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Sugarcane Bagasse as a Biosorbent for Removal of Dyes

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ABSTRACT

Organic and inorganic pollutants affecting surface water sources are a serious problem in the developing world, therefore removing these potentially harmful contaminants from the aquatic environment using environmentally friendly methods is important. Biosorption or the passive binding of pollutants in aqueous solutions using dead biomass may be accomplished by utilizing a variety of low-cost agro-industrial wastes, which offer a cost-effective alternative to conventional methods for pollutant removal from aqueous solutions. The application of sugarcane bagasse as a cost-effective natural biosorbent is the focus of this review. The use of Sugarcane Bagasse (SB) biosorbent in both its raw and modified forms for dye removal from wastewater is studied in this article. SB activation and modification approaches were studied using physical, chemical, biological, composite formation, and grafting procedures. Aside from that, the impact of several optimization parameters on the adsorption process, such as adsorbent dose, preliminary dye concentration, pH, temperature, and contact period, was examined. Also discussed dye-loaded SB regeneration problems and solutions. The opportunities for future waste-derived adsorbent research were investigated.

1. INTRODUCTION:

The world is changing as a result of advancements in technology. Environmental disruptions and pollution issues are among the consequences of fast growth. In addition to other requirements, industrial water consumption increased fast, resulting in the production of huge volumes of wastewater containing different contaminants **(Bulgariu et al.,2019).**

Dyes are a major source of pollution in industries such as paper, leather tanning, food processing, plastics, cosmetics, rubber, printing, dye manufacture, and textiles. They're compounds with a unique chemical structure that attaches to surfaces to provide color. These structures, which may be found in stable dyes, are extremely difficult to work with and only biodegrade to a small extent **(Yagub et al.,2014)**.

The release of synthetic dye effluent into the environment hurts the environment's ecological state, resulting in several undesirable changes occurring in the environment. Because dyes have a high water solubility even at low concentrations, highly colored effluents can be particularly damaging to surrounding water bodies. These chemicals are undesirable because they change the natural look of rivers and lakes, as well as affect aquatic life and interfere with sunlight transmission, decreasing photosynthesis and oxygenation in water**(Albadarin et al.,2014).**

Dye pollution of water bodies may be harmful to aquatic creatures, resistant to natural biological destruction **(Bulgariu et al.,2019),** and disrupt biological cycles. They also represent a risk to human health, since studies have revealed that some of these items are carcinogenic or mutagenic, as well as causing allergies, dermatitis, and skin irritation **(Shoukat et al.,2017).**

The direct release of dyes from different sources has placed world water security in danger. Up to 10,000 dyes are present globally, with yearly output exceeding 7105 tonnes, and they are used to color items in sectors such as textiles, paper, food, and pharmaceuticals **(Robinson et al., 2001),(Pearce et al., 2003),(Azari et al., 2020).**

Approximately 10-15% of the entire yearly dye use in the textile sector is released as waste into the environment **(Reisch et al., 1996, Tara et al., 2019)**. Indian textile firms use more than 100 liters of water to produce 1 kilogram of textiles, leading to a huge volume of dyed effluent that pollutes surface and groundwater resources in many areas of this country. **(Srivastava et al., 2019)**.

The removal of dyes from wastewater is highly problematic, including high prices, the production of toxic products, and the use of a lot of energy. To minimize dye concentration in wastewater, efficient, cost-effective, and environmentally acceptable methods must be developed **(Robinson et al.,2001)**As a result, new solutions must be found, as well as the creation of technology that produces less environmental impact. Color removal from wastewater using less expensive and ecologically friendly technology, on the other hand, is a major challenge **(Reisch et al.,1996).** The biosorption process has many advantages over conventional treatment methods, including low cost, high performance, minimum chemical consumption, no additional nutrient needs, biosorbent regeneration capacity, and metal reusability**(Azari et al.,2020).**

SCB (sugarcane bagasse) is a major by-product of the sugarcane industry and one of the world's greatest agricultural wastes. It's the fibrous waste left behind after crushing and extracting sugarcane juice from sugarcane stalks. **(Azari etal.,2020)**The majority of this trash is burned to generate energy, resulting in the release of greenhouse gases into the environment **(Yano etal., 2020).** As a result, developing cleaner methods to utilize such trash without damaging the environment is critical. One option is to reuse waste SB as an adsorbent in wastewater treatment to remove pollutants like as dyes, heavy metals, pesticides, and other chemicals.

Around 54 million tonnes of dry SCB are generated each year in the world, and massive volumes of SCB are burned in the fields, causing major pollution. SCB also has a lignin cellulose and polymeric structure (50 percent cellulose, 25 percent hemicellulose, and 25 percent lignin) and is a common, cheap, and promising type of industrial waste **(Tahir et al.,2016)**As a result, using this agricultural waste as a low-cost adsorbent might give a two-fold benefit in terms of reducing pollution. First, the volume of by-products could be decreased, and second, wastewater pollution could be minimised at a reasonable cost using a low-cost adsorbent **(Srinivasan et al.,2010).**

2. Biosorption concept:

The removal of chemicals from a solution using biological material is known as biosorption. Organic and inorganic compounds, as well as soluble and insoluble forms, can be used for Biosorption substances. Biosorption is a natural physiochemical mechanism that allows specific biomass to passively aggregate and bind impurities to its cellular structure. Biosorption is not to be associated with bioaccumulation, which is the active, metabolicallydriven accumulation of metals and other elements by living organisms **(Gadd 2009).** Biosorption is more successful than traditional bio-treatment procedures at reducing pollutant ions to extremely low levels**(Fomina and Gadd 2014),** and in some cases completely removing them, thanks to the use of low-cost biosorbent materials**(Moubarik and Grimi 2015).**

Biosorbent dose, initial pollutant concentration, solution pH and temperature, contact time, and sorbent particle size all have a major impact on the sorption process and its potential. In general, as the surface area of the adsorbent rises, more active sites that bind pollutant ions are exposed, increasing adsorption efficiency **(Homagai et al. 2010).** Adsorption efficiency, on the other hand, reduces when the initial concentration of pollutant ions rises, showing that the potential active sites for binding pollutants have been saturated **(Tao et al. 2015).**

The pH of the solution is a crucial part of the adsorption process because it regulates the amount of electrostatic charges given by pollutant ions, which can impact the rate of adsorption **(Önal et al. 2006).**

3. About dyes and classification:

Dyes are unsaturated organic compounds with a complicated structures that absorb light and impart colour to the visible spectrum, **(A. Rehman, et al.,2020).**A dye is a material that absorbs a part of the visual spectrum (chromophore). The colour is determined by the percentage of light that is replicate rather than absorbed by the dye. The conjugated double bonds provide a chemical structure that is favorable to light absorption. As a result, aromatic amines are frequently found in dyes.

Dyes are distinguished by their capacity to absorb visible light radiation (from 380 to 750 nm) The selective absorption of energy by specific groups of atoms known as chromophoric groups leads to the change of white light into colored light through reflection on a body, transmission, or diffusion. A dye, for instance, is a substance capable of absorbing specific types of light and subsequently reflecting the complementary colors, **(A. BENAISSA et al., 2012).**

Based on the material's origin classified as follows:

- Natural Dyes:

Plants, invertebrates, and minerals provide natural dyes and colorants. Vegetable colors derived from plants account for the majority of natural dyes, for example, Roots, berries, bark, leaves, and timber. Fungi and lichens are two more organic sources. **(V. Sivakumar et al.,2009), (A. K. Samanta et al.,2011), (A. K. Samanta and P. Agarwal et al.,2009).** Plants, insects/animals, and minerals may all be used to make natural dyes **(I. Zerin et al.,2020).** They produce effluent that may be handled by biodegradation and are typically less allergic and harmful than synthetic dyes **(P.M. dos S. Silvaetal et al.,2020).**

- Synthetic Dyes:

Synthetic dyes may be found in a wide range of products, including clothing, paper, food, and wood. This is because they are less expensive to make, as well as being brighter, colorfast, and easier to apply to cloth. Acid Dyes, Azo Dyes, Basic Dyes, Mordant Dyes, and other dyes are examples of synthetic dyes. Around 7 × 107 tonnes of synthetic dyes are generated for the textile industry each year, with almost 10% of the dyestuff being discharged to the environment as effluent after dying and processing **(V.V. Chandanshive, et al.,2018).** It is reasonable to predict that dye production will rise in tandem with expected increases in textile fiber output **(S.M. Burkinshaw et al.,2013).**

Based on the presence of chromophores classified as follows:

The chromophore is made up of several atom groups, the most frequent of which are nitro(NO2), azo(NN), nitroso (NO), thiocarbonyl (CS), carbonyl (CO), and alkenes (CC). The activation of the electrons in a molecule causes the chromophore to absorb electromagnetic radiation **(AD Laurent et al.,2010).** The molecule containing them becomes chromogenic **(A. BENAISSA et al.,2012).** Only by adding extra groups of atoms called "autochrome" to the chromogenic molecule can it be colored **(A. BENAISSA et al.,2012).** These autochromes groups allow the dyes to be fixed and can change their hue. They can be acidic or basic (COOH, SO_3, and OH) (NH_2, NHR, and NR_2).

Methods of Application are classified as follows:

The application method is determined by the nature of both the dye and the fabric. They are categorized according to the technique used in their application.

- Direct Dyes:

They are mostly used for coloring paper goods. These dyes have a solid look following washing**(A.C. Jalandoni-Buan, et al.,2010).** Many factors, such as chromophore, fastness qualities, and application features, are taken into consideration. Direct dyes that are chromophoric include azo, oxazine, and stilbene, phthalocyanine as well as certain thiazole and copper complex azo dyes **(D.P. Chattopadhyay et al.,2011).**

- Vat dyes:

They are mostly soluble in boiling water, with a few exceptions soluble in the presence of a small amount of Na2CO3. Because of their affinity for cellulosic fibers, this dye class is designed for usage with them, and their application on nanofibers has yet to be studied **(T. Hihara et al.,2002), (S. Sirianuntapiboon et al.,2006).** Indigo is a vat dye that belongs to the general family. C.I. Vat Blue 1, **(M.Sanchez et al., 2015)** is the exact Colour Index number.

- Reactive dyes:

Reactive dyes have gained popularity as a result of their excellent wet fastness, brightness, and color diversity. **(S. Zhang et al.,2005).** According to Mahmoodi et al., **(N.M. Mahmoodi, et al.,2010)**, reactive dyes are frequently utilized because of their reactive groups' ability to attach to fibers, their stability, and processing conditions, among other things **(S.S. Hassan et al.,2009, J.A. Taylor et al.,2000).** These dyes make up the second biggest group of dyes **(M. Ghiyasiyan- Arani et al.,2016, M.A. Rauf et al.,2013).** Cellulosic fibers, as well as a tiny fraction of silk and wool fibers, are dyed using reactive dyes **(S.Mortazavi-Derazkola, et al.,2017, A. Gürsesetal et al., 2016, G.S. Shankarling et al.,2017, H. A. Shindy et al., 2017).** These dyes provide a wide range of hues with the good light fastness and great wash fastness on cotton, as well as improved dyeing production conditions and vibrant colors **(R. Christie et al., 2014, Y.-Q. Zhang et al.,2016).**

4. Application of dyes:

Dyes are colorful organic chemicals used to dye fibers and other materials. Currently, over 10,000 dyes are widely available. Artificial dyes have become more popular than natural colors produced by insects and plants, including their leaves, roots, shells, and flowers, over the years. Artificial dyes are in great demand in sectors for a variety of reasons, including lower manufacturing costs, simplicity of usage, and speed **(Katheresan et al., 2018).**

A dye is a type of material in a broad sense, but it is not the same as material in a limited definition. However, the dyes and materials have always had a very intimate interaction. Traditional dyes are primarily used to dye fabrics, but with the advancement of material science and the expansion of dye types and functions, dyes have become more widely and extensively used in materials such as LCD (Liquid Crystal Display) components, thermistors, varistors, solar energy, and lasers. Dyes are becoming more essential in material science, economics, the military, and people's lives. As a result, undertaking research into their applications in material science has become crucial.

5. Toxicity of Dyes:

According to reports, water pollution causes 70–80 percent of all diseases in developing nations, particularly impacting women and children (WHO and UNICEF, 2000). The majority of dyes are hazardous, harming living creatures and the environment as shown in **Fig 1.**

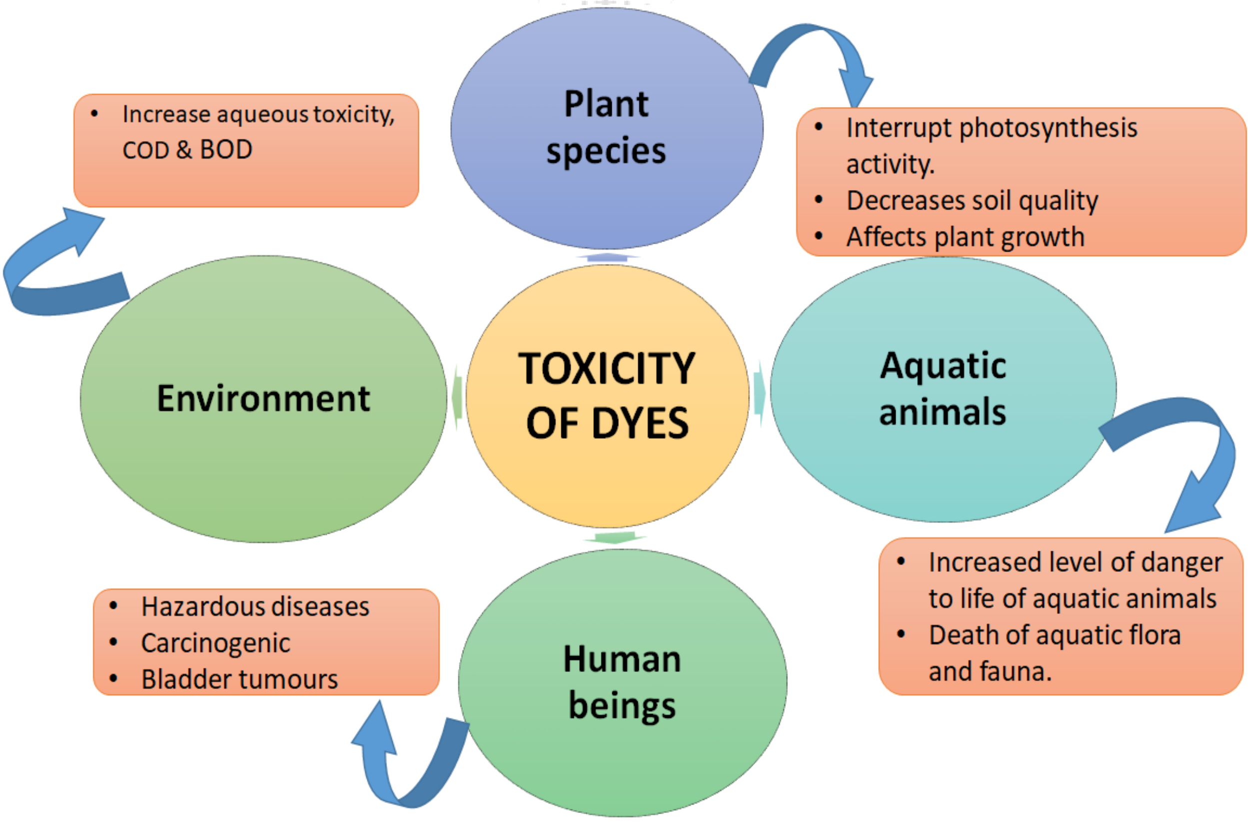

Fig 1. Toxicity caused by Dyes.

Dyes damage the visual quality of water and prevent sunlight from penetrating it, affecting the ecosystem's flora and fauna **(Allen et al., 2004), (Siddiqui et al., 2018).** Acidic and azo dyes have been shown to harm the gastrointestinal tract, eyes, respiratory system, and skin, as well as cause enzymatic problems, cancer, and allergenicity in humans **(Mittal et al., 2008). (Saratale et al., 2011), (Gupta et.al.,2005),(Chung, 2000),(Akarslan and Demiralay, 2015),(Platzek et al., 1999).**The amine group in azo dyes is primarily responsible for their toxicity.

In humans, basic dyes cause skin, allergic, reproductive, and developmental problems, laryngitis, mutations, skin cancer, an increase in the number of shocks, jaundice, neurotoxic effects, cyanosis, and tissue destruction **(Imam and Babamale, 2020),(Jain et al., 2007).**Because reactive dyes are water soluble, they have serious environmental consequences **(Taştan et al., 2010),(Asgher and Bhatti, 2012).** Synthetic food dyes when consumed directly create significant problems, disrupting the proper functioning of different organs in the human body **(Mittal et al., 2020)**.

As a result, dyes that are discharged directly or indirectly into water bodies constitute a huge environmental danger, and their removal from wastewater or household water is essential.

6. Sugarcane bagasse composition:

Sugarcane bagasse is a fibrous material left behind after crushing and extracting juice from sugarcane stalks, and it is one of the most common lignocellulosic agro-industrial wastes **(Paixo et al. 2014).** Sugarcane bagasse is made up of cellulose, hemicelluloses, lignin, ash, and a small number of extractives, among other things. SB's XRD displays a shoulder peak at 2 = 16°-18°, with a low signal corresponding to the amorphous fraction of cellulose and a maximum signal at 2 = 19°–25°, corresponding to the crystalline form of cellulose. In nature, hemicellulose and lignin are amorphous **(Said et al., 2018).**

Because of its many and diverse functional groups, lignocellulosic matter provides a strong attractive force for pollutant ion binding **(Okoro and Okoro et al., 2011).**Bioadsorbents generated from sugarcane bagasse are composed of macromolecules that include humic and fulvic compounds, lignin, cellulose, hemicelluloses, and proteins with a variety of functional groups that act as adsorptive sites, such as –OH, –COOH, –NH2, –CONH2, –SH2, and –OCH3 groups **(Rezende et al. 2011).** These sites allow bioadsorbents to attract and bind pollutant ions, either by exchanging hydrogen ions for them (ion exchange), adsorption, or complexation (donation of electron pairs) **(de Moraes Rocha et al. 2015).**

Bagasse from sugarcane and its derivatives are very effective in removing toxins. **(Boni et al. 2016)**, attributed to the existence of unique binding sites **(Yu et al. 2015b)** and high levels (10.3 percent) of silica **(García and Rico 2006)**; additionally, biological polymers such as cellulose and lignin can provide additional properties to the developed adsorbent materials **(Ngah and Hanafiah 2008).**

sugarcane bagasse is easily handled and modified **(Karnitz et al. 2010)**, and it blends well with other agro-industrial wastes such as tea trash, corncobs, sawdust, apple peel, and grape stalks **(Abdolali et al. 2014).** These properties, along with the low cost of huge quantities of sugarcane bagasse, make this material a promising biosorbent candidate for further research.

7. Sugarcane bagasse-derived adsorbents:

Sugarcane bagasse and its variants have been thoroughly investigated for the removal of a variety of hazardous chemicals in recent decades. Bagasse has been used as a viable biosorbent in three different forms: raw bagasse, bagasse fly ash, and bagasse-based activated carbon. Raw sugarcane bagasse is a well-studied biosorbent that eliminates pollutants without the use of additional chemicals or physical treatments, making it particularly eco-friendly **(Alomá et al. 2012). (Moubarik and Grimi 2015).**

(Diriba et al. 2014) conducted comparative research on the removal of nitrite ions from aqueous solutions using raw sugarcane bagasse and wheat straw under their optimum circumstances; raw sugarcane bagasse removed 90% of the nitrite ions, whereas wheat straw only removed 63%. Sugarcane bagasse that has been modified can also be beneficial; for example, **Raghuvanshi et al. (2004)** discovered that chemically activated sugarcane bagasse was quicker and more efficient than raw bagasse at removing dye. Sugarcane bagasse-based activated carbon and bagasse fly ash are also strong adsorbents, capable of removing a variety of contaminants from aqueous solution, including metals **(Tao et al. 2015)**, dyes **(Amin et al., 2008)**, phenolic compounds **(Akl et al. 2014)**, herbicides and pesticides **(Deokar et al. 2016).**In ideal circumstances, bagasse fly ash has been shown to remove up to 96 percent of various heavy metal ions from an aqueous solution **(Gupta and Ali 2004).**

Sugarcane bagasse and its derivatives are adept in binding hazardous chemicals due to the existence of a range of binding sites in both the raw and modified forms. **Figure 2** depicts a schematic depiction of the sorption of different contaminants by sugarcane bagasse and its derivatives.

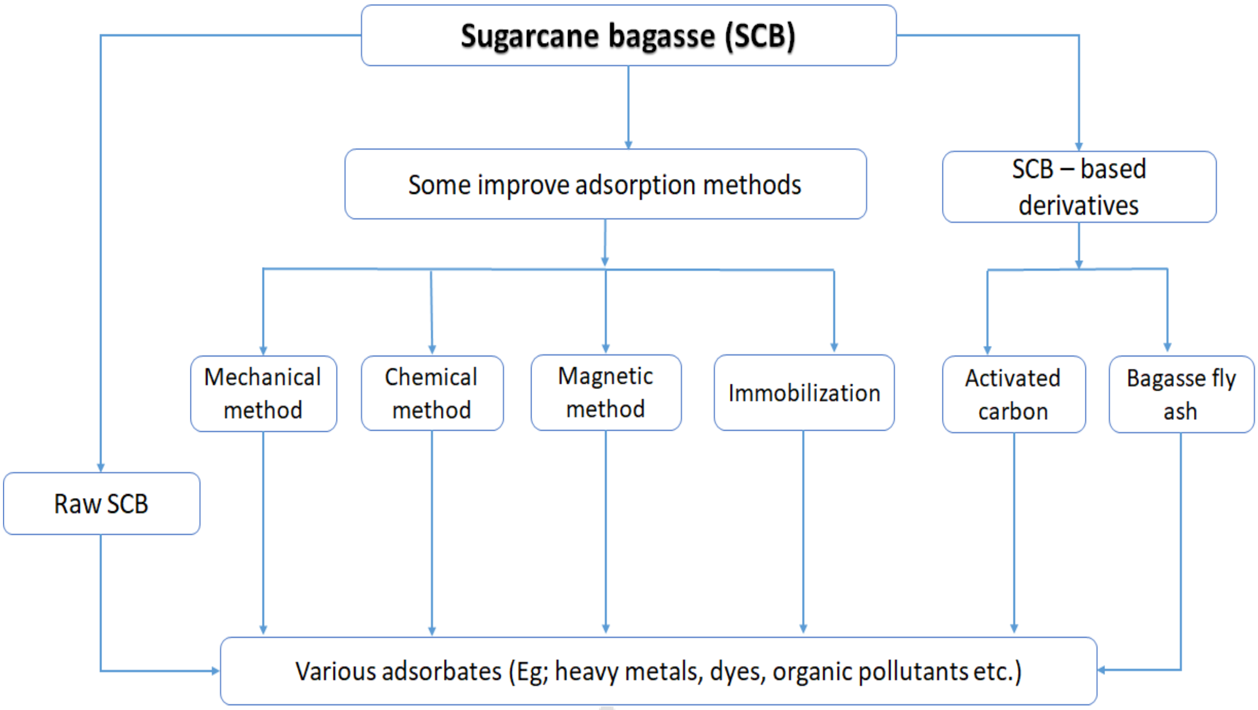

Fig 2. The sorption of different contaminants utilizing sugarcane bagasse (SCB) and its derivatives are depicted schematically (bagasse activated carbon and bagasse fly ash)

8. Different types of Dye removal methods from wastewater:

Dye-containing effluents can be treated using a variety of methods. As illustrated in **Fig. 3**, the technologies may be classified into three main categories: physical, chemical, and biological.

All of these approaches are explained in detail below, along with their benefits and drawbacks.

8.1 Chemical methods:

Chemical methods, like coagulation and flocculation, have traditionally been widely used for the removal of organic toxins **(Ukiwe et al., 2013).** Electrochemical destruction, Fenton's process, oxidation with NaOCl, ozonation, photochemical, and UV irradiation are the most common chemical color removal techniques. Coagulation-flocculation, like Fenton's method, generates a significant volume of sludge. The chemicals used to enhance coagulation and flocculation conditions are extremely costly **(Nidheesh et al., 2013).**

Gaseous ozone is used in the ozonation process, which has a shorter half-life (20 minutes) and creates hazardous by-products. Chemical techniques have various drawbacks, such as large-scale chemical and reagent use, cost of precipitation, and sludge formation and discharge. Chemical dye removal methods are often more expensive than biological and physical dye removal methods **(Katheresan et al., 2018)**, making them economically unattractive since they require a lot of electricity to operate the equipment or reactors where chemical dye removal takes place **(Crini, 2006).**

8.2 Physical methods:

Physical dye removal is the most popular of the three methods due to its simple design, versatility, and efficiency **(Saharan et al., 2019).** The mass transfer mechanism is usually used to do this. Adsorption, membrane filtration, ion exchange, reverse osmosis, nanofiltration, and other physical dye removal techniques are often used. Membrane filtration is a quick process that eliminates all dyes, however, it produces concentrated sludge.

Nanofiltration and irradiation are both costly procedures. The reverse osmosis technique requires a high level of pressure. For wastewater treatment, the adsorption technique involves the use of both conventional and non-conventional adsorbents. Nontraditional adsorbents such as activated carbon made from waste products or natural biomass, as well as hen feather, are cheap, effective, and easy to regenerate **(Mittal and Mittal, 2015).**

Also, as compared to biological or chemical dye removal procedures, this approach requires the least quantity of chemicals **(Crini and Lichtfouse, 2019).** Because this approach does not use living organisms, it is thought to be more reliable than biological dye removal techniques **(Katheresan et al., 2018).**

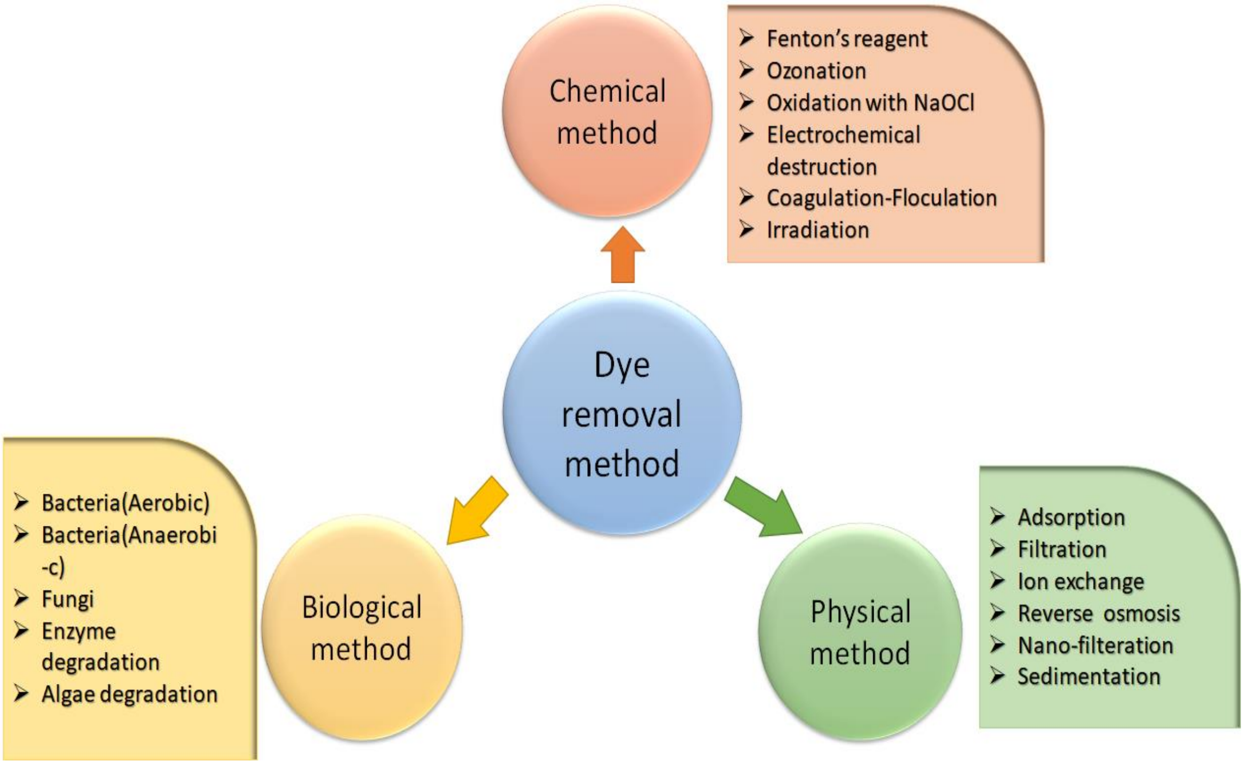

Fig 3. Different types of Dye removal methods from wastewater.

8.3 Biological methods:

A variety of microorganisms are being examined for dye absorption and decomposition. Dye biodegradation or bioaccumulation in wastewater is caused by these microorganisms. Biological treatment procedures are divided into aerobic and anaerobic treatment categories based on various oxygen needs. Anaerobic biological treatment techniques are common biological treatment methods that are used because of their high efficiency and broad application. However, adsorption and recovery of redox mediators are difficult in this procedure.

To oxidatively decolorize different dye solutions, aerobic biological techniques are utilized, but specialized enzymes that catalyze oxidation processes are required **(Al Prol, 2019).** Bacillus sp., Enterococcus sp., and Pseudomonas sp. are some of the aerobic bacteria utilized for color removal. Escherichia coli, Clostridium sp., are anaerobic bacteria **(Sarayu and Sandhya, 2012; Bhatia et al., 2017).** Fungi such as Aspergillus sp., Candida sp., Phanerochaete sp., and Trametes sp. **(Fu and Viraraghavan, 2001)**, as well as algae such as Chlorella sp., Spirogyra sp., Lemnaminuscula, Closterium sp., and others, have been investigated for dye removal from wastewater. Factors including microorganism tolerance to seasonal variations, toxicity of particular chemicals, and the need for huge land areas for bioreactor construction all impact the efficacy of biological treatment systems.

8.4 Combination of different methods:

A number of researchers have investigated at the biological, chemical, and physical techniques listed above, however not all dye removal methods can ensure efficient dye removal.The wastewater is also treated using a mixture of the procedures mentioned above. Dyes were efficiently removed from wastewater utilising the Fenton reaction in combination with the synergistic impact of UV light. It is a costly process, but it does not result in sludge or a foul smell **(Katheresan et al., 2018).**

The removal of Methylene Blue dye was investigated using TiO2/adsorbent nanocomposites. MB was effectively removed from wastewater using a combination of photocatalysis and adsorption **(Zhang et al., 2010)**. It has also been observed that ozonation and biological degradation have a synergistic impact **(Ulson et al., 2010)**. Ozonation of remazol black B resulted in up to 96 percent decolorization, which was followed by biological treatment, which decreased the toxicity of the resultant effluents. **(Harrelkas et al. 2008)** investigated textile dye anaerobic photocatalytic treatment.

9. Agricultural waste biosorbents for dye removal:

Because of its cheap cost, mechanical simplicity, simple regeneration, sludge-free operation, and lack of hazardous intermediates, adsorption has been recognized as an efficient and productive method for the sequestration of dye pollutants from wastewater among the techniques used to date **(Crini, 2006).** The construction of an ideal adsorbent, on the other hand, is a big problem for researchers in this area. Due to their economic efficiency, availability, special chemical composition, and renewable nature, waste products produced from agricultural biomass are widely employed for wastewater treatment.

Because agro-waste biomass activated carbon has a low ash content and a suitable hardness **(Ahmedna et al. 2000)**, converting agricultural wastes into low-cost adsorbents is a potential solution for solving environmental concerns while also reducing preparation costs. Various agricultural wastes have been investigated as low-cost adsorbents during the previous few decades, but SB beat the others, as shown in **Table 1.**

Table 1: Dye removal using various agricultural wastes

Adsorbent used	**Dye used**	**Qmax (mg/g)**	**References**
Rice husk	Direct Red-31 Direct Orange-26	74.074 29.412	**(Safa and Bhatti, 2011)**
Orange peel powder	Direct Red 23 Direct Red 80	10.718 21.052	**(Ardejani et al., 2007**
Banana peel powder	Reactive Black 5	49.2	**(Munagapati et al., 2018)**
Peanut husk	Indosol Yellow BG	25.9	**(Sadaf and Bhatti, 2014a)**
Walnut shell	Malachite Green dye	90.8	**(Dahri et al., 2014)**
Coconut coir dust	Methylene Blue	29.5	**(Etim et al., 2016)**
SB(Sugarcane bagasse)	Methylene Blue	90.11	**(Raghuvanshi et al., 2004)**
SB modified	Malachite Green	157.2	**(Xing and Deng, 2009)**
SB modified	Direct Red 80	28.9	**(En-Oon et al., 2016)**
SB modified	Methylene Blue	571.4	**(Yu et al., 2011)**

Several review papers **(Bharathi and Ramesh, 2013; Bhatnagar and Sillanpää, 2010; Dai et al., 2018; Zhou et al., 2015; Anastopoulos et al., 2020)** have explored the different low-cost adsorbents for the removal of heavy metals, dyes, phenols, and pharmaceutical wastes. We aim to create SB as an environmentally sustainable, low-cost biosorbent for the removal of various dyes from aqueous solutions, both in its raw and modified forms, in this review. The effect of SB alteration on specific surface area and porosity was investigated using physical, chemical, biological, grafting, and composite production methods.

Bagasse is the solid material left over after sugarcane juice is extracted. According to **de Moraes Rocha et al.**, the average composition of 60 SB samples is 42.19 percent cellulose, 27.6% hemicelluloses, 21.56 percent lignin, 5.63 percent extractives, and 2.84 percent ashes **(de Moraes Rocha et al., 2015).** In nature, hemicellulose and lignin are amorphous **(Said et al., 2018).**

10. Removal of dyes using SB:

The functional groups like –COOH, –OH, –NH2, – OCH3, –CONH2, and –SH **(Rezende et al, 2011)** found in bioadsorbents formed from SB can attract and bind pollutant ions to the adsorptive sites of the adsorbent via chelating, complexing, coordinating, and hydrogen bonding **(Zhou et al., 2015).** SB has a low adsorption capacity when used without treatment, however it may be changed using several ways to enhance adsorption capacity and efficiency. SB can be modified in a variety of ways, including physical, chemical, biological, grafting, and composite fabrication.

10.1 Physical or Mechanical Modifications:

For the treatment of dyes, several physical techniques such as screening, coagulation, precipitation, adsorption, membrane filtering, Cutting, grinding, milling, boiling, steaming, autoclaving, thermal drying, and carbonization are used to change SB. The surface area and particle size of the adsorbent are changed using these techniques **(Ren et al., 2014).**

With SB surface area in the range of 0.58-0.66 m2/g, Congo Red adsorption followed the intra-particle diffusion model very well, whereas it was regulated by multi-adsorption stages with SB surface area in the range of 1.31-1.82 m2/g **(Zhang et al., 2011).**

According to **Zhang et al., 2013**, milling SB improved the surface area from 0.58 to 0.66 m2 g1, resulting in a 5.6 percent improvement in methylene blue dye removal efficiency, eliminating 96.6 percent of the dye. Also, in the surface area range of 0.58–0.66 m2/g, the quantity of Rhodamine B dye adsorbed by cutter ground SB increased linearly from 81.7 percent to 87.0 percent and subsequently increased to 93.7 percent with ball-milled SB with surface area of 1.31 m2/g. Due to the dissolution and removal of minerals and organic components from the surface, heated and boiled SB exhibited a higher adsorption capacity than native SB, according to **Noreen and Bhatti (2014),** resulting in the creation of a greater number of active sites on the surface.

10.2 Chemical Modifications:

Coagulation-flocculation, oxidation, ozonation, Fenton oxidation, photocatalytic oxidation, irradiation, ion exchange, and electrochemical therapy are some of the chemical treatment procedures. Although SB has been used as an adsorbent in its natural state, it has a low adsorption capability. The general use of SB in its raw form is severely limited as a result of the challenges. As a result, efforts have been focused on developing new adsorbents by appropriately altering the SB. Several significant research on the production of chemically modified SB has been undertaken in recent years. SB can be chemically changed using acids, bases, organic solvents, surfactants, chelating agents, and a variety of other chemicals. SB was also immobilized by forming beads out of sodium alginate and CaCl2 that can be easily removed from the reaction mixture after adsorption.

The main motivation for chemically modifying SB is to either increase surface area and porosity by simply soaking raw SB powder in a chemical, which generally results in the oxidation of existing functional groups on the surface or to create new functional groups on the surface of SB by chemically reacting –OH of SB cellulose with various reagents. For example, the esterification process between SB and acids like citric acid, tartaric acid, and propanoic acid, leads to the formation of more functional groups. These additional functional groups on the surface enhance the binding of dye molecules and enhance adsorption effectiveness.

The effect of chemical changes on lignocellulosic materials is widely studied using infrared spectroscopy. Due to the carboxylic acid and ester functional groups, the FTIR spectrum of EDTAD-modified SB showed two strong bands at 1740 and 1726 cm-1 in comparison to that of SB, indicating acylation of the hydroxyl functional group to generate an ester bond with subsequent release of a carboxylic acid functional group **(Xing and Deng, 2009).**

The intensity of the peak at about 1100 cm1 attributed to C–OH stretching vibration in native SB decreases on modification with tartaric acid and after dye adsorption due to interactions of oxygen and hydrogen of the –OH group of SB in FTIR spectra of the SB, tartaric acid treated SB, and dye loaded modified SB **(Said et al., 2018).**

10.3 Biological Modification:

Biological treatment is one of the most well-known and widely used technologies for dye treatment since it is low-cost and environmentally safe because it does not require the use of chemicals and uses less energy **(Punzi et al. 2015; Ahmad et al. 2015).** The basic concept behind this therapy is that Dyes are transformed into more simple and harmless forms by utilizing various microbes.

Recently, research has focused on combining SB with a variety of microorganism species to improve the effectiveness of pollutant adsorption. (**Crespo et al., 2020**) used SB colonized with the fungus Pleurotusostreatus to remove Red 4B dye at a concentration of 50 ppm at pH 2, dose 0.4g/40ml, and a contact period of 260 minutes. As a result of the fungal colonization, the acid, and phenolic groups increased, giving colonized SB a Qmax of 10.63 mg/g and non-colonized SB a Qmax of 37.13 mg/g.

10.4 Grafting:

A new, creative, and cost-effective grafting technique for the modification of SB-based cellulose has been developed. **Ren et al., 2014** used a free radical graft copolymerization of SB with acrylic acid, acrylamide, and N, N-methylene bisacrylamide as a cross-linker to create an SB/poly (acrylic acid-co-acrylamide) hydrogel. **Ge et al., 2017** used a solid phase grafting technique to create a maleic anhydride grafted SB. For the removal of Methylene Blue dye from the aqueous solution, the modified SB had an adsorption efficiency of 82 mg/g, compared to just 47.8 mg/g for the unmodified SB. **Pan et al., 2018** also created a gel-like bio adsorbent by cross-linking thiourea-modified SB cellulose with carboxymethyl cellulose, which had a higher specific surface area and highly porous structure than single cellulose, allowing dye molecules to interact more with the hydrogel's active sites.

10.5 Composites:

In the last decade, there has been a lot of advancement in the field of magnetic nanocomposites (MNCs). Magnetic nanoparticles are nanoparticles that can be controlled by applying a magnetic field to them. MNCs are novel adsorbents made from natural biomass that can efficiently remove a wide range of pollutants. It's a composite that combines attraction and adsorption. Adsorption of dye molecules onto the surface of MNCs, followed by separation of dye-loaded MNCs using an external magnetic field, is how dyes are removed using MNCs. It provides a simple and rapid way for separating dye-loaded adsorbents, eliminating the need for centrifugation and filtering.

MNCs are also very reusable, as they can be washed and reused after the desorption of colors. Co-precipitation is the most widely utilized technique for preparing MNCs. The main difficulty with this approach is an agglomeration of produced nanoparticles during the washing, separating, and drying steps. The size and state of the nanoparticles generated with this approach are determined by the type of salt used (chlorides, sulfates, nitrates, perchlorates, and so on), the number of ferrous and ferric particles utilized, temperature conditions, pH, solvent, and other variables such as mixing rate **(Saravanan et al., 2020).**

The magnetic PEI-modified SB composite's surface morphology consisted of many small 50 nm diameter particles that gathered but were still less than 100 nm in size, giving a large surface for the adsorption of Orange II dye molecules **(Gao et al., 2019b).**

The SEM-EDX and FTIR studies revealed that the iron oxide-treated SB had a porous structure, with a more crystalline character than the SB before the alteration **(Buthiyappan et al., 2019).** Researchers have also reported the production of SB composites with CNT, graphene oxide, titania, polyaniline, and polypyrrole, in addition to magnetic nanocomposites. The surface area of the SB biochar composite with 1% CNTs was 390 m2/g, which was nearly 40 times higher than the unmodified SB. This resulted in a substantial increase in adsorption efficiency. In addition, in comparison to unmodified SB, the composite's pore 297 volume was raised to 0.22 cc/g **(Inyang et al., 2014).** SB-activated carbon and TiO2–SB-activated carbon composites had specific surface areas of 437 and 515 m2/g, respectively, and the total pore volume of SB-activated carbon was 0.1184 cc/g, increasing to 0.1495 cc/g in TiO2–SB activated carbon composite due to the formation of a small number of mesopores in the composite photocatalyst to increase the pore volume **(El-Salamony et al., 2017).**

11. Limitations with utilizing SB as an adsorbent:

SB has been effectively used as a low-cost biosorbent for dye removal from wastewater, although it does have certain drawbacks. Before it can be utilized as a biosorbent, it must be cleaned and processed to remove contaminants from its surface Because raw SB has a limited adsorption capability, it must be modified with the assistance of several chemicals, which might make the process more expensive. Furthermore, certain dyes have a high adsorption capacity with SB at low pH, therefore determining the best adsorption conditions also requires the use of chemicals. In some situations, a high adsorbent dose is necessary, resulting in increased solid waste generation. To limit the amount of solid waste produced, desorption is utilized to regenerate the adsorbents for reuse, which might increase the cost of the process and result in lower efficiency after a few cycles. The reusability of zinc sulfate-activated SB adsorbent was investigated using desorption research. After the first cycle, 90 percent of the Victoria Blue-84 dye was removed, but the removal rate gradually dropped. The elimination was only 72 percent after four times due to a reduction in the activity of the surface after several adsorption and desorption cycles, resulting in lower adsorption efficiency **(Rachna et al., 2019).** This dye-loaded solid waste might be used instead of raw

SB to make bricks, particle board panels, composites, and other products. However, these difficulties must be solved to use SB for wastewater treatment in a practical manner.

12. future perspectives and Conclusions:

Rapid industrialization and urbanization release hazardous dyes into the environment, causing pollution and creating a serious threat to all living species. Various approaches for removing dyes from wastewater have been developed. For removing dyes from aqueous solutions, adsorption utilizing different low-cost agro-industrial wastes has proved to be more promising than other expensive treatment techniques. It's worth noting that most agro-industrial wastes are no longer used in their natural state, but are instead treated in several methods to improve porosity and adsorption surface area. The current research provided essential insight into the use of SB as a precursor material for producing adsorbents for wastewater treatment to remove dyes from aqueous solutions in both their raw and modified forms.

Surface design as well as other physicochemical experimental conditions influence adsorption effectiveness. As a result of the research, the best conditions for dye removal were discovered, including pH of the solution, temperature, adsorbent dose, dye starting concentration, and contact duration.SB holds a lot of promise for wastewater remediation of dye-containing effluents in the actual world. More progress is needed in the field of SB nanocomposites and polymeric composites, which have tremendous potential for enhancing the efficiency of the process, to produce a perfect adsorbent that can be utilized commercially.

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