of linked voids and pores across the samples is shown by SEM examination, which also investigates the morphological structure of activated carbon.

During chemical impregnation, some chemical reactions have also been observed with the deposited scale of wasted activated carbon. The findings unequivocally show that activated carbon is very good at removing pollutants from water, especially those that come from industrial effluents.

Acknowledgments
Sincere gratitude is extended by the authors to CIPET: IPT, Lucknow for all experimental effort and testing facilities.

Author contributions
Ravi Verma Formal analysis, Investigation, Original draft, Writing - review & editing.
Dr. Manish Choudhary Supervision, Validation, Writing - review & editing.

Conflict of interest
The authors have no conflicts of interest to declare that are relevant to the content of this article.

REFERENCES

1. R. Verma and M. Choudhary, "Utilizing Plastic Trash to Produce Char & Activated Carbon for Wastewater Treatment: A Review," Int J Res Appl Sci Eng Technol, vol. 13, no. 3, pp. 1795–1798, Mar. 2025, doi: 10.22214/ijraset.2025.67664.
2. J. Oladejo, K. Shi, Y. Chen, X. Luo, Y. Gang, and T. Wu, "Closing the active carbon cycle: Regeneration of spent activated carbon from a wastewater treatment facility for resource optimization," Chemical Engineering and Processing - Process Intensification, vol. 150, Apr. 2020, doi: 10.1016/j.cep.2020.107878.
3. M. N. Nasruddin, M. R. Fahmi, C. Z. A. Abidin, and T. S. Yen, "Regeneration of Spent Activated Carbon from Wastewater Treatment Plant Application," in Journal of Physics: Conference Series, Institute of Physics Publishing, Dec. 2018. doi: 10.1088/17426596/1116/3/032022.
4. E. Da'Na and A. Awad, "Regeneration of spent activated carbon obtained from home filtration system and applying it for heavy metals adsorption," J Environ Chem Eng, vol. 5, no. 4, pp. 3091–3099, Aug. 2017, doi: 10.1016/j.jece.2017.06.022.
5. A. Şencan and M. Kiliç, "Investigation of the Changes in Surface Area and FT-IR Spectra of Activated Carbons Obtained from Hazelnut Shells by Physicochemical Treatment Methods," J Chem, vol. 2015, 2015, doi: 10.1155/2015/651651.
6. R. P. K. Dasanayaka, "APPLICATIONS OF ACTIVATED CARBON IN WASTE WATER TREATMENT AS A LOW COST MEDIA," 2021. [Online]. Available: http://www.ijeast.com.
7. Z. Heidarinejad, M. H. Dehghani, M. Heidari, G. Javedan, I. Ali, and M. Sillanpää, "Methods for preparation and activation of activated carbon: a review," Mar. 01, 2020, Springer. doi: 10.1007/s10311-019-00955-0.
8. A. F. Nugraha, A. J. Naindraputra, C. S. A. L. Gaol, I. Ismojo, and M. Chalid, "Polypropylene-based Multilayer Plastic Waste Utilization on Bitumen Modification for Hot-Mixed Asphalt Application: Preliminary Study," Journal of Applied Science, Engineering, Technology, and Education, vol. 4, no. 2, pp. 157–166, Nov. 2022, doi: 10.35877/454ri.asci1119.
9. R. Zhu et al., "Analysis of factors influencing pore structure development of agricultural and forestry waste-derived activated carbon for adsorption application in gas and liquid phases: A review," Oct. 01, 2021, Elsevier Ltd. doi: 10.1016/j.jece.2021.105905.
10. F. T. Ademiluyi and E. O. David-West, "Effect of Chemical Activation on the Adsorption of Heavy Metals Using Activated Carbons from Waste Materials," ISRN Chemical Engineering, vol. 2012, pp. 1–5, Dec. 2012, doi: 10.5402/2012/674209.
11. T. S. Hui and M. A. A. Zaini, "Potassium hydroxide activation of activated carbon: A commentary," Oct. 01, 2015, Korean Carbon Society. doi: 10.5714/CL.2015.16.4.275.
12. R. Verma and M. Choudhary, "Sustainable valorization of plastic waste into activation char through pyrolysis," Int J Environ Health Res, pp. 1–13, Mar. 2025, doi: 10.1080/09603123.2025.2474093.
13. O. A. Babatunde, S. Garba, and Z. N. Ali, "Surface Modification of Activated Carbon for Improved Iodine and Carbon Tetrachloride Adsorption," American Journal of Chemistry, vol. 6, no. 3, pp.

74–79, 2016, doi: 10.5923/j.chemistry.20160603.02.

14. W. Tahir and S. Choudhry, "Production of activated carbon from tea waste and its application in water treatment," 2017. [Online]. Available: http://www.innspub.net.
15. C. Bläker, J. Muthmann, C. Pasel, and D. Bathen, "Characterization of Activated Carbon Adsorbents – State of the Art and Novel Approaches," Aug. 01, 2019, Wiley-Blackwell. doi: 10.1002/cben.201900008.
16. M. Grassi, G. Kaykioglu, V. Belgiorno, and G. Lofrano, "Removal of Emerging Contaminants from Water and Wastewater by Adsorption Process," 2012, pp. 15–37. doi: 10.1007/978-94-007-3916-1_2.