# Conventional and Non-Conventional Adsorbent for Heavy Metal and Dye Removal from Contaminated Water

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## ABSTRACT

The elimination of emerging pollutants has become a global concern due to their detrimental impact on the environment and even humans. The effects of water contamination have prompted efforts to find economical and ecologically acceptable treatment methods to reduce therelated environmental risks.Adsorption and the related technologies (filtration/biofiltration) where this process takes place have attracted a lot of attention because of their affordability, ease of use, and efficacy, particularly when it comes to removing dyes from wastewater. As a result, both conventional (activated carbon, clays, zeolites) and non-conventional (agro-industrial/forestry/industrial wastes, nanomaterials, among others) materials have demonstrated efficiencies greater than 90%. The focus of the research has been on biosorption, an emerging technology, as a means of remediating heavy metals and dyes through a novel technique. Because the functional groups are present, adsorption employing agriculture and food industry wastes has demonstrated a higher absorption rate than the standard approach. These days, this chapter discusses the use of pigeon feather and sorghum straw as an alleged adsorbent for getting rid of harmful synthetic organic dyes that come from waste water. Therefore, as a valorization alternative for these residues, the present work has examined the synthesis of modified nanocomposites film from agro-industrial residues and food industrial residue derived from the sorghum processing industry and poultry farm for use in the removal of Methylene blue (MB) and Crystal violet (CV) from contaminated water.

**Keywords:** Conventionaladsorbent,non-conventionaladsorbent, adsorption, Methylene blue, Crystal violet

## 1. INTRODUCTION

Many adsorbents have been tested for their ability to reduce dye concentrations in aqueous solutions [1]. Activated carbon is a commonly used conventional adsorbent, but it can be expensive and not suitable for large-scale treatment [2]. In addition to activated carbon, other adsorbents such as peat, chitin, silica, and agricultural wastes have also been reported. However, these alternative adsorbents often have lower adsorption capacities compared to activated carbon [3]. Therefore, there is a need for the development and utilization of newer and advanced adsorbent materials to overcome the limitations of conventional adsorbents and

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improve the efficiency and effectiveness of adsorption processes [4]. These newer adsorbent materials offer unique properties, such as high surface area, tunable pore sizes, and specific functional groups, which allow for improved adsorption capacities and selectivity [5].In conclusion, the development and utilization of advanced adsorbent materials is crucial for addressing the limitations of conventional adsorbents and improving the efficiency of adsorption processes in various applications, including wastewater treatment, gas removal, and CO2 capture. Furthermore, these advanced adsorbent materials offer the potential for more sustainable and cost-effective solutions, which are essential in addressing environmental challenges and promoting a greener future. In conclusion, the utilization of advanced adsorbent materials is necessary to overcome the limitations of conventional adsorbents and enhance the efficiency of adsorption processes in various applications [6]. Therefore, the use of conventional adsorbents for adsorption processes has certain limitations in terms of their effectiveness and efficiency. Therefore, the development and utilization of newer and advanced adsorbent materials is crucial to overcome these limitations and improve the efficiency of adsorption processes.Wastewaters from industry make up a sizable amount of this pollution [7].

**Conventional Adsorbents for Water Treatment:**

Water pollution is a major environmental concern, particularly due to the presence of heavy metals and dyes in wastewater [8]. Conventional adsorbents have been widely used for water treatment to remove these contaminants [9]. Conventional adsorbents include activated carbon, zeolites, and clay minerals [10] Activated carbon is a commonly used conventional adsorbent for heavy metal and dye removal.It has a high adsorption capacity and is effective in removing a wide range of contaminants [11].Zeolites, on the other hand, have a porous structure that allows for effective adsorption of heavy metals and dyes. Clay minerals, such as bentonite and kaolin, have also shown promise as conventional adsorbents for water treatment. These materials are readily available and can be easily processed for use as adsorbents. However, conventional adsorbents have certain limitations [12]. They can be expensive, especially in large-scale applications, and their separation from the treated water can be challenging.

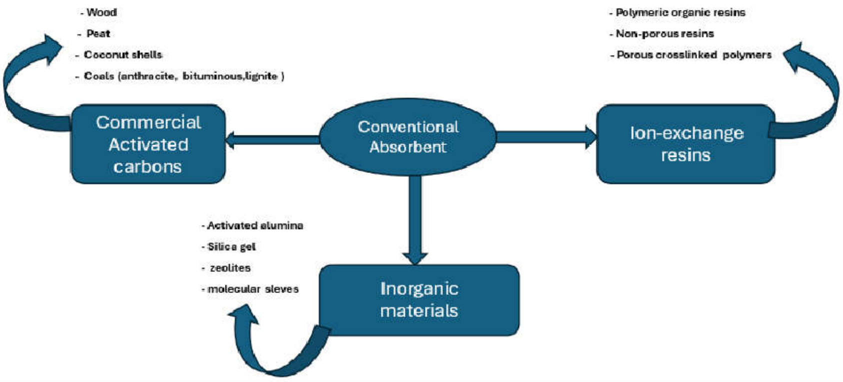


**Figure 1. Conventional adsorbents for the removal of pollutants from wastewaters [13].**

## Non-Conventional Adsorbents for Contaminant removal in water treatment:

To overcome the limitations of conventional adsorbents, researchers have explored the use of non-conventional adsorbents for heavy metal and dye removal from contaminated water [7].non-conventional adsorbents include nanostructured materials, bioadsorbents, and low-cost adsorbents. Nanostructured materials, such as graphene, fullerenes, and metal organic frameworks, have shown promise in removing heavy metals from contaminated water [14].Their high surface area and unique properties make them effective adsorbents for pollutants.Bioadsorbents, such as chitosan and lignin, offer an economical and environmentally friendly approach to water treatment. They have demonstrated outstanding removal capabilities for heavy metals and dyes, surpassing the performance of commercial activated carbon [15]. Low-cost adsorbents, including chitosan, zeolites, and waste slurry, have also been found to be highly efficient in removing heavy metals from contaminated water. Overall, the use of non-conventional adsorbents provides opportunities for improved efficiency and cost-effectiveness in water treatment [11]. Moreover, the advancements in nanotechnology have opened up new possibilities for utilizing nanomodified adsorbents in wastewater treatment [16].These nanomodified adsorbents offer the potential for innovative solutions to address the issue of water pollution [17]. In conclusion, both conventional and non-conventional adsorbents have shown promise in removing heavy metals and dyes from contaminated water. While conventional adsorbents such as clay minerals have been effective, non-conventional adsorbents offer advantages such as lower cost, higher efficiency, and environmental friendliness [18]. These non-conventional adsorbents, particularly nanostructured materials and bio adsorbents, have demonstrated outstanding removal capabilities for heavy metals and dyes in wastewater treatment processes [19].non-conventional adsorbents, including nanostructured materials, bio adsorbents, and low-cost adsorbents, offer innovative and efficient solutions for the removal of heavy metals and dyes from contaminated water. Therefore, it is crucial for researchers and professionals in the field of water treatment to continue exploring and utilizing both conventional and non-conventional adsorbents to provide effective and sustainable solutions for the removal of heavy metals and dyes from contaminated water [11]. In conclusion, both conventional and non-conventional adsorbents have shown promise in removing heavy metals and dyes from contaminated water.While conventional adsorbents such as activated carbon and minerals have been widely used for the removal of heavy metals and dyes from contaminated water, non-conventional adsorbents, such as chitosan, zeolites, waste slurry, and nanomodified materials, have emerged as promising alternatives [20].

These non-conntional adsorbents have demonstrated higher removal capacities and lower cost compared to conventional adsorbents. They also offer the potential for innovative and sustainable solutions to address water pollution.Therefore, it is recommended to further explore the potential of these non-conventional adsorbents and their application in water treatment processes. In conclusion, both conventional and non-conventional adsorbents have shown promise in removing heavy metals and dyes from contaminated water[21]. Non-conventional adsorbents, such as graphene, fullerenes, and metal organic frameworks, offer advantages in terms of cost-effectiveness and efficiency, and they have the potential for wider applications in wastewater treatment.Overall, the use of both conventional and non-conventional adsorbents is essential in addressing the issue of heavy metal and dye removal from contaminated water [22].Both conventional and non-conventional adsorbents, including nanostructured materials and bio adsorbents, have proven to be effective in removing heavy metals and dyes from contaminated water [11]. Furthermore, the utilization of non-

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conventional adsorbents provides additional benefits such as lower cost, higher removal capacities, and the potential for sustainable and environmentally friendly solutions.In conclusion, the use of both conventional and non-conventional adsorbents is crucial for effectively addressing the removal of heavy metals and dyes from contaminated water [11].

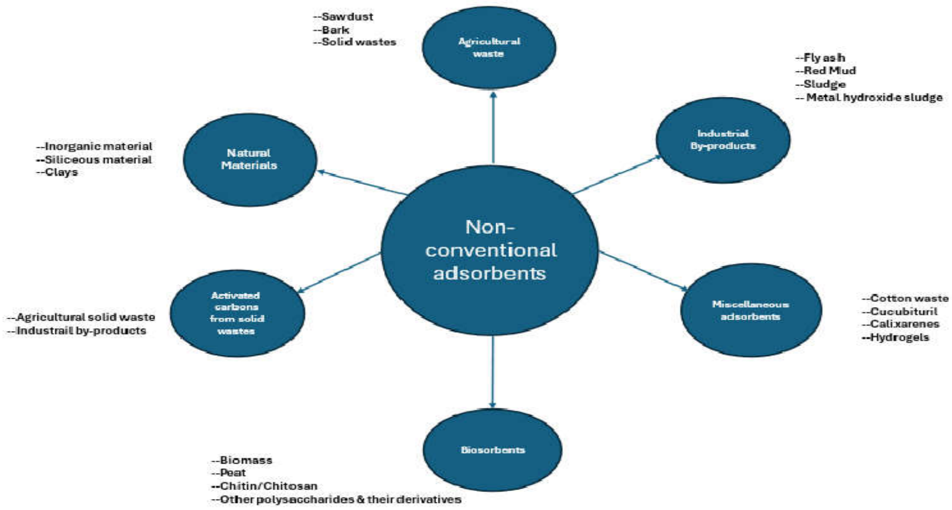


**Figure 2.Non-conventional adsorbents for the removal of pollutants from wastewaters [23].**

## Heavy Metal Removal from Water Sources:

There are various adsorbents that can be used for the removal of heavy metals from contaminated water sources. Conventional adsorbents, such as activated carbon and minerals, have been widely used for this purpose [24]. However, non-conventional adsorbents have also shown promising results in terms of their efficiency and cost-effectiveness [25].However, non-conventional adsorbents have also emerged as promising alternatives. These include materials such as zeolites, waste slurry, nanomodified materials like graphene and metal organic frameworks[26].

**Table 1: WHO guideline for metal concentration in drinking water [53].**

| Metal | Cu | Cr | Cd | Hg | Pb | As | Ni |
|---|---|---|---|---|---|---|---|
| Permissible limit, ug/L | 2000 | 50 | 3 | 3 | 10 | 10 | 700 |

These non-conventional adsorbents have demonstrated higher removal capacities and lower cost compared to conventional adsorbents. In conclusion, both conventional and non-conventional adsorbents have proven to be effective in the removal of heavy metals from contaminated water [27]. Different adsorbents can be used for the removal of heavy metals and dyes from contaminated water sources. Conventional adsorbents, such as activated carbon and minerals, have been widely used for this purpose [28]. However, non-conventional adsorbents are gaining attention due to their improved efficiency and cost-effectiveness.Figure (3) Harmful effect of heavy metal on human health according to [29].

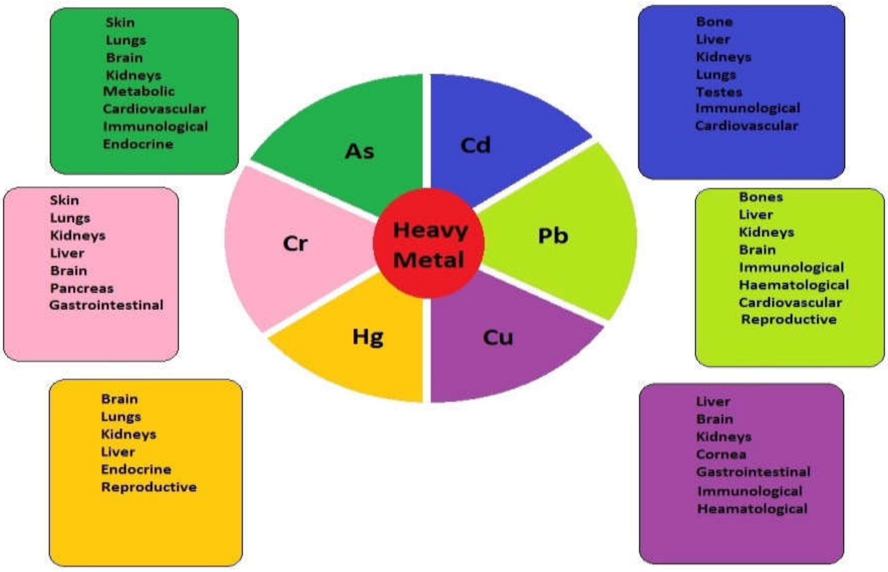


**Figure 3.Harmful effects of heavy metals on human health.** [29]**.**

**Dye Elimination Techniques in Water Treatment:**

In water treatment processes, various techniques are employed for the elimination of dyes from contaminated water [11]. These techniques include adsorption, coagulation/flocculation, advanced oxidation processes, and membrane filtration. Among these techniques, adsorption is considered one of the most efficient methods for dye removal. It involves the use of adsorbents to attract and bind dye molecules, thereby removing them from the water. Some conventional adsorbents that have been commonly used for dye removal include activated carbon, clay minerals, and zeolites [30]. However, non-conventional adsorbents are emerging as promising alternatives for dye elimination.These non-conventional adsorbents, such as nanostructured materials, bio adsorbents, and low-cost adsorbents, offer advantages in terms of their enhanced adsorption capacity, cost-effectiveness, and eco-friendliness.Some examples of non-conventional adsorbents for dye removal include graphene, fullerenes, graphitic carbon nitride, and metal organic frameworks. These materials have shown exceptional dye removal capabilities and hold great potential for application in water treatment processes [31].In conclusion, both conventional and non-conventional adsorbents have proven to be effective in the removal of heavy metals and dyes from contaminated water sources and offer viable solutions for water treatment processes. Organic adsorbents such as bio adsorbents, agricultural waste materials, and natural polymers are considered non-conventional adsorbents that have emerged as promising alternatives for dye removal due to their abundant availability, low cost, and eco-friendly nature.

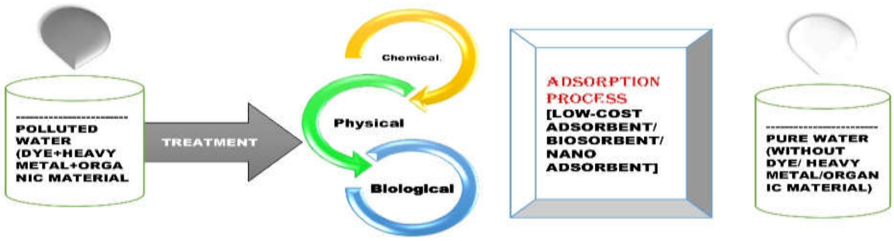


**Figure 4: Schematic diagram of Adsorption process**

**Comparing Conventional and Non-Conventional Adsorbents:**

When comparing conventional and non-conventional adsorbents, it is important to consider factors such as adsorption capacities, selectivity, and cost-effectiveness [32]. Conventional adsorbents, such as activated carbon, have been widely used for water purification due to theirbiosorption capacities and versatility [33]. However, these conventional adsorbents can be expensive to produce and may require extensive processing [34]. On the other hand, non-conventional adsorbents such as nanomaterials, bio adsorbents, and low-cost materials offer alternative options that can overcome the limitations of conventional adsorbents. These non-conventional adsorbents provide enhanced adsorption capacities, selectivity, and cost-effectiveness for water purification processes [35].For example, nanomaterials, such as carbon nanotubes and graphene oxide, have shown high adsorption capacities due to their large surface area and unique structural properties [36]. Bio adsorbents, derived from natural sources such as agricultural waste and biomass, have also gained attention for their eco-friendly nature and ability to remove contaminantssuch as heavy metals and dyes.Additionally, low-cost adsorbents, such as agricultural by-products and industrial waste materials, offer a cost-effective alternative for water treatment [37]. These non-conventional adsorbents can often be obtained at low cost or even as waste products, making them more economically viable options for water purification. In summary, both conventional and non-conventional adsorbents have their advantages and limitations.

One of the main challenges in removing contaminants from water is the presence of heavy metals and dyes.Heavy metals are toxic substances that can have detrimental effects on human health and the environment.[38].They can enter water sources through industrial discharge, mining activities, and agricultural runoff [39]. Dyes, on the other hand, are synthetic organic compounds commonly found in wastewater from industries such as textiles, paper, and leather.These dyes not only pose aesthetic concerns but can also be toxic and carcinogenic. To effectively remove heavy metals and dyes from contaminated water, both conventional and non-conventional adsorbents can be utilized [40]. Some conventional adsorbents commonly used for heavy metal and dye removal include activated carbon, zeolites, clay minerals, and silica gel [41]. However, these conventional adsorbents have certain limitations, such as high cost, limited adsorption capacity, and selectivity for specific contaminants.Non-conventional adsorbents, on the other hand, offer alternative options for efficient and cost-effective removal of heavy metals and dyes.They can be derived from various sources, including carbon nanomaterials, bio adsorbents, and low-cost materials like agricultural waste and industrial by-products[25,41]. These non-conventional adsorbents, derived from natural sources such as agricultural waste and biomass, have also gained attention for their eco-friendly nature and ability to effectively remove contaminants from water. Some examples of non-conventional adsorbents that have shown promise in heavy metal and dye removal include rice husk, [42] sugarcane bagasse, [43]sawdust, [44]coconut shell, [45]and groundnut shell [46].These materials are abundant and readily available, making them attractive options for water purification.Additionally, the use of nanostructured adsorbents has been explored in recent years.These nanostructured adsorbents, such as metal oxides and carbon-based nanomaterials, have unique properties that enhance their adsorption capacity andefficiency in removing heavy metals and dyes from water.In conclusion, a combination of both conventional and non-conventional adsorbents can be used for the efficient removal of heavy metals and dyes from contaminated.

**Innovative Materials for Water Decontamination:**

In today's rapidly changing world, the significance of accurate weather forecasts cannot be overstated.Similarly, the issue of water pollution and the need for effective removal of heavy metals and dyes from contaminated water has become a pressing concern.Adsorption is one of the most efficient techniques for removing noxious heavy metals from water.Traditional adsorbents, such as activated carbon, zeolites, clay minerals, and silica gel, have been commonly used for this purpose [47].Despite their effectiveness, these conventional adsorbents often have limitations such as high cost, limited capacity, and selectivity for specific contaminants. To overcome these limitations, researchers have turned to non-conventional adsorbents derived from natural sources and waste materials.These non-conventional adsorbents, including carbon nanomaterials, bio adsorbents, and agricultural waste and industrial by-products, offer alternativeand low-cost options for water purification. They have shown promising results in removing heavy metals and dyes from contaminated water [48].Furthermore, nanotechnology has emerged as aninnovative approach for water decontamination.Nano adsorbents, such as metal nanoparticles and carbon-based nanomaterials, have been developed to enhance the adsorption capacity and efficiencyof these materials in removing heavy metals and dyes from water.These nanostructured adsorbents have unique properties, such as high surface area, tuneable pore size, and functional groups, which enhance their adsorptioncapacity and selectivity.By utilizing a combination of conventional and non-conventional adsorbents, including nanostructured materials, it is possible to achieve efficient removal of heavy metals anddyes from contaminated water. This approach can significantly contribute to the protection of human health and aquatic ecosystems, as well as addressing water scarcity issues.In addition to this, the efficiency of developed materials for adsorption of the heavy metals is discussed in detail along with the comparison of their maximum adsorption capacity in tabular form [49]. Non-conventional adsorbents, such as carbon nanomaterials, bio adsorbents, and agricultural waste and industrial by-products, offer alternativeand low-cost options for the removal of heavy metals and dyes from contaminated water. These non-conventional adsorbents have shown promising results and offer advantages such as lower cost, higher capacity, and selectivity for specific contaminants. Overall, the use of both conventional and non-conventional adsorbents, including nanostructured materials, provides a comprehensive solution for the removal of heavy metals and dyes from contaminated water, offering cost-effective and efficient methods for water purification.In conclusion, the use of non-conventional adsorbents derived from natural sources, waste materials, and nanomaterials offers a promising solution forthe removal of heavy metals and dyes from contaminated water. The combination of conventional and non-conventional adsorbents, including nanostructured materials, provides a comprehensive and cost-effective solution for the removal of heavy metals and dyes from contaminated water [18]. This comprehensive approach to water purification using a combination of conventional and non-conventional adsorbents, including nanomaterials, offers an efficient and cost-effective solution for removing heavy metals and dyes from contaminated water. In summary, a wide range of organic and inorganic pollutants, including heavy metals and dyes, pose a serious concern for human health and aquatic ecosystems. Adsorption techniques using both conventional and non-conventional adsorbents, including nanostructured materials, have shown great potential for efficiently removing heavy metals and dyes from contaminated water.

## The Role of Adsorbents in Environmental Remediation:

Adsorbents play a crucial role in environmental remediation by effectively removing pollutants, such as heavy metals and dyes, from contaminated water. They act as a "sponge," attracting and binding to these contaminants, preventing them from further polluting the water. Conventional adsorbents, such as carbon nanomaterials, bio adsorbents, and agricultural waste and industrial by-products, offer alternative and sustainable options for the removal of heavy metals and dyes from contaminated water [50]. On the other hand, non-conventional adsorbents, including nanostructured materials, provide even more advantages in terms of lower cost, higher capacity and selectivity, and faster adsorption rates. Overall, the use of both conventional and non-conventional adsorbents is essential for effective and efficient removal of heavy metals and dyes from contaminated water, and offers a promising solution for water purification [50]. non-conventional adsorbents, such as nanostructured materials, have shown great potential in removing heavy metals and dyes from contaminated water. They offer advantages such as higher adsorption capacity, faster removal rates, and greater selectivity [51]. Thesenano adsorbents are considered as a viable alternative to conventional adsorbents due to their unique properties and have drawn significant attention in the field of water treatment.

## Future Perspectives on Adsorbent Use in Water Treatment:

Future perspectives on adsorbent use in water treatment involve further exploration and development of nano adsorbents. Thesenano adsorbents have the potential to revolutionize water treatment processes, providing more efficient and cost-effective solutions for removing heavy metals and dyesfrom contaminated water. In addition, research should focus on improving the transport and stability of nano adsorbents in aqueous media, as well as addressing any potential health and environmental concerns associated with their use. By utilizing the unique properties of carbon nanostructures, such as fullerenes, carbon nanotubes, graphene, and graphene oxide, researchers have been able to develop efficient adsorbents for the removal of heavy metals and dyes from contaminated water. Furthermore, the development of innovative adsorbents using novel materials and techniques should also be explored

## Conclusion:

In conclusion, both conventional and non-conventional adsorbents play a crucial role in the removal of heavy metals and dyes from contaminated water. They provide advantages such as lower cost, higher capacity, selectivity, and faster adsorption rates. The use of nanostructured materials as non-conventional adsorbents offers even greater potential for efficient water purification. The future of adsorbent use in water treatment lies in the continued exploration and development of nano adsorbents, utilizing materials such as fullerenes, carbon nanotubes, graphene, and graphene oxide. Thesenano adsorbents have unique properties and show promise in revolutionizing water treatment processes. In addition, further research should focus on improving the transport and stability of nano adsorbents in aqueous media and addressing any potential health and environmental concerns associated with their use.

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