# Treatment of Residual Effluents From the Textile Industry Based on Adsorption Methods Using Agro-Industrial Waste as Adsorbent Agents: A Systematic Review

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## Abstract

Currently, textile companies and industries in general dispose of a large amount of effluents which have a high amount of toxic substances, among them are colorants, mostly used in textile industries. Faced with this problem, treatment techniques or methods arise for the elimination of these colorants, among them is one of the most important as the adsorption method that is characterized by its effectiveness in the removal of colorants, the resulting activated carbon being the main However, this adsorbent agent is sometimes very expensive, so an ecological and low-cost alternative is the use of agro-industrial or agricultural residues as adsorbent agents. In this research, information is collected about agro-industrial residues that can eliminate dyes and assessing their adsorption effectiveness. By means of the PRISMA method and by means of a search strategy, 48 articles were obtained, which we dedicated to carrying out and achieving the objective of the research.

## Keywords
agro-industrial waste, colorants, textile industry, adsorption, wastewater.

## 1. Introduction
According to Maattanen et al. (2019), the annual consumption of textile fibres has increased over the past decade, from 50 million tonnes to more than 70 million tonnes. The textile industry is one of the most important in Peru (Santillán and Maza 2018), however, according to Castro et al. (2019), the environmental impact of this industry is related to the large amounts of water consumption, to the variety and quantity of chemicals used throughout all textile processing activities. In this sense, the effluents generated from the manufacturing, dyeing and finishing processes of textiles are very variable in composition and contain a complex mixture of toxic substances such as salts, metals, biocides, surfactants, pigments, dyes, among others. For the latter, and from the environmental point of view, their elimination is one of the main problems facing the textile sector.

Also, dyes are very important chemicals for various industries such as food, cosmetics, pharmaceuticals, printing inks, leather, and plastic, however, the textile industry is the main consumer of dyes worldwide (Piaskowsk et al. 2018).

The dyes are classified as cationic, anionic and non-ionic, depending on the ionic charge in the molecule, and it is the cationic dyes that have reported greater toxicity (Hincapié-Mejía et al. 2018). However, a more specific classification is proposed in Kaya (2021), the main dyes are grouped as acid dyes, basic dyes, direct dyes, mordant dyes, tub dyes, reactive dyes, dispersed dyes, azo dyes and sulfur dyes, where azo dyes account for 60-70% of all dyes.

According to Saini (2018), the high concentration of dyes in water bodies stops the oxygenation capacity of the receiving water and cuts off sunlight, thus altering the biological activity of aquatic life and the photosynthesis process of aquatic plants such as algae. The polluting effects of these dyes are also due to their non-biodegradability, so they continue to accumulate in sediments, fish or other forms of aquatic life.

The use of methods for the treatment of wastewater from the textile industry before it is discharged is intended to, firstly, meet the increasingly stringent requirements of the relevant regulations, secondly, to safeguard the aquatic ecosystem, and, thirdly, to have the capacity to reuse the water that is a main element in this industry.

Singh y Arora (2011) mentions three kinds of methods for the treatment of synthetic dyes: physical methods, chemical methods, and biological methods. Among these methods, the one of interest for this research is the adsorption method, located in the group of physical methods, since, for (Bharathi and Ramesh 2013). among wastewater treatment technologies, adsorption is gaining relevance due to its multiple advantages, including the availability of known process equipment, sludge-free operation and sorbate recovery.

However, within the adsorbents for this method of absorption, activated carbon is the most popular and used for effluent treatment, and although it has been shown, according to Gupta and Suhas (2009), that they are good materials for the removal of different types of dyes and other contaminants from textile effluents, their use is sometimes restricted in view of their higher cost.

This is how low-cost adsorbents appear, which in Bhatnagar and Sillanpää (2010), are defined as natural materials, waste or by-products of industries or synthetically prepared materials, which cost less and can be used as adsorbent agents.

On the other hand, this type of adsorbents, in addition to representing economic benefits, have environmental advantages Bhatnagar and Sillanpää (2010). As is the case with agro-industrial waste, which is an abundant waste material that needs proper and necessary disposal (Khunt et al. 2019).
This article will investigate agro-industrial waste, specifically seeking to answer the question about which agro-industrial waste is the most effective in treating certain dyes found in wastewater generated by the textile industry.

In subsequent chapters, the methodology used to search for the relevant information will be developed, as well as the results derived from said search.

### 1.1 Objective
Synthesize the pertinent information about which agro-industrial waste is capable of eliminating the dyes found in the different industries.

## 2. Methods
The methodological design embodied in this chapter is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method.

### 2.1 Eligibility Criteria
The different criteria for information eligibility will be explained, on which sources of information the search was carried out, the search strategy applied, the process of selecting studies and collecting data. In addition, additional information will be shown that will put in context the current horizon of the topic to be developed.

However, before performing the search and in order to have a clear picture regarding what you want to investigate, it becomes important to remember the objective and the research questions.

Research Questions:
What are the most found types of dyes in different industries?
What are the agro-industrial waste most used to remove dyes?
Which dye is the most harmful to the environment?
Is using agro-industrial waste as adsorbent agents an effective and viable alternative?
How is the removal efficiency of a dye measured?

Different criteria were defined that allowed to delimit which articles are of relevance for this study and which are not, in this way, the inclusion and exclusion factors originate.

Inclusion factors:
It includes review articles where a large amount of information is collected about other authors about experiments carried out in which they use agro-industrial waste for the elimination of dyes.
Experimental articles are included where the removal of a dye using an agro-industrial waste is demonstrated.

Articles made from 2016 to the present are included.
Articles with areas of knowledge related to chemistry, environmental, engineering and thermodynamics are included.

Exclusion factors:
Articles that only show the abstract or do not have the complete research are excluded.
Articles discussing the removal of heavy metals or other objects other than dye are excluded.
Articles that are not in the English language and that the type of document is not an article or revision are excluded.

## 2.2 Search Strategy

The search strategy was carried out as follows in the 3 sources of information, the combination of keywords for the search of the information with the Bolean connectors was as follows: TITLE-ABS-KEY (adsorbents AND dyes AND (agro-industrial OR agricultural)). Then, the search was limited by the year of publication of the articles, from 2016 to the present. The search was then limited to publications that are articles and reviews. Finally, the search was restricted to articles that are in the English language only.

Below is the list of keywords found in the articles obtained as a result of the search. It can be seen that the keywords that stand out the most are adsorption, agro-industrial residues, and dyes, and that by detachment from them, there are other words that are a focus of stalking for research, among them: adsorption kinetics, adsorbents, adsorption isotherms and one of the most important that is the adsorption capacity, since that is the indicator that tells us how effective the removal of a dye by an adsorbent agent can be, in this case, an agro-industrial waste (Figure 1).

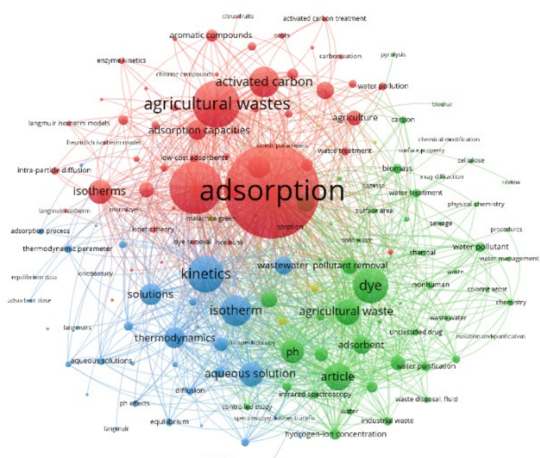


Figure 1. List of keywords in Scopus

The following figure 2 shows the number of articles made each year from 1969 to the present, which denotes the importance that has been given to the study of this topic in recent years.

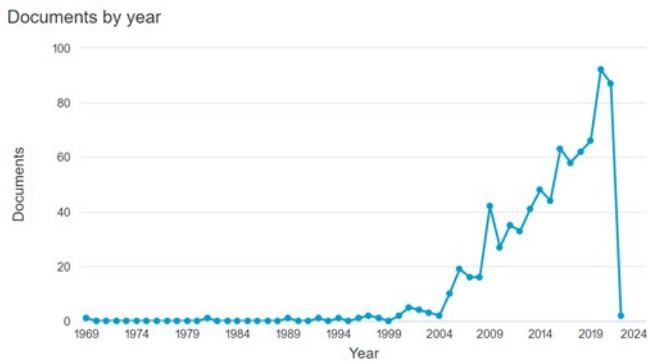


Figure 2. Number of documents per year according to Scopus

## 2.3 Study Selection Process

After the article search process, it was necessary to determine which ones matter for this systematic review, therefore we defined article exclusion criteria. An analysis of the title and abstract was carried out by the authors, and visually excluded those articles that were not related to the subject, that did not deal with agro-industrial waste and articles that dealt with the elimination of heavy metals or others other than dyes, among other criteria.

Finally, the duplicate articles that were obtained in the 3 databases were eliminated. It is necessary to mention that the same search process or strategy was carried out in the 3 databases mentioned above.

## 2.4 **Data Collection Process**

After making the selection of the articles, we proceeded to review each of the selected articles and extract all the relevant data that allow us to achieve the objective of the research, based on the method of documentary analysis.
A data record will be used, in which all the documents of interest that were reviewed will be recorded, as well as their main descriptive data and their main events such as author, abstract, objective, methodology used, all the relevant variables associated with the adsorption experiments, results, conclusions, among others.

# 3. Data Collection

As a way of summarizing the process of searching for the information that at the end of every achievement to provide a certain number of articles, the flowchart is shown in figure 3, which is the one that the PRISMA method recommends for its understanding.

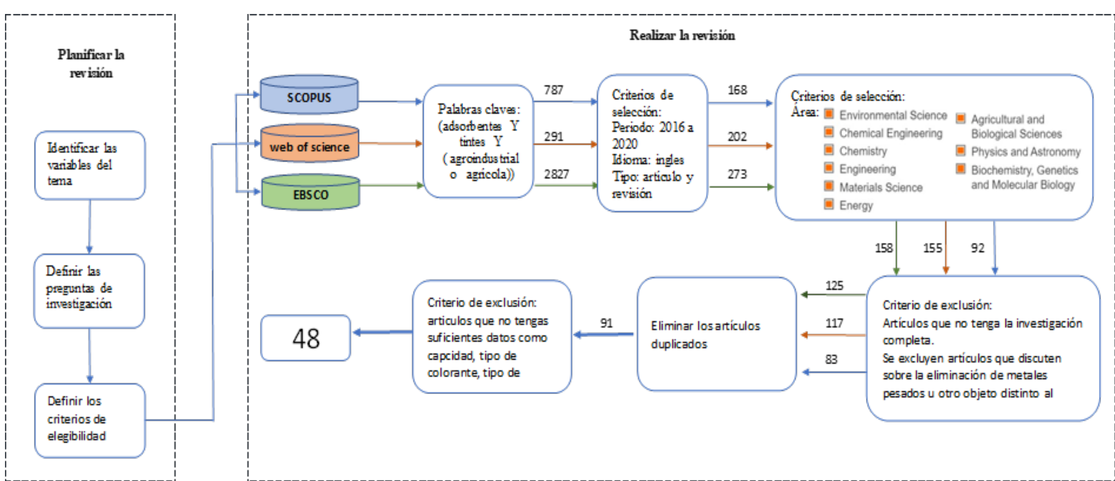


Figure 3. Search Strategy Flowchart

# 4. Results and Discussion

## 4.1 Colorants

According to Yeow et al. (2021) dyes are one of the biggest problems in terms of environmental pollution, and that it is important to treat the effluents that contain them before being discarded. The author classifies dyes in two ways, the first is based on the type of surface on which they can be applied, the method of application and the chemical composition. While in the second classification it organizes them based on their chemical structure (Figure 4). Below are some tables in which this classification can be better visualized and in which you also have a significant amount of dyes.

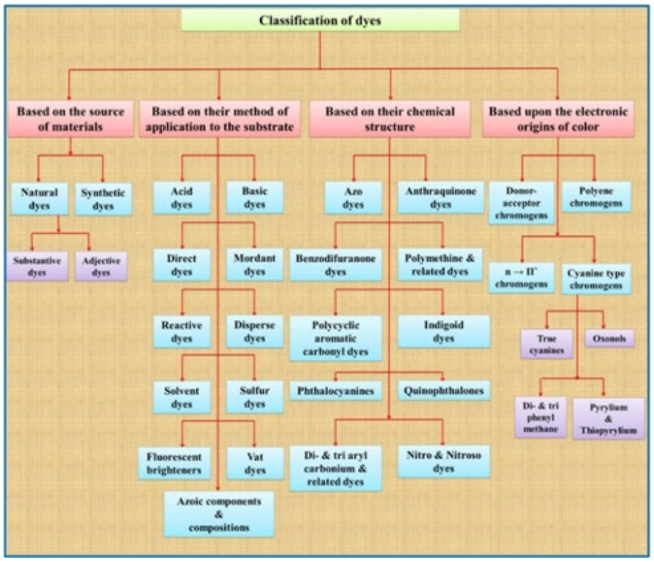


Figure 4. Classification organizes based on chemical structure

## 4.2 Treatment Methods

It is for the reason of contamination that there are treatment methods for these very polluting dyes, according to Ahmad et al. (2015), different methods have been developed: physical, chemical and biological. In addition, among all dye removal techniques, the adsorption process is the best choice for dye discoloration and offers the best results for the removal of various types of dissolved dye materials.

In this research we will work with the adsorption method, which belongs to the group of physical methods and even more specifically using agro-industrial waste as an adsorbent.

## 4.3 Agricultural Waste

Commercial activated carbon has several disadvantages, it is quite expensive, the higher the quality, the higher the cost, it is not selective and ineffective against dispersed dyes. The regeneration of saturated carbon is also expensive, not simple and results in the loss of the adsorbent (Demirbas 2009).

Agricultural solid waste usually contains main components: cellulose, lignin, hemicelluloses. In addition, they are available and abundant in large quantities and have a high adsorption potential due to the variety of functional groups (–OH, –C=O, –C–O, –NH2) in their surface adsorbents (Bushra et. al, 2021). The basic structural unit of lignin is phenylpropane, which is bound together with the help of hydroxyl, methoxyl and carbonyl groups, forming a complex three-dimensional structure. Both cellulose and hemicellulose also contain the hydroxyl, ether and carbonyl groups present in lignocellulosic materials. All these functional groups are beneficial in the process of synthesis of adsorbents. Therefore, according to Bushra et. al (2021), agricultural solid waste can be used as economic and ecological adsorbents, as they are abundant and renewable sources.

These agro-industrial residues generally do not require pre-treatment, and this also reduces preparation costs, which are much lower than those associated with heat treatments in activated carbon production. (Bonetto et. al, 2020).

Therefore, the use of low-cost agricultural waste materials in the treatment of dye removal is the area of greatest interest to environmental researchers and scientists. For many small-scale industries, the use of commercially available activated carbons is expensive and their use requires regeneration and reactivation procedures. To overcome these problems, interests are focused on producing activated carbons from agricultural waste, which is considered a promising material for removing contaminants (Bushra et al., 2021). In addition, the conversion of agricultural by-products into activated carbon provides another disposal method that minimizes environmental pollution (Bushra et al., 2021). In this way, the use of these adsorbents will bring a double advantage which is to decrease the volume of agricultural waste and the treatment of water waste at a reasonable cost (Thuong et al., 2019).

In this research, agro-industrial waste without carbonization treatment and activated carbons made from agro-industrial waste will be studied.

### 4.4 Adsorption Method

According to Dutta et. al (2021), adsorption is considered one of the most important and useful decontamination processes. It is considered a fast, low-cost, simple, sludge-free process, with high efficiency, mechanical stability and recycling facilities.

Adsorption is the deposition of molecules at the two-phase interface, which can be liquid-solid, liquid-gas, liquid-liquid, or gas-solid. For example, the appearance of adsorption in a solid-liquid system is able to remove solutes from the solution and accumulate them on the solid surface (Yeow et al. 2021).

### 4.5 Isotherms and Adsorption Kinetics

Adsorption can be quantitatively assessed through isotherms. The equilibrium study provides fundamental information to evaluate the ability of different adsorbents to adsorb a given adsorbate (Mendonça de Oliveira et al. 2020).

The interaction between adsorbate and adsorbents, and the equilibrium distribution of the adsorbate between the liquid and solid phase can be explained by the adsorption isotherm (Novera et al. 2021), as well as the maximum adsorption capacity and dynamic equilibrium of the system (Choi and Yu, 2019).

The Langmuir and Freundlich isotherm models are the most used adsorption isotherms in adsorption process studies (Zhu et al. 2019).

Langmuir's isotherm model is based on the adsorption of monomolecular layers and assumes that the adsorbent surface is homogeneous, and each part of the adsorbent surface has the same adsorption capacity. When the adsorbent reaches the saturated state on the surface of the adsorbent, the adsorption capacity reaches the maximum value. There is no transfer motion on the adsorbent surface when the saturated state is reached. In dynamic equilibrium, the adsorption rate and the desorption rate of the adsorbate in the adsorbent are the same (Zhu et al. 2019).

On the other hand, kinetic study is essential to study an adsorption system. Kinetic curves provide information about the adsorption rate and also about the time needed to reach equilibrium (Georgin et al. 2017).

Several kinetic models are used to examine the mechanism of control of the adsorption process, chemical reaction, diffusion control and mass transfer. The most commonly used models are pseudofirst order and pseudosecond order (Mendonça de Oliveira et al. 2020).

### 4.6 Adsorption Parameters

Adsorption performance was affected by several parameters, including temperature, pH, initial dye concentration, and adsorbent dose. Each parameter has its characteristics and varies with the type of dye and the adsorbent used. In large-scale applications, optimizing these parameters is beneficial as it provides an understanding of the adsorption mechanism (Bushra et al. 2021).

pH is a critical parameter to consider when removing dyes from aqueous solutions, as it can affect the load on the surface of the adsorbent (Loulidi et al. 2020). According to Bushra et al. (2021), the adsorption rate varies with the change in the pH of the medium. At low pH, the removal efficiency of the cation dye decreases, and for the anionic dye, it increases due to the highly protonated surface of the adsorbent that favors the adsorption of the anionic groups resulting in an improvement in adsorption. However, at high pH, it shows an inverse order. The zero charge point (pHpzc) determines the adsorption capacity of the adsorbent surface and is defined as the pH value where the total net charge of the particles on the surface of the adsorbent is neutral. Therefore, according to Mendonça de Oliveira et al. (2020), when pH > pHpzc, a favorable adsorption of cationic dye is achieved; however, anion dye adsorption is observed when the surface is positively charged (pH < pHpzc).

Adsorbent dosing is another important process parameter for determining the capacity of an adsorbent under operating conditions. Generally, the percentage of dye removal increases with increasing adsorbent dose, where the number of adsorption sites on the surface of the adsorbent will increase with increasing amount of adsorbent. The effect of adsorbent dosing gives an idea of the adsorption capacity of a dye to adsorb with the least amount of adsorbent, to recognize the adsorption capacity of a dye from an economic point of view (Zhu et al. 2016).

Below, the matrix made from the data collected from the chosen articles is shown, as you can see there are 3 main data: the adsorbent, the dye and the adsorption capacity (Table 1).

Table 1. Matrix of dyes and adsorbents

| Adsorbent | Coloring | Adsorption capacity (mg/g) or elimination percentage (%) | Reference |
|---|---|---|---|
| Corn stem | Malachite Green | 90% | (Abubakar & Batagarawa, 2018) |
| Corn stem | Congo red | 84.70% | (Abubakar & Batagarawa, 2018) |
| Metroxylon | Methylene blue | 83.5 mg/g | (Amode et al., 2016) |
| Cauliflower leaf | Methylene blue | 149.22 mg/g | (Ansari et al., 2016) |
| Apple pulp | Methylene blue | 133.15 mg/g | (Bonetto et al., 2021) |
| Bean pod powder | Bright blue remail | 1.23 mg/g | (Chang et al., 2021) |
| Bean pod powder | Bright violet remail | 1.22 mg/g | (Chang et al., 2021) |
| Corn cob | Methylene blue | 417.1 mg/g | (Choi & Yu, 2019) |
| Sugarcane bagasse | Basic red 46 | 95% | (Cueva-Orjuela et al., 2017) |
| Wheat bran | Crystal violet | 25.66 mg/g | (Das et al., 2019) |
| Orange peel | Methylene blue | 62.89 mg/g | (de Oliveira et al., 2020) |
| Marula seed shell | Methylene blue | 33 mg/g | (Edokpayi et al., 2019) |
| Almond shell | Methylene blue | 52.35 mg/g | (El Khomri et al., 2021) |
| Almond shell | Crystal violet | 44.78 mg/g | (El Khomri et al., 2021) |
| Almond shell | Congo red | 26.92 mg/g | (El Khomri et al., 2021) |
| Orange peel | Methylene blue | 192.31 mg/g | (Giraldo et al., 2021) |
| Sugarcane bagasse | Optilon red | 90% | (Gita et al., 2017) |
| Leaves of the potato plant | Methylene blue | 52.6 mg/g | (Gupta et al., 2016) |
| Leaves of the potato plant | Malachite Green | 33.3 mg/g | (Gupta et al., 2016) |
| Potato plant stem | Methylene blue | 41.6 mg/g | (Gupta et al., 2016) |
| Potato plant stem | Malachite Green | 27 mg/g | (Gupta et al., 2016) |
| Coconut leaf | Methylene blue | 112.35 mg/g | (Jawad et al., 2016) |
| Coconut shell | Reactive Black 5 | 0.82 mg/g | (Jozwiak et al., 2018) |
| Coconut shell | Reactive yellow 84 | 0.96 mg/g | (Jozwiak et al., 2018) |
| Coconut shell | Acid yellow 23 | 0.53 mg/g | (Jozwiak et al., 2018) |
| Coconut shell | Acid red 18 | 0.66 mg/g | (Jozwiak et al., 2018) |
| Coconut shell | Basic violet 10 | 28.54 mg/g | (Jozwiak et al., 2018) |
| Coconut shell | Basic red 46 | 68.52 mg/g | (Jozwiak et al., 2018) |
| Walnut shell | Methyl red | 52.44 mg/g | (Kaya, 2017) |
| Walnut shell | Methyl orange | 29.87 mg/g | (Kaya, 2017) |
| Walnut shell | Methyl yellow | 28.54 mg/g | (Kaya, 2017) |
| Hazelnut shell | Methyl red | 51.11 mg/g | (Kaya, 2017) |
| Hazelnut shell | Methyl orange | 27.88 mg/g | (Kaya, 2017) |
| Hazelnut shell | Methyl yellow | 26.55 mg/g | (Kaya, 2017) |
| Almond shell | Crystal violet | 12.2 mg/g | (Loulidi et al., 2020) |
| Corn cob | Methylene blue | 333 mg/g | (Medhat et al., 2021) |
| Betel nut shell | Methylene blue | 149.92 mg/g | (Novera et al., 2021) |
| Aloe vera leaf shell | Congo red | 1850 mg/g | (Omidi Khaniabadi et al., 2016) |
| Orange peel | Auromine yellow | 95% | (Paul et al., 2020) |

| | | | |
|---|---|---|---|
| Psylium stem | Coomassie bright blue | 237.2 mg/g | (Periyaraman et al., 2019) |
| Rice husk | Methylene blue | 98.95% | (Phihusut & Chantharat, 2017) |
| Rice husk ash | Methylene blue | 92.70% | (Phihusut & Chantharat, 2017) |
| Cucumis sativus | Crystal violet | 33.22 mg/g | (Smitha et al., 2017) |
| Cucumis sativus | Rhodamine B | 40.82 mg/g | (Smitha et al., 2017) |
| Walnut shell | Methylene blue | 51.55 mg/g | (Tang et al., 2017) |
| Durian shell | Methylene blue | 235.8 mg/g | (Thuong et al., 2019) |
| Durian shell | Crystal violet | 527.64 mg/g | (Thuong et al., 2019) |
| Sunflower peel | Direct orange 26 | 11 mg/g | (Tomcazk & Tosik, 2017) |
| Sesame shell | Acid red 88 | 25 mg/g | (Zarei et al., 2017) |
| Bamboo shell | Methylene blue | 54.17 mg/g | (Zhu et al., 2016) |
| Bamboo bud skin | Methylene blue | 29.88 mg/g | (Zhu et al., 2019) |

## 5. Conclusions

Through this research it was possible to verify that agro-industrial waste is an important source of matter to function as adsorbent agents in the elimination of dyes. In addition, it was possible to know many agro-industrial wastes capable of adsorbing and eliminating dyes in textile effluents and industries in general. There is a wide variety of dyes that are currently used, the most studied in experiments of elimination of dyes with agro-industrial residues as adsorbent agents are methylene blue, crystal violet, red congo and malachite green. Also, among the most used agro-industrial waste, coconut shell, almond shell, walnut shell and hazelnut shell take place.

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