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Textile Effluent as a Potential Problem for Environmental and Human Health: Causes and Overcome Techniques

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Abstract

The textile industry is one of the world's major consumers of water, and its effluent comprises a variety of contaminants such as dyes, degradable organics, detergents, stabilizing agents, desizers, inorganic salts, and heavy metals. There is a lot of color. Water pollution has a large impact on the photosynthetic activity of aquatic plants and animals. Because of the presence of heavy metals and chlorine in man-made colors, it may also have an effect on human health. Before being discharged into a body of water, textile wastewater effluent must be treated. In this study, pollutants found in wastewater from textile companies will be discovered, along with techniques to clean up waste water and how they effect on human health and the environment.[1, 2]

Keywords: Textile Effluent, Environmental and Human Health, Dye removal, heavy metal removal

Introduction

The shifting fashion and lifestyle trends, as well as the growing worldwide population, drive rising demand for textile items.[3] The textile business is recognized as the most polluting industry due to the wide range of chemicals used in manufacturing processes. Over 100,000 dyes and 2000 different types of chemicals are used in the business, and yearly textile dye output exceeds 500,000 tones.[4]

One of the most water-intensive and harmful businesses is the textile industry. A textile processing unit of average size produces around 125 L of effluent.[5]

The wastes produced by the dyeing of products such as yarn and cloth contribute the most to textile wastewater contamination[6]. Even trace levels of dye leftovers in textile industry wastewater can create considerable contamination[7]

Colorant wastes colorize the water, preventing sunlight from reaching the depths of bodies of water and endangering the livestock that lives in the impacted rivers, lakes, and oceans. The oxygen levels in damaged aquatic habitats also fall as a result of decreased photosynthetic activity caused by colourants that limit sunlight penetration. Heavy metals are the other most prominent harmful elements in these wastewaters, which have biologically detrimental effects on aquatic ecosystems as well as deteriorating effects on human health.[8]

The pollution included in these effluents is extremely important, and it is therefore critical that these discharges be handled properly.

Efforts have been done to date to remove organic dyes/pollutants from wastewater utilizing a variety of approaches (chemical, physical, and biological). It has been observed that standard color removal processes (e.g., ozonation-, bleaching-, hydrogen peroxide/ultraviolet (UV) and electrochemistry-based) are difficult to use since most textile dyes contain complicated aromatic molecular structures that make their disintegration challenging. In the presence of light and oxidants, these dyes remain stable. They can also resist aerobic digestion conditions.[9]

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As the impacts of liquid pollution become more widely recognised, researchers are seeking for novel ways to clean and purify, and this research will identify the pollutants created by the textile industry and their impact on the environment and individuals, as well as methods of disposal.

Textile Wastewater Characterstics

Characterizing textile wastewater is critical for developing effective treatment technologies and process flow. The textile effluent has contained a great amount of color, biological oxygen demand (BOD), chemical oxygen demand (COD), salt, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS).[10]

A large amount of pollution is produced throughout various textile production processes, which are split into two groups, such as:

a) **The dry method:** which involves the following processes, requires very little water:
- Opening, blending, and mixing - carding - combing - spinning - weaving - knitting.

b) **The wet process:** requires more water which includes stages like as - sizing - desizing – scouring – bleaching – mercerizing – dyeing - printing - finishing. [11]

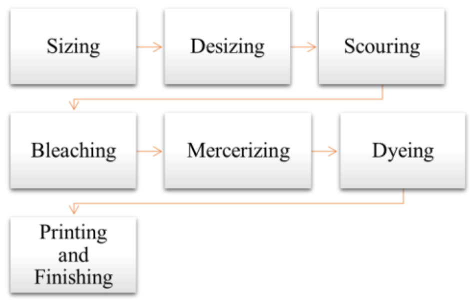


Figure 1. Various steps of wet textile processing.[11]

Pollutants generated during textile wet processing steps and their health effects

Table 1. Pollutants generated during textile wet processing steps and their health effects [11]

Textile process	Chemical used	Pollutant nature	Health effects
Sizing	Starch, waxes, carboxymethyl cellulose (CMC), polyvinyl alcohol (PVA)and wetting agents	High in Biological oxygen demand (BOD) and chemical oxygen demand (COD).	Affects central nervous systems, carcinogenic and mutagenic.
Desizing	Starch, CMC, PVA, fats, waxes and pectin	High in BOD, COD, high suspended solids (SS) and high dissolved solids (DS)	Bloating and diarrhoea, irritation to eyes and skin.
Scouring	NaOH, surfactants, soaps, fats, pectin, oils, sizes and waxes.	Disinfectants, insecticide residues, NaOH, detergents oils, knitting lubricants, spin finishes and spent solvents. Non-ionic detergents may cause bloating and diarrhoea, irritation to eyes and skin	Non-ionic detergents may cause bloating and diarrhoea, irritation to eyes and skin.
Bleaching	Sodium hypochlorite, H2O2, acids, surfactants, sodium silicate (NaSiO3), sodium phosphate, short cotton fibres, organic stabilizers and alkaline pH.	High alkalinity and high suspended solids, H2O2, stabilizers and high pH.	Causing severe irritation to respiratory tract, prolonged exposure will affect the liver and kidney, leading to death.
Mercerizing	Sodium hydroxide and cotton wax.	High pH, low BOD and high dissolved solids	-
Dyeing	Dyestuffs, urea, reducing agents, surfactants, metals, salts, oxidising agents, acetic acid, detergents and wetting agents.	Intense colour, high in BOD and dissolved solids, low in suspended solids, heavy metals, salt, surfactants, organic assistants, cationic materials, colour, COD, sulphide, acidity/alkalinity and spent solvents.	Eye and respiratory problem.
Printing	Metals, colour, formaldehyde, pastes, urea, starches, gums, oils, binders, acids, thickeners,	Strong colour, high in BOD, oily appearance, suspended solids, slightly alkaline, urea,	Harmful health hazards.

	crosslinkers, reducing agents and alkali	solvents, colour, metals heat and foam.	
Finishing	Softeners, solvents, resins and waxes.	COD, suspended solids, toxic materials and solvents.	Suppression of the haematological system.

1. Heavy Metal Pollution

Textile effluents contain high levels of dyes and chemicals, as well as amounts of heavy metals, which can cause a variety of health issues.[12]

A The presence of heavy metals in textiles can occur naturally or as a result of the manufacturing and dyeing processes. Storage protection chemicals can also cause heavy metals to seep into textile fibres. Using heavy metals, colour pigments for textile dyes are created.[13]

For the manufacturing of colour pigments for textile dyes, heavy metals, in particular lead (Pb), chromium (Cr), cadmium (Cd), and copper (Cu), are employed extensively. Such heavy metals may exist naturally in textile structures or may seep into textile fibres during production, the dyeing process, or through storage-related protective chemicals. These highly dangerous heavy metals that have leached into the environment are capable of bioaccumulating in aquatic life, natural waterbodies, and even possibly in the soil.[14]

1.1. Heavy metals found in industrial effluent and their effects on the environment and human health:

Heavy metals are often categorized based on their density; metals having a density more than 5 g/cm3 fall into this category.[15] Despite being present in nature, heavy metals are extremely hazardous and may accumulate in the soil, water, and human body.[16]

The metal atom will combine with the dyestuff already present on the fabric to form a complex. The following section discusses the principal heavy metal ions produced by textile industries:

Chromium (Cr) :Textile heavy metal contamination has become a severe environmental issue, threatening human health and ecological equilibrium. Apart from textiles, chromium is widely utilized in metallurgy, electroplating, metal deep processing, steel manufacture, atomic power plants, fungicides, tanner printing, pigments, polishing, and dyeing.[17]

This metal may be absorbed by plants from the environment, and as a result, its concentration rises up the food chain.[18]

It produces a variety of health effects, including asthma attacks, rhinitis, laryngitis, pulmonary fibrosis, acute gastrointestinal pain, liver and kidney damage, necrotic diarrhea, nausea, carcinogenic and genotoxic effects, lung cancer, prostate cancer, stomach cancer, kidney cancer, urinary system cancer, and bone cancer.[19, 20]

Lead (Pb): Heavy metal pollution is primarily connected with industrial wastes. Lead exposure can cause digestion difficulties, neurological diseases, high blood pressure, reproductive health problems, kidney dysfunction, muscle and joint discomfort, fertility problems in adults, and the greatest lead exposure can cause developmental brain damage in infants and young children. Additionally, it is extremely damaging to plants, causing fastening-related chlorophyll damage and corresponding growth retardation.[18]

Cadmium (Cd): Cd is one of the most toxic heavy metals found in industrial waste and is frequently utilized in textiles, batteries, ceramics, and electronic components.[21, 22]

Human carcinogenic, respiratory disease, gastrointestinal diseases, renal failure, kidney damage and kidney stone formation, stomach and urinary bladder cancers, bronchiolitis, COPD, emphysema, fibrosis, skeletal damage, bone weakening, congenital disabilities, anemia, and inhibits calcium control in biological systems are some of the health effect.[23]

Zinc (Zn): Zn is essential for the regulation of various biochemical processes and physiological functions in living tissues. Brass plating, wood pulp manufacturing, textile waste, ground and newsprint paper manufacture, steelworks with galvanising lines, zinc, and brass metal works are all industrial sources of zinc. Excess zinc exposure causes severe health problems such as stomach cramps, nausea, skin irritations, cramping, vomiting, and anaemia. These effects on human health and the environment are required for successful treatment of zinc in wastewater discharge. Although zinc is considered an important micronutrient for life, excessive amounts of it can be hazardous.[24]

Because these metals pose serious health risks to people and other living things, removing toxic heavy metals from textile effluent is an important concern. In order to lessen the pollution load on the environment, it is important to develop treatment technologies to eliminate dangerous metal ions from textile waste.

1.2. Methods for heavy metal removal from effluent from the textile industry:

For the treatment of dye industrial effluent, a number of techniques have been developed, including adsorption to organic and inorganic matrices, photocatalysis, enzymatic or microbiological separation, chemical oxidation, etc. [25]

One of the most effective techniques for the removal and treatment of inorganic and organic contaminants in the wastewaters of the dye industry is the adsorption process using solid adsorbents. Due of its low initial cost and minimal demand for land, this system has a straightforward design and is simple to operate. Finding inexpensive adsorbents with significant pollutant-binding ability has lately attracted the interest of researchers.[26]

1.2.1. **Activated Carbon**

Adsorption is a crucial step in the process of removing dyes from wastewater. Because of its great adsorption capability, activated carbon is the most often utilized adsorbent. [27]

Due to its high porosity, high surface reaction affinity, and vast surface area, activated carbon is an excellent adsorbent for many organic and inorganic chemicals, however the price is relatively expensive.

Therefore, academics have focused on a variety of alternatives, including natural resources, industrial waste, and agricultural byproducts.[28]

1.2.2. Zeolite

Due to their ion exchange capabilities, zeolites are relatively affordable, efficient adsorbents to adsorb heavy metals from wastewater samples.[29] Zeolites are employed in a variety of applications because of their porous structure, including ion exchange, solvent and gas removal, petrochemical cracking, adsorption, etc. Zeolites may transform hazardous wastes into ecologically friendly goods.[30]

Table (2): Type of dyes, their application, and chemical classes

Dye type	Characteristics	Fiber type	Fixation rate (%)	Possible pollutants	Toxicity
Direct dyes	Water-soluble, anionic compounds, low wash fastness	Cellulose fibers	70–95	Color, salt, unfixed dyes, copper salt and dye-fixing agents.	Carcinogenic
Acid dye	Water-soluble, anionic compounds.	Natural fibers and synthetic polyamide.	80–93	color, organic acids and dyeing auxiliaries	Carcinogenic
Basic dyes	Water-soluble, applied from weakly acid bath and very bright shades	Wool, silk, cotton and modified acrylic fibers.	97–98	color, organic acids and dyeing auxiliaries.	Carcinogenic
Reactive dyes	Water soluble, covalent bond with fiber and most favorable dye class	Cellulose fiber	60–90	color, salt, alkali, unfixed dye and soaping agents.	Dermatitis, allergic conjunctivitis, rhinitis, occupational asthma or other allergic reactions.
Azoic dyes or naphthol dyes	In-situ color formation by coupling reaction.	Cellulose fiber	-	Alkali, unfixed color, naphthol, diazotized base, soaping agent	Carcinogenic
Sulphur dyes	water-insoluble, Sulphur-containing organic compounds, solubilized on a weak alkaline reduction.	Cellulose fibers, especially with polyester, nylon and acrylic	60–70	color, sodium sulphide, alkali, oxidizing agent	—
Vat dyes	Water-insoluble, chemically complex, solubilized on a substantial alkaline reduction	Cellulose fibers, wool, nylon, polyesters and acrylics	80–95	color, alkali, sodium hydrosol-phite, alkali, soaping agent	—
Disperse dyes	Water-insoluble, low molecular weight	cellulose acetate and triacetate, polyamide and acrylic fibers	80–92	color, organic acids, dispersing agents, carriers.	Carcinogenic and allergic reactions

1.2.3. Clay

An organic substance with residues of metal oxides and clay minerals, clay is a fine-grained natural soil or rock material.[31]

They have been used for years to remove harmful heavy metals from aqueous solutions due to their high adsorption ability. Different heavy metals may be efficiently removed from contaminated water samples using both natural and modified clay forms.[32]

2. Textile dye pollution

Large amounts of highly colored effluent containing a varied spectrum of persistent contaminants are generated by the textile industry. Every year, around 7107 tons of synthetic dyes are produced worldwide, with over 10,000 tons of such dyes used by the textile industry.

A few characteristics influence dye classification, including solubility, affinity with different fibers, and fixing rate. In the textile business, cationic, anionic, and non-ionic dyes are utilized based on particle charge dispersion in aqueous solutions. Water-soluble colors and water-insoluble dyes are divided based on solubility. Water-soluble anionic dyes are direct, acidic, and reactive dyes; water-soluble cationic dyes are basic dyes; and insoluble dyes include disperse, Sulphur, and azoic indigo and vat dyes. Table 2 briefly describes these colors and their properties, as well as potential contaminants, including toxicity.[33]

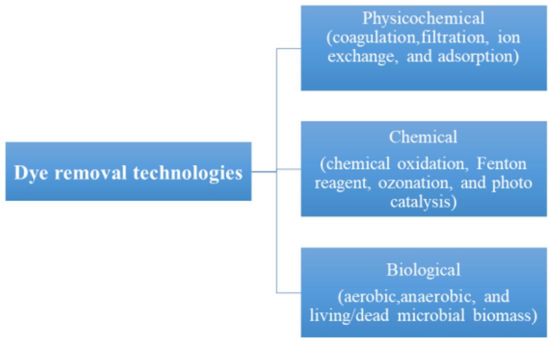
Textile dyes are not strongly bound to fabric and are discharged as effluent alongside wastewater into aquatic habitats such as lakes, rivers, streams, and ponds without previous treatment, creating major ecotoxicological hazards with toxic effects on aquatic life.

Dye Toxicity to Human Health and Environment:

- Dyes are harmful even at low concentrations (l mgL 1) in the environment because they have a complex chemical structure that is resistant to degradation. The majority of the colors are non-biodegradable, posing a serious environmental hazard.
- Significant health problems brought on by dye pollution in water include skin rashes, headaches, blurred vision, nausea, diarrhoea, exhaustion, soreness in the muscles and joints, dizziness, difficulty breathing, irregular heartbeat, seizures, and, surprisingly, cancer.
- Chrome mordant is another sort of toxicity spreading dye that is harmful to both humans and the environment. Mordants are heavy metal salts of aluminum, iron, copper, chromium, or tin, with alum and ferrous sulphate being reasonably safe mordants.
- Because of their huge size and ability to penetrate through cell membranes, phthalocyanine dyes are considered non-genotoxic. Reactive dyes in textiles are known to cause skin irritation and sensitization, dermatitis, allergic conjunctivitis, rhinitis, occupational asthma, and other allergic reactions.
- Textile dye toxicity is classified into two categories: acute toxicity and chronic or genotoxicity. Acute toxicity concerns oral intake and inhalation; genotoxicity is a serious long-term possible health danger of a few textile dyes. Genotoxic substances usually cause a chemical reaction that damages deoxyribonucleic acid (DNA).[34]

2.1. Methods for dye removal from effluent from the textile industry:

The textile sector is expected to generate huge volumes of effluents including roughly 280,000 tons of refractory textile dyes.[35] Textile effluent must be treated before it is discharged into the environment. Several treatment technologies, including physical, chemical, biological, and combination, have been developed to remove pollutants from textile wastewater. We'll provide examples of efficient color removal techniques for textile sector effluents.[36]



2.1.1. Physicochemical Method:

Coagulation, adsorption, filtration, and ion exchange are some of the physicochemical approaches that have been developed.

- **The coagulation** process is a well-known physicochemical approach for removing contaminants from textile effluent water. Alum and iron salts are employed as a coagulant to improve the agglomeration of tiny particles in wastewater. These methods are crucial for removing disperse dye from effluents, but they have limited performance when there are reactive and vat dyes in the water, and they have their own limits due to the low dye removal performance and the large number of by-products.[37, 38]

- **Absorption technology** the high removal of colours from wastewater, which contains a range of pigments, makes absorption technique very appealing. Adsorbents must be chosen for the colour mitigation procedure because of the high affinity, capacity, and desorption fundamental qualities of adsorbent election criteria.[39] Diverse researchers have employed inexpensive adsorbents such bentonite, zeolite, ash, biomass by-products, and resins for adsorption applications. Additionally, a number of studies tested various biomass wastes used as adsorbents to remove colors from textile effluent wastewater, including wheat residue, rice husk, modified ginger wastes, etc. Various researchers reported the following studies. Reactive Red-24 (RR-24) was removed using modified wheat residue (MWR) as an adsorbent in one investigation. Modified ginger waste (MGW) was used to get rid of the dye crystal violet (CV). In a different investigation, Reactive Orange 84 was eliminated using activated carbon made from leftover cotton flower petals. Adsorbent (Potato plant waste) was used to absorb dye (Methylene blue and malachite green).[40-43]
- **Filtration techniques** including ultrafiltration (UF), nanofiltration (NF), microfiltration (MF), and reverse osmosis (RO) have been utilized to remove contaminants from textile effluents. For the removal approaches, filter media selection criteria that take into account the temperature and chemical composition of textile wastewater are crucial. Membrane technologies are used in textile factories to minimize BOD, COD, and color in effluent wastewater.[44]
- **ion exchange** method There is a lot of application for the ion exchange method. However, its use in removing dye from water has been restricted. The benefit of this method is that no adsorbents are lost. It could be used to get rid of water-soluble colors. But for water-insoluble pigments like dispersion dyes, it is ineffective.[45, 46]

2.1.2. Methods of Chemical Treatment:

Chemical treatment technologies are frequently used to eliminate hazardous contaminants from industry effluent wastewater, including dye, toxic metals, and odor.

- **Advanced oxidation processes (AOP)** create hydroxyl radicals in large quantities. Various oxidants, including Cl, O3, ClO2, and H2O2, are used to treat wastewater. Oxidizing chemicals are used to attack the information that the chromophore conveys.[47]
- **Fenton Treatment** which occurs when Fe 3+ ions combine with H2O2, uses compounds that are an iron salt to speed up the breakdown of H2O2 and increase the oxidation of complex organic contaminants that are resistant to biological degradation.[48]
- **Ozonation:** The ozonation process is a chemical technique for successfully removing synthetic colors from effluents. The action of the ozone gas in the ozonation process breaks the conjugated double bond in azo dyes, which is responsible for the dyes' color.[49]

The following studies were explored by various researchers using combination therapy approaches:

The removal of Rhodamine dye from water using a hybrid of H2O2, CCl4, and Fenton's reagent was explored[50],as were combinations of TiO2/UV/H2O2 for azo dye removal[51] Remazol Brilliant Blue R, Red Procion, and Yellow Procion using the Heterogeneous Photocatalytic technique[52],Pollutant (Textile dye bath effluent), oxidation method (H2O2/UV, UV, and O3), and consequence (98% decolorization accomplished with H2O2/UV on biotreated dye bath effluent). The use of AOPs after biotreatment has outperformed biodegradability) .[52]

2.1.3. Biological Treatment:

Biological approaches are more affordable alternatives for treating textile effluent than physiochemical and photochemical technologies, which are expensive and have significant limitations. These techniques are being applied in the textile sector using various microbes.[53]

- **Fungal for Removal of Dyes** This technique cannot be applied commercially since a single strain of bacteria or fungi can only eliminate one color and not another.
- **Algae for Removal of Dyes** Algae play an important role in the removal of dyes from wastewater through adsorption or degradation processes. Furthermore, instead of employing commercial activated carbon for colour, an alternative biosorption technique is use .[54] In a pond experiment, natural colonizing algae and duckweed plants were shown to efficiently cleanse textile effluent. [55]

The most efficient techniques for eliminating organic contaminants from textile wastewater are biological procedures, which may be divided into anaerobic and aerobic procedures. Due to the resistance of many colors, particularly azo dyes, aerobic approaches did not produce the optimum results for color removal in field applications. The urban anaerobic sludge blanket reactor is capable of handling very resistant substances and provides the greatest results when treating xenobiotics.[2]

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Author Declarations

The authors declare that the data supporting the findings of this study are available in the article

The authors declare that there is no conflict of interest.

References

1. Adane, T., A.T. Adugna, and E. Alemayehu, *Textile industry effluent treatment techniques.* Journal of Chemistry, 2021. **2021**: p. 1-14.
2. Siddique, K., et al., *Textile wastewater treatment options: a critical review.* Enhancing Cleanup of Environmental Pollutants: Volume 2: Non-Biological Approaches, 2017: p. 183-207.
3. Uzal, N., L. Yılmaz, and Ü. Yetiş, *İndigo boyama atıklarının ön arıtımı: kimyasal çöktürme ön filtrasyon süreçlerinin karşılaştırılması, 6.* Ulusal Çevre Müh. Kongresi, 2005. **429**: p. 437.
4. KAPDAN, İ.K. and F. KARGI, *Removal of textile dyestufes from wastewater by adsorptive biodegradation.* Turkish Journal of Engineering and Environmental Sciences, 2000. **24**(3): p. 161-170.
5. Varadarajan, G. and P. Venkatachalam, *Sustainable textile dyeing processes.* Environmental chemistry letters, 2016. **14**: p. 113-122.
6. Mercimek, H., *Trametes versicolor'ın tekstil boyalarının gideriminde kullanım olanakları.* ÇÜ Biyoteknoloji Anabilim Dalı Yüksek Lisans Tezi, 2007. **64**.
7. Şener, S., *Use of solid wastes of the soda ash plant as an adsorbent for the removal of anionic dyes: Equilibrium and kinetic studies.* Chemical Engineering Journal, 2008. **138**(1-3): p. 207-214.
8. Banat, I.M., et al., *Microbial decolorization of textile-dyecontaining effluents: a review.* Bioresource technology, 1996. **58**(3): p. 217-227.
9. Akbari, A., J. Remigy, and P. Aptel, *Treatment of textile dye effluent using a polyamide-based nanofiltration membrane.* Chemical Engineering and Processing: Process Intensification, 2002. **41**(7): p. 601-609.
10. Gupta, V., *Application of low-cost adsorbents for dye removal–a review.* Journal of environmental management, 2009. **90**(8): p. 2313-2342.
11. Velusamy, S., et al., *A review on heavy metal ions and containing dyes removal through graphene oxide-based adsorption strategies for textile wastewater treatment.* The Chemical Record, 2021. **21**(7): p. 1570-1610.
12. Ristic, N. and I. Ristic, *Cationic modification of cotton fabrics and reactive dyeing characteristics.* Journal of Engineered fibers and fabrics, 2012. **7**(4): p. 155892501200700408.
13. Bhardwaj, V., P. Kumar, and G. Singhal, *Toxicity of heavy metals pollutants in textile mills effluents.* Int. J. Sci. Eng. Res, 2014. **5**(7): p. 664-666.
14. Mathur, N., P. Bhatnagar, and P. Bakre, *Assessing mutagenicity of textile dyes from Pali(Rajasthan) using Ames bioassay.* Applied ecology and environmental research, 2006. **4**(1): p. 111-118.
15. Gu, Q. and R.-L. Lin, *Heavy metals zinc, cadmium, and copper stimulate pulmonary sensory neurons via direct activation of TRPA1.* Journal of Applied Physiology, 2010. **108**(4): p. 891-897.
16. Mathur, H., et al., *Analysis of pesticide residues in blood samples from villages of Punjab.* CSE Report, India, 2005: p. 1-15.
17. Malaviya, P. and A. Singh, *Physicochemical technologies for remediation of chromium-containing waters and wastewaters.* Critical reviews in environmental science and technology, 2011. **41**(12): p. 1111-1172.
18. Jaishankar, M., et al., *Toxicity, mechanism and health effects of some heavy metals.* Interdisciplinary toxicology, 2014. **7**(2): p. 60.
19. Miretzky, P. and A.F. Cirelli, *Cr (VI) and Cr (III) removal from aqueous solution by raw and modified lignocellulosic materials: a review.* Journal of hazardous materials, 2010. **180**(1-3): p. 1-19.
20. Mohan, D. and C.U. Pittman Jr, *Activated carbons and low cost adsorbents for remediation of tri-and hexavalent chromium from water.* Journal of hazardous materials, 2006. **137**(2): p. 762-811.
21. Gibb, H.J., et al., *Lung cancer among workers in chromium chemical production.* American journal of industrial medicine, 2000. **38**(2): p. 115-126.
22. Leonard, A. and R. Lauwerys, *Carcinogenicity and mutagenicity of chromium.* Mutation Research/Reviews in Genetic Toxicology, 1980. **76**(3): p. 227-239.
23. Snoussi, Y., M. Abderrabba, and A. Sayari, *Removal of cadmium from aqueous solutions by adsorption onto polyethylenimine-functionalized mesocellular silica foam: Equilibrium*

properties. Journal of the Taiwan Institute of Chemical Engineers, 2016. **66**: p. 372-378.
24. Tunali, S. and T. Akar, *Zn (II) biosorption properties of Botrytis cinerea biomass.* Journal of hazardous materials, 2006. **131**(1-3): p. 137-145.
25. Santos, S.C. and R.A. Boaventura, *Adsorption modelling of textile dyes by sepiolite.* Applied Clay Science, 2008. **42**(1-2): p. 137-145.
26. Rashed, M.N., *Adsorption technique for the removal of organic pollutants from water and wastewater.* Organic pollutants-monitoring, risk and treatment, 2013. **7**: p. 167-194.
27. Tchobanoglous, G., F.L. Burton, and H.D. Stensel, *Wastewater engineering.* Management, 1991. **7**(1): p. 4.
28. Jaroniec, M. and J. Choma, *Characterization of heterogeneity of activated carbons by utilizing the benzene adsorption data.* Materials chemistry and physics, 1986. **15**(6): p. 521-536.
29. Babel, S. and T.A. Kurniawan, *Low-cost adsorbents for heavy metals uptake from contaminated water: a review.* Journal of hazardous materials, 2003. **97**(1-3): p. 219-243.
30. Shevade, S. and R.G. Ford, *Use of synthetic zeolites for arsenate removal from pollutant water.* Water research, 2004. **38**(14-15): p. 3197-3204.
31. Toprakezer, F., *Nanokompozit sentezinde kullanılacak na-bentonit kilinin saflaştırılması.* Çukurova Üniversitesi Fen Bilimleri Enstitüsü, 2009.
32. Uddin, M.K., *A review on the adsorption of heavy metals by clay minerals, with special focus on the past decade.* Chemical Engineering Journal, 2017. **308**: p. 438-462.
33. Purkait, M., S. DasGupta, and S. De, *Adsorption of eosin dye on activated carbon and its surfactant based desorption.* Journal of environmental management, 2005. **76**(2): p. 135-142.
34. El-Gaayda, J., et al., *Natural flocculants for the treatment of wastewaters containing dyes or heavy metals: a state-of-the-art review.* Journal of Environmental Chemical Engineering, 2021. **9**(5): p. 106060.
35. Zhou, L., et al., *Core nitrogen cycle of biofoulant in full-scale anoxic & oxic biofilm-membrane bioreactors treating textile wastewater.* Bioresource Technology, 2021. **325**: p. 124667.
36. Praveen Kumar, G. and K. Bhat Sumangala, *Decolorization of azo dye Red 3BN by bacteria.* International Research Journal of Biological Sciences, 2012. **1**(5): p. 46-52.
37. Holkar, C.R., et al., *A critical review on textile wastewater treatments: possible approaches.* Journal of environmental management, 2016. **182**: p. 351-366.
38. Liang, C.-Z., et al., *Treatment of highly concentrated wastewater containing multiple synthetic dyes by a combined process of coagulation/flocculation and nanofiltration.* Journal of Membrane Science, 2014. **469**: p. 306-315.
39. Jadhav, A.J. and V.C. Srivastava, *Adsorbed solution theory based modeling of binary adsorption of nitrobenzene, aniline and phenol onto granulated activated carbon.* Chemical engineering journal, 2013. **229**: p. 450-459.
40. Charola, S., et al., *Fixed-bed adsorption of Reactive Orange 84 dye onto activated carbon prepared from empty cotton flower agro-waste.* Sustainable Environment Research, 2018. **28**(6): p. 298-308.
41. Gupta, N., A.K. Kushwaha, and M. Chattopadhyaya, *Application of potato (Solanum tuberosum) plant wastes for the removal of methylene blue and malachite green dye from aqueous solution.* Arabian Journal of Chemistry, 2016. **9**: p. S707-S716.
42. Kumar, R. and R. Ahmad, *Biosorption of hazardous crystal violet dye from aqueous solution onto treated ginger waste (TGW).* Desalination, 2011. **265**(1-3): p. 112-118.
43. Zhong, Q.-Q., et al., *Preparation, characterization of modified wheat residue and its utilization for the anionic dye removal.* Desalination, 2011. **267**(2-3): p. 193-200.
44. Chollom, M.N., et al., *The applicability of nanofiltration for the treatment and reuse of textile reactive dye effluent.* Water Sa, 2015. **41**(3): p. 398-405.
45. Slokar, Y.M. and A.M. Le Marechal, *Methods of decoloration of textile wastewaters.* Dyes and pigments, 1998. **37**(4): p. 335-356.
46. Toor, M.K., *Enhancing adsorption capacity of bentonite for dye removal: physiochemical modification and characterization*. 2011.
47. Asghar, A., A.A.A. Raman, and W.M.A.W. Daud, *Advanced oxidation processes for in-situ production of hydrogen peroxide/hydroxyl radical for textile wastewater treatment: a review.* Journal of cleaner production, 2015. **87**: p. 826-838.
48. Ayyaru, S. and S. Dharmalingam, *Enhanced response of microbial fuel cell using sulfonated poly ether ether ketone membrane as a biochemical oxygen demand sensor.* Analytica chimica acta, 2014. **818**: p. 15-22.
49. Forgacs, E., T. Cserháti, and G. Oros, *Removal of synthetic dyes from wastewaters: a review.* Environment international, 2004. **30**(7): p. 953-971.
50. Nie, S., et al., *Synergistic effect of hydrodynamic cavitation and plasma oxidation for the degradation of Rhodamine B dye wastewater.*

Journal of Water Process Engineering, 2022. **49**: p. 103022.
51. Abid, M., et al., *Design of halloysite-based nanocomposites by electrospinning for water treatment.* Colloids and Surfaces A: Physicochemical and Engineering Aspects, 2022. **651**: p. 129696.
52. Azanaw, A., et al., *Textile effluent treatment methods and eco-friendly resolution of textile wastewater.* Case Studies in Chemical and Environmental Engineering, 2022: p. 100230.
53. Ghosal, S., et al. *Elimination of Anionic Dye from Wastewater through Coagulation/Flocculation process*. in *PREPARE@ u®| FOSET Conferences*. 2022.
54. Fernández, L.A.G., et al., *Fundamentals in applications of algae biomass: A review.* Journal of Environmental Management, 2023. **338**: p. 117830.
55. Selvaraj, D., N.K. Dhayabaran, and A. Mahizhnan, *An insight on pollutant removal mechanisms in phycoremediation of textile wastewater.* Environmental Science and Pollution Research, 2022: p. 1-21.