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RICE HUSK AS AN EFFICIENT AGRICULTURAL WASTE ADSORBENT FOR THE REMOVAL OF DYES FROM WATER BODIES: A REVIEW

Nisha [a], Renu Mavi [a], Manvi Chaudhary [b], Geetanjali Singh [a], Preeti Singh [a]*

[a]Department of Chemistry, Faculty of Science, Swami Vivekanand Subharti University, Meerut 250005, U.P. India. Email: preetisingh121002@gmail.com
[b]Department of Forensic Science, Faculty of Science, Swami Vivekanand Subharti University, Meerut 250005, U.P. India.

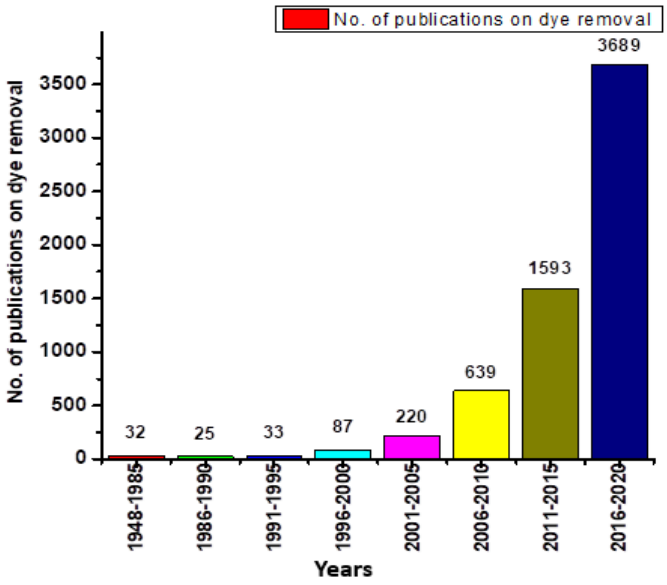
Abstract
A rapid increase in toxic dye wastewater generated from industries becomes a major public health issue. However, there are several biological as well as physicochemical treatment processes have been reported, that exhibit different removal capacities depending on the experimental parameters. Among all, the adsorption process is considered as one of the most potential because of its high removal efficiency, low cost, easy operation and reusability of the adsorbents. In this context, one of the agricultural wastes, rice husk being comparatively cost effective as well as abundant material can be considered as an adsorbent for the elimination of various contaminants including toxic dyes from the natural water bodies as well as wastewater. By utilizing this rice husk as an adsorbent, most of the pollutants like dyes (both cationic and anionic), heavy metals, organic compounds, pesticides, and inorganic anions can be removed efficiently. The present review will discuss the utility of rice husk adsorbent in the removal of hazardous and toxic dyes from wastewater. Moreover, the effect of several parameters such as pH, adsorbent dosage, dye initial concentration, and temperature, the adsorption potential will be elaborated.

Introduction

Due to the rapid growth of global population, environmental pollution has been increasing with each passing day which affects the water quality, resulting in an increasing freshwater crisis worldwide. [i,ii] Water pollution has attained the attention of various researchers and scientists around the world. Therefore, the concern of eliminating various contaminants from water and wastewater has grown enormously with rapid proliferation of industrial and urban pollutants. [iii] There are several pollutants such as heavy metals, dyes (cationic and anionic), phenols (including other organic compounds), inorganic anions and pesticides (which are toxic to diverse living life forms and organisms) are present in the wastewater streams of many industrial processes [iv,v,vi] Among them, the increasingly used dyes like malachite green (MG), congo red (CR), methylene blue (MB), methyl orange (MO), methyl red (MR),

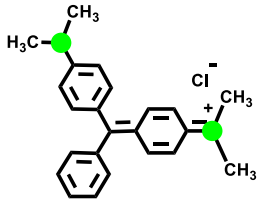
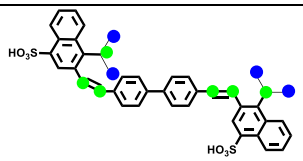
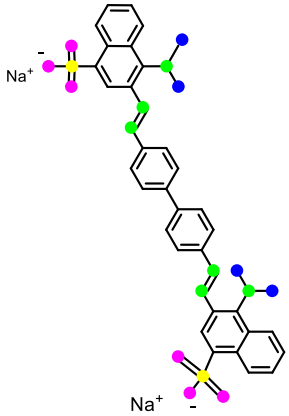
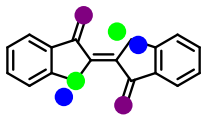
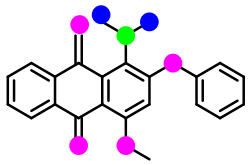
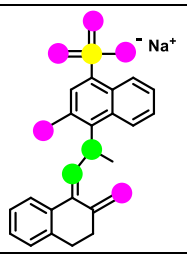
and crystal violet are the major sources of industrial pollutants [vii,viii] generated from different industries such as cosmetic, textile, food, pharmaceutical, paint and varnish and paper industries.[ix,x] All of the above-mentioned industries face challenges with increasing pressure, regarding environmental and waste management related concerns, as a result of quantity and toxicity of the wastewater generated. Consequently, research in this area is going on, and there is an upsurge in the number publications on selected keyword 'Dye Removal', as represented in Figure 1. [xi]

Figure 1: Frequency of number of publications on dye removal with selected keyword 'dye removal'.



The direct disposal of untreated dyes containing effluents into water bodies possess an adverse effect on photosynthetic activity in aquatic life, subsequently affecting the water quality, as well as human health. [xii,xiii,xiv] Table 1 highlights various eco toxicological effects of various dyes on living organisms. Though, there are several methods reported for the removal of dyes as well as other industrial effluents from wastewaters which include membrane filtration, adsorption, coagulation, oxidation, ion exchange and precipitation. However, only few of these were adopted because of their economic value, high efficiency, selectivity and applicability to a wide variety of pollutants. Most of the methods are in separation has merits and demerits like coagulation method is most commonly used method in industries, that does not involve the formation of toxic substances, but, inherent sludge formation and its disposal becomes the biggest drawback. In case of dyes, due to their chemical structures, these are resistant to fading upon exposure to light, water and other chemicals. Therefore, these are problematic to decolorize once they are released into the aquatic environment. Most of the methods which are reported usually require expensive set up facilities and have high maintenance costs. In this regard, more cost-effective alternative technologies or sorbents for the treatment of aquatic system are required for wastewater treatment.

Table 1: Classification, example, applications, solubility in water and ecotoxicological effect of various dyes

Type of dyes	**Chemical structure**	**Example**	**Dye applications**	**Solubility in water**	**Ecotoxicological effects**	**Ref.**
Acid dye		Malachite Green	Textile, leather, and pharmaceuticals	Readily soluble	Carcinogenic and mutagenic effects	[xv]
Basic dye		Congo Red	paper	Readily soluble	Altering the chemical and physical properties of water bodies	[xvi]
Direct dye		Vat Blue 1	Colouring paper products	soluble	Toxic to aquatic animal and plants	[xvii]
Vat dye		--	Insoluble pigment, indigo and natural fibres	Water insoluble	Affects the quality of water which cause allergic reactions	[xviii]
Disperse dye		Disperse d red 60	Polyester, nylon, cellulose acetate	Water insoluble	Carcinogenic, cause soil and water pollution	[ix]
Mordant dye		Mordant black 17	Textile fibres	Water soluble	Exhibit allergic reactions	[xx]

Adsorption technology, which involves the movement of solids from the bulk liquid to the surface of adsorbent.[xx] However, the number of articles on physicochemical as well as biological treatment is more, which confirms that among all methodologies, adsorption is

considered to be one of the most useful decontamination techniques.[xxi] Adsorption with activated carbon is highly efficient for the removal of various impurities / pollutants from wastewater, but, the high cost of activated carbon prevents its large-scale application as an adsorbent. Hence, there is an urgent need for the effective removal of such contaminants from wastewaters which provide remarkable features like low – cost, reusable and eco-friendly adsorbents that can be utilized for the elimination of various toxic dyes as well as other organic pollutants.

Overview of natural adsorbent for the removal of toxic dyes

In this context, natural materials that are available in larger quantities or certain types of waste products from industrial or agricultural operations can possess potential as an inexpensive adsorbent. The easy availability and low cost of agricultural byproducts make them good alternative as adsorbents for the removal of dyes. Therefore, in this field the agricultural waste biomass is gaining attention for wastewater treatment through adsorption technique.[xxii] Based on this perspective, rice husk, which is an agro-based waste, has emerged as an individual source for the utilization as an adsorbent in the wastewater treatment.[xxiii] Rice husk contains about 20% of silica and it has been reported as a remarkable adsorbent for the removal of dyes as well as other pollutants. More than 50% of the world's population has husk as their staple food. Rice husk is extensively generated and used in India, due to its widespread availability and low cost. India being the second largest rice producer worldwide produces around 20 million tons of rice husks. [xxiv] These rice husks as a commodity waste have an ability to be converted into activated carbon, which has application as an adsorbent in the wastewater treatment. [xxv] It would also add value to these agricultural commodities, helping in deducting the cost of waste disposal and provide a potentially cost-effective alternative to the existing commercially available adsorbents.

Rice husk is selected to be utilized as a precursor material because of its insolubility in water, granular structure, insolubility in water, chemical stability, mechanical strength, and its local availability at almost no cost.

Properties of rice husk

Rice husk possesses a granular structure, is insoluble in water and has chemical stability and enhanced mechanical strength which makes it a good adsorbent material for treating various wastes from water and wastewater. On the basis of chemical analysis like Energy dispersive X-ray spectroscopy (EDX), it is reported that the most abundant component in rice husk is silicon.[xvi]

Based on scanning electron microscopy (SEM), the morphology of rice husk facilitate the adsorption of dyes and other pollutants, because of the irregular surface of rice, which makes it possible for the adsorption of dyes in different parts of this material. Various physical characterizations of rice husk have demonstrated some properties such as the presence of functional groups (carboxyl, silanol etc.) that make adsorption processes possible, which can be investigated by FT-IR. The role of chemical structure of the rice husk is of major importance in order to understand its adsorption process. The Fourier Transform Infrared Spectroscopy (FTIR) technique is an important technique to identify the characteristic functional groups, that play an important role in the adsorption of dyes from water and wastewater. Table 2 shows the adsorption capacities of possible dyes on rice husk.

Utilization of rice husk as an adsorbent for dye removal

Dyes and pigments are released into the water bodies from various industrial sectors such as dye manufacturing and textile finishing industries. Several methods are available for the treatment of dyes bearing wastewater. Among them, the adsorption technique is considered to be an attractive alternative for the treatment of wastewater, especially when the adsorbent is economical and does not need any additional pre-treatment before its utilization. The adsorption capacities of various dyes onto rice husk (RH), is mentioned in figure 2. Consequently, rice husk can be utilized as an adsorbent for the removal of diversified range of dyes such as cationic as well as anionic.

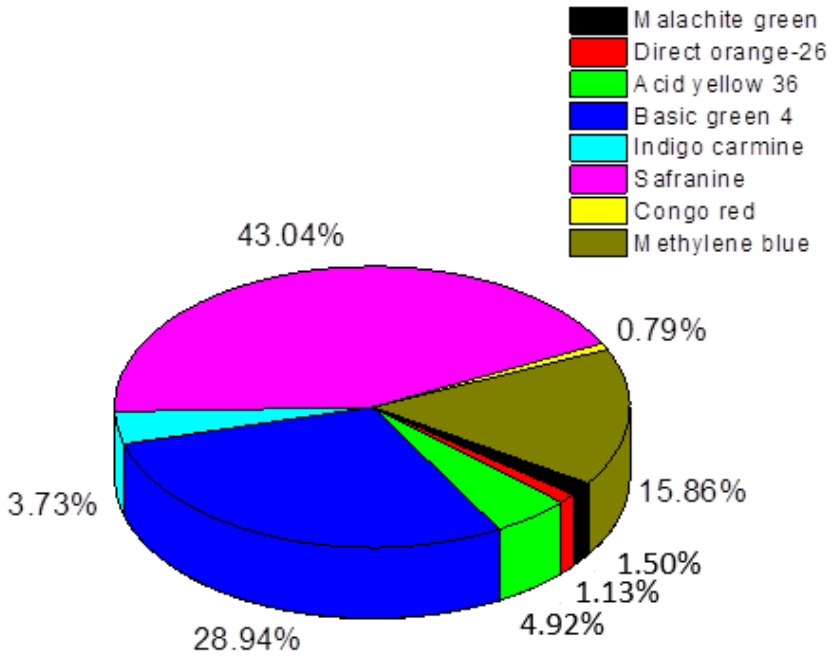


Figure 2: Demonstration of adsorption capacities of different dyes [xxvii]

Critical assessment of adsorption research

There has been remarkable increase in adsorption – related research for the removal of various dyes from wastewater during the last few years. Various factors are there that affects the way and capacity of the dye adsorption such as pH, temperature, initial concentration and amount of adsorbent. By optimizing these parameters, it can greatly affect the development of the dye removal process on an industrial level. Some of the factors have been investigated in most of the studies and are discussed below.

Effect of pH

The acidity of the solution is one of important factor which affects the adsorption capacity for wastewater treatment. The efficiency of adsorption depends on the pH of the solution due to change in pH, which lead to change in the degree of melting properties. Hence, pH is considered as important parameter in color adsorption.[xxviii]

Effect of dye initial concentration

This effect is closely related to the dye concentration and the sites present on the adsorbent surface. Generally, the efficiency of dye removal decreases with increasing initial dye concentration that leads to saturation of adsorption sites on its surface.[xxix]

Effect of temperature

Temperature is also an important factor for the adsorption process because the amount of adsorbent capacity is related to the process temperature.[xxx] If the amount of adsorption sites increase on increasing the temperature, this attributes to the fact that it is an endothermic process. This is because of the increment of the mobility of dye molecules, as the number of active sites increases with increase in temperature.

Effect of amount of adsorbent

It is an important factor to determine the capacity of adsorbent for the given amount of adsorbent. Generally, the dye removal efficiency increases with increase in the amount of adsorbent with increase in number of the active sites.[xxxi]

Conclusion(s)

The disposal of colored dyes wastewater in the environment causes environment pollution is a matter of concern. It has been reported that the toxic dyes possess carcinogenic, mutagenic allergic and dermatitis effect on living organisms. This review highlights the investigations carried out by various scientists on the removal of various dyes from wastewater using agricultural waste rice husk adsorbent. According to literature survey, it was demonstrated that rice husk has been utilized as a potential, low-cost, easily available and reusable adsorbent material for the elimination of various dyes from wastewater. It was observed that due to the presence of silica, rice husk exhibited high performance in the adsorption of toxic dyes from wastewater. Various factor such as solution pH, adsorbent dosage, initial dye concentration and temperature were identified as important factors for investigating the adsorption capacity. Therefore, the high selectivity for the required adsorbate is most important for the materials in the elimination of dyes from enormous quantities of aqueous solutions.

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