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Utilizing Plastic Trash to Produce Char & Activated Carbon for Wastewater Treatment: A Review

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Abstract: Converting plastic waste into char and activated carbon is a promising approach to both waste management and environmental restoration. Plastic waste is collected from various sources and sorted based on its type and composition. The sorted plastic waste is then subjected to a process called pyrolysis, which involves heating the matter in an inert atmosphere. This process breaks down long-chained polymers present in plastics into smaller hydrocarbons, gases, and char. Char can be further processed through activation to increase its surface area and porosity for better absorption. Activated carbon adsorbs organic pollutants, heavy metals, and other contaminants, effectively purifying the water. It can also remove odors and improve water clarity.

The present review is an attempt to provide an overall understanding of the work done in using waste plastic as a source of producing activated Carbon and the various application potentials of this activated Carbon primarily for wastewater purification.
Keywords: Activated carbon; Plastic waste; Adsorbent;Sustainability.

I. INTRODUCTION

The increased prevalence and inescapability of plastic in the contemporary era has led to a yearly rise in the amount of plastic produced worldwide by a variety of businesses and households, resulting increase intothe plastic waste generation[1]. In the context of thermal recycling of plastic waste, pyrolysis transforms garbage into energy fuel, vapor compounds, and char. It's a useful technique to produce energy from waste. Plastic trash is pyrolyzed at temperatures between 200 and 1300 degrees Celsius [2].

The conversion of plastic waste into char starts with collecting the waste from various sources and segregating it based on its type and composition. Plastics have varying properties and compositions based on their origin which can influence the processing and recycling of their waste [3].

For the conversion of plastic waste into char by thermal recycling, the most suited way is to process the homogeneous kind of plastic waste. It makes it possible to have more control over the conversion process and may produce final goods of a higher value[4].

Pyrolysis involves heating of the plastic material in the absence of oxygen to break it down into smaller molecules without combustion. This thermal degradation process typically occurs in temperature rangesbetween 300°C to 900°C depending on the type of plastic and the desired products [3]. The absence of oxygen prevents combustion and allows for the thermal degradation of the plastic material. Generally, pyrolysis is performed in the presence of nitrogen gas. As the plastic waste heats up, it undergoes thermal decomposition, breaking down into smaller hydrocarbon molecules, volatiles, and char as a solid residue [5]. Residence time in the reactor, temperature, heating rates, and the type of plastic are the key factors during pyrolysis.

Pyrolysis byproducts are usually collected and divided into several fractions. Condensing volatile gasses into liquid fuel or gathering solid char for additional processing could be included in this [2].

The solid residue known as char consists mainly of carbon. The char's surface area, porosity, shape, and chemical composition may vary depending on the pyrolysis process's parameters [6]. A soil supplement, fuel source, or synthesis of activated carbon is among the several uses for the char resulting from pyrolysis [7] .

The conversion of char into activated carbon involves a process called activation, which significantly increases the surface area and volume of the char. Activation aims to significantly enhance the char's volume and surface area by creating a network of tiny pores throughout the material [8]. This transformation unlocks the true potential of activated carbon for adsorption applications. Char, formed from the pyrolysis of various materials like plastic waste or biomass, has some inherent porosity.

It is also found that after activation pore size of the char reduced marginally, like a sponge – the more holes it has, the greater its surface area for absorbing liquids. Similar to this, activated carbon's porosity results in a greater surface area that is capable of adsorption [9].

To transform the char into activated carbon, we typically take into account chemical and physical activation techniques. High temperatures (usually between 600 and 900°C) and activating chemicals like steam or CO_2 are used in the physical approach (Thithaiet al., 2021). The char reacts with the heated gasses, creating new pores and disintegrating the existing ones. When creating activated carbon with particular pore shapes and high purity, physical activation is usually chosen [11]. Before the high-temperature treatment, the char is impregnated with an alkaline solution such as potassium hydroxide (KOH) in the chemical activation process. These substances interact with the carbon structure to form pores and promote their growth in the heating phase that follows [12]. When compared to physical activation, chemical activation is typically more effective in producing a very micro-porous structure (extremely small pores). Chemical activation is frequently used to create activated carbon with customized pore properties because it provides more control over pore formation (Jirimaliet al., 2022).

Before being used or processed further, the removal of moisture becomes essential. In a simple way, the dry heating in sunlight for prolonged time is self-sufficient for moisture removal. For desired particle size distribution, the activated carbon can either be ground or sieved mechanically, depending on the application. This technique is widely used to optimize the accessibility and surface area of activated carbon for adsorption operations.

Char gets transformed into activated carbon after the activation process. This material has superior adsorption properties and is hence particularly helpful in numerous industrial and environmental applications.Water and wastewater can be efficiently cleansed with activated carbon. It securely removes organic pollutants, unpleasant tastes, and smells from water, as well as chlorine and volatile organic compounds (VOCs), making it suited to drinking and industrial use.

1) Volatile Organic Compounds (VOCs): On account of physical and chemical properties, activated carbon is widely applicable as anadsorption material for trapping volatile organic compounds[14]. Between physical and chemical methods of developing activated carbon, the chemically activated carbon dominates due to low-temperature need, short activation time, and better pore distribution. For the desired pore size in activated carbon, different impregnation solvents can be applied [15].
2) Disinfection By-Products (DBPs):Elimination of harmful microbes is a required parameter while heating the contaminated water. Alone the activated carbon was found insufficient to deal with such contamination. But along with other techniques like ultraviolet treatment and ozone treatment, the activated carbon has been recommended strongly to reduce disinfection by-products from the waste stream of water(Srivastav, Patel, and Chaudhary, 2020).
3) Cosmetics and Pharmaceuticals Products: Pharmaceuticals and personal care products found in waste streams affect the water quality significantly.Activated carbon has better surface morphology and surface carbon content. Char has been found to have the property of absorbing cosmetics and pharmaceuticalproducts. So, the combination of biochar and chemically activated carbon has been recommended to cure the water stream contaminated with PPCPs(Zhu et al., 2022).
4) Adsorption of Inorganic Contaminants:

- Chlorine:Except than the bacteria, calcium, and magnesium fluids and other inorganic compounds, the activated carbon was found effective in the removal of free chlorine and chloramines. A type of activated carbon known as granular activated carbon or GACis mostly used in water treatment filters for eliminating chlorine traces from the feed water at large scale(Mazhar et al., 2020),[19].
- Heavy Metals and toxic elements: the industrial wastewater samples have been found to have toxin elements such as mercury, cadmium, arsenic (As), chromium, and lead (Pb), posing significant health concerns on ecology(Rathi and Kumar, 2021),[21]. The activated carbon was found suitable for heavy metals and toxin adsorption. Plastic waste-generated activated carbon could be the sustainable solution when cost constraintslimit the scope of traditionally generated activated carbon (Kumar et al., 2019),[23].
- Taste and Odor Control: Activated carbon has been found superior adsorbent in most of the studies for eliminating taste and odor. In available types of activated carbon, the granular activated carbon has been reported as more susceptible to adsorbing diluted contaminants from wastewater causing odor and unpleasant taste, as compared to powdered form activated carbon and extruded activated carbon [24].
- Color Removal:The color in wastewater stream has been found due to humic and fulvic acids, natural tannins along with synthetic chemical dyes. Activated carbons in powdered form have proven efficiency in improving the visual quality of water by eliminating color-causing agents like tannins and humic chemicals [14].

- Removal of Microorganisms:Being a highly porous material, activated carbon was found superior for surface adsorption [25].
- However, using certain chemical treatments along with inorganic impregnation such as silver and copper, the performance of activated carbon was found enhanced. The modified activated carbon has been proven tremendous and removing microorganisms effectively from contaminated wastewater stream (Sweetman et al., 2017),[27].
- Pre-Treatment:At the primary level during the purification of water, activated carbon can be utilized.With the ability to eliminate numerous organic and inorganic contaminants, water quality improvement, and encourage effectiveness in membrane filtration or disinfection, the activated carbon role was found significant[28].
- Groundwater Remediation:Groundwater hasan ample amount of suspended particles of different sizes. So, for eliminating unwanted solid particles activated carbon is used to effectively treat contaminated groundwater by surface adsorption. Granular activated carbon derived from biomass andmicro-mesoporous granular activated carbon derived from charcoal have been used in bulk for groundwater remediation. Utilization of activated carbon in both ex-situ (pump and treat) and in situ treatment processes provides adaptable alternatives for groundwater remediation, contributing toward improved environmental health and safety.(Dai et al., 2018),[30].
- Swimming Pool and Spa Treatment:Activated carbon is a beneficial substance for utilization in swimming pools and spa filtration systems to eliminate contaminants and increase the cleanliness of the water. Common filtration beds are used in water treatment for this purpose.The effectiveness of the filtration bed has been improved by activated carbon layers dispersed into the bed(Łaskawiec, Dudziak and Wyczarska-Kokot, 2019).

In summary, activated carbon is a versatile and effective adsorbent that finds widespread use in wastewater treatment and water purification processes, contributing to the production of clean, safe, and aesthetically pleasing water for various purposes.

II. CONCLUSION

The presentreview summarizes the dominance of activated carbon over other traditional adsorbents for the removal of contaminations from wastewater streams. The traditional methods of developing activated carbon have been found to face cost-related challenges. So, activation of carbon by using the char derived via pyrolysis of carbon-containing waste plastic could be the new horizon for developing sustainable adsorbent.

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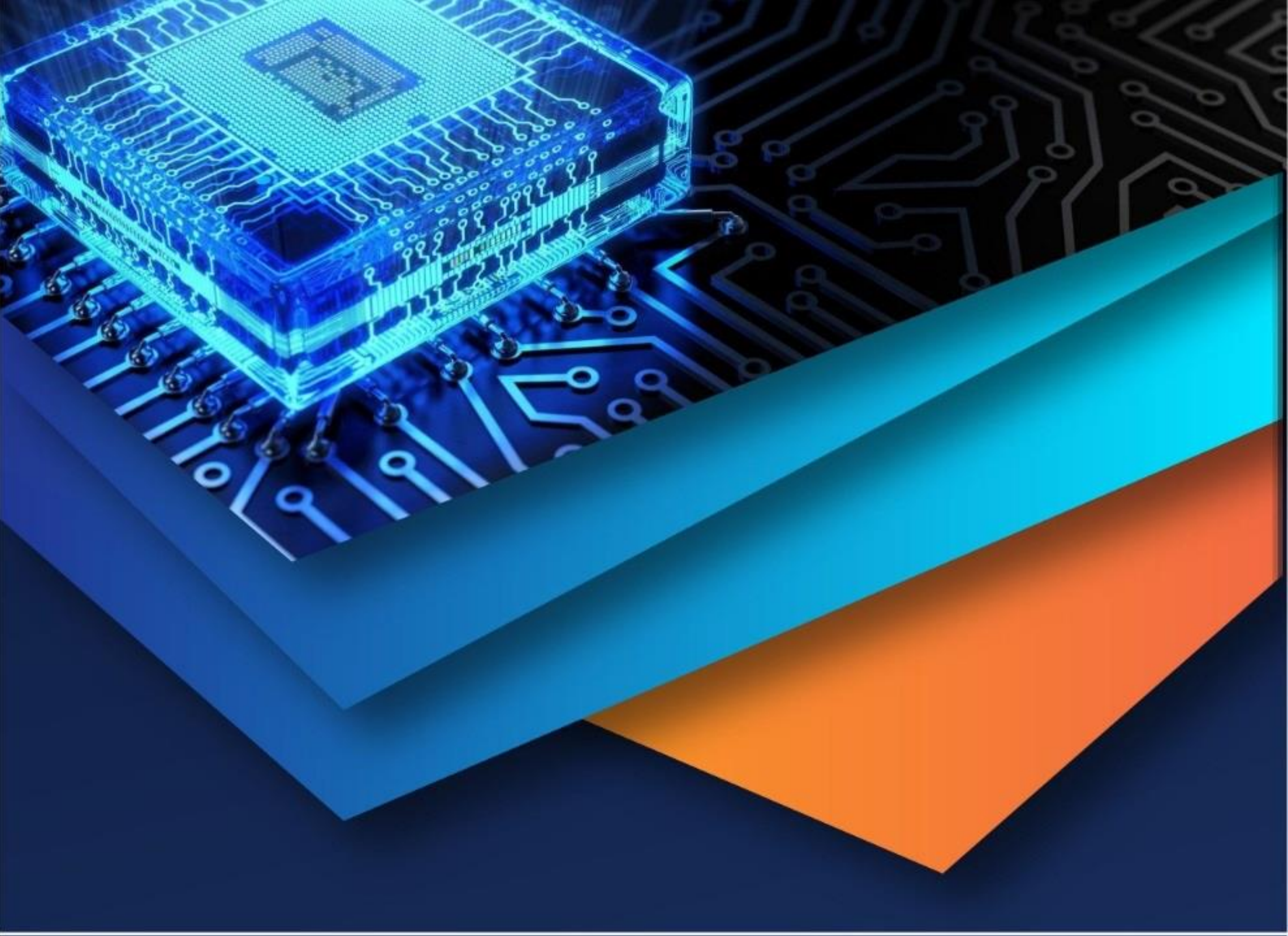

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