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Review

Modern enabling techniques and adsorbents based dye removal with sustainability concerns in textile industrial sector -A comprehensive review

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ABSTRACT

Wastewaters from the textile industry are hazardous effluents containing toxic complex components that without appropriate treatment severely impact the environment; causing harmful effects to the aquatic ecosystems, as well as to human health. The present study extensively reviews the dyes and chemicals utilized in the textile industry focusing on the traditional treatment methods -chemical, biological, physical and hybrid systems-for their removal from industrial wastewaters. In addition, a critical analysis on Internet of Things based management systems for their remote monitoring and control of the water quality is reported. It was found the absence of a common platform for the integration of the different traditional treatment methods in association with modern technologies is the main limiting factor for an effective sustainable manufacturing. Therefore, it is the aim of this research to broaden the scope of potential solutions, proposing cost-effective high-performing combined strategies with promising benefits for future industrial applications.
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1. Introduction

The economic aspect in the textile sector is dominant and it is an active sector across the globe. The production stages of the textile industry have a long and complex chain and dying is one of the most important in this chain. Dyeing is carried out in order to obtain a good appearance in textile products and to ensure that the products are colored according to their end use. For this purpose, many chemicals and auxiliaries are used. Some of the dyestuffs and pigments used (dyeing bath residues, printing pastes, and paints,

paints past their expiration dates, etc.) are in the hazardous waste group while others are in the non-hazardous waste group. Textile industry emits a wide variety of pollutants from all stages in the processing of fibers, fabrics and garments. Primary environmental concern in textile industry is the amount of textile effluents discharged and the chemical load it carries.

1.1. Overview of dyes and textile effluents

Water pollutants from textile industry sectors affect the environmental conditions by generating huge volumes of outlets mixed with various dyes. It is mandatory to use effective treatment methods using special adsorbents or other modern technology to remove the contamination of water before releasing them into water streams.

Dyes used for textile materials are classified into two types, natural dyes, and synthetic dyes as shown in Fig. 1. Due to increase in population the present trend is moving away from natural dyes.

Azo dyes are used to provide different colour intensities and variations. Acid dyes can be used in textiles materials such as silk, nylon and wool. It also finds its application in leather, cosmetics, printing and food materials. Metal-complex dyes are carcinogenic when reacting with water and they are mostly used in wool textiles (Berradi et al., 2019). Direct dyes which are soluble in nature are used for rayon, nylon and cotton fabrics. Basic dyes generally find their usage in modified categories of nylons and polyester fabric materials. They are also used as a dying agent in medicines as well. Reactive dyes can be used for silk fabrics as well as celluloid fibre materials.

1.2. Review of related surveys on textile effluent treatment

Usages of dyes are one of the harmful categories of pollutants that need to be removed from the environment. Discharge of those dyes to water resources causes harmful health effects (Lellis et al., 2019) and leads to serious health concerns to humans besides, affecting the environment. Dye adsorption techniques are carried out by clays when mixed with limestone. Most of the dyes were biodegradable and are stable to heat, light as well as oxidizing agents. They also produce an impact on the aquatic ecosystem by affecting the aesthetic value because of coloration (Petcu et al., 2016). Drastic increase of toxic materials from industrial outlets has triggered different techniques for removing the wastes from the waste water outlets (Almasian et al., 2015). Different types of physical, chemical, biological and electrochemical processes are applied in the field of textile effluent color removal from industrial wastewater (Collivignarelli et al., 2019). After treatment methods, different types of clays are used and the treated dye is passed through this mixture and an adsorption process is carried out. Using ultrasonic tester based techniques; area and volume of the sphere are increased for adsorption. Some clays are fibrous in nature. These types of clays can be removed by using magnetic separating technique. As adsorbents, magnetic materials such as ferrite, iron oxide nanoparticles can be used which can be used to separate clay water. The legal framework determining the current industrial textile wastewater treatment practices consists of most significant parameters (Grace et al., 2016). The permissible values of pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), sulphide, chloride, magnesium and calcium, as recommended by Central Pollution Control Board are 6.9, 30 ppm, 250 ppm, 2000 ppm, 2 ppm, 500 ppm, 50 ppm, and 75 ppm, respectively (Praveen et al., 2018).

1.3. Motivation for writing the survey

Fostering of a sustainable and better industrial ecosystem is a obligatory requirement for upholding a better environment in the coming future. As the environment gets polluted mainly due to industrial outlets, it causes numerous health risks to people, terrestrial animals, aquatic creatures and plants. Understanding that the textile sector based effluents has a major share in polluting the environment, we were motivated and inspired to take up this challenge of writing this review article. This review article focuses on establishing a sustainable environment by providing integrated classic and modern approaches for eliminating the dyes from the textile effluents. Earlier surveys mentioned in section 1.2, had thoroughly studied the classic effluent treatment methods and adsorbents. Nevertheless, modern affordable methods were not given due importance. The present survey deals with the modern enabling techniques such as internet of things, remote sensing, sensor technology, etc., along with classic approaches and comprehensive list of potential adsorbents. Besides, it explores all the possibilities to combine both classic and modern approaches for the effective treatment of the effluents. This article opens a new horizon for the research community to explore and come up with better feasible solutions taking advantage of artificial intelligence based techniques to meet the meet the requirements of Industry 4.0. Implementation of these modern techniques would help us to reap huge benefits such as cost reduction in effluent treatment and reduction in water consumption to a greater extent (Lom et al., 2016).

1.4. Categorizing mechanism, contribution and organization of the article

Survey of literature is a systematic methodology of identifying, followed by evaluating the relevant organized articles in a well-focused domain of research. The outcome of this systematic approach ends with investigation gaps and potential future directions (Hart, 2018). This important portion forms the base for future tasks of research and controls the design objectives of new research investigations (Tranfield et al., 2003).

There is a lack of common platform for pooling different classical methods of treatment of textile dyes along with different modern promising approaches. Researchers and practitioners gain a good overview of the scope of the possibility of treatment of textile effluents for sustainability. Sustainability could be often achieved by combining suitable combinations of diverse approaches. For instance, combining a classical biological treatment with an advanced IoT based technology offers huge scope of unlimited possibilities. Equally important next objective of this survey deals with the role of different types of adsorbents involved in textile water treatment. Pros and cons of using organic and inorganic adsorbents are critically analysed and compared.

Research methodology of writing this survey article, consists of three phases namely, planning phase, development phase and dissemination phase.

1.4.1. Phase 1: survey planning phase

It deals with the motivation of writing this survey article. In the last decade, more number of articles and patents are focused towards industrial ecology and use of various adsorbents. In the Fig. 2, 2316 articles/patents appeared with the focus of water treatment during the period of 2011–2018. Before 2000, 703 articles/patents dealt with this issue and in 2001–2010, around 360 articles and 548 patents surfaced. This clearly shows the present issue of industrial ecology and shift of focus of research scientists to alleviate that menace of pollution that pose a great threat to human lives (Fig. 3).

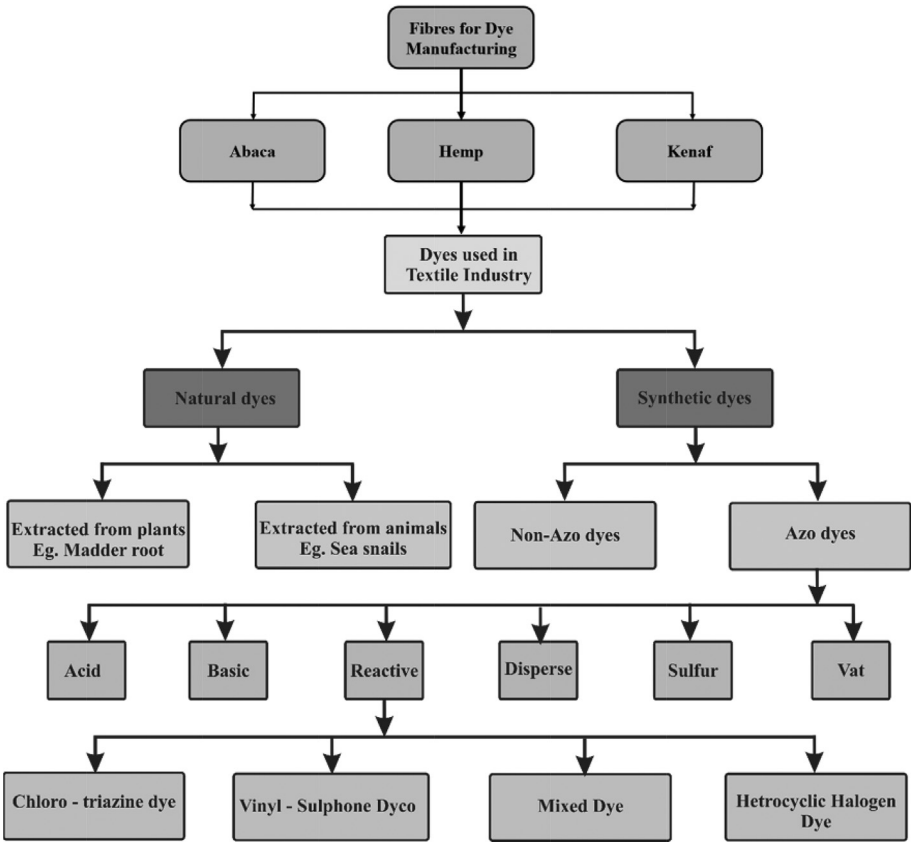


Fig. 1. Classification of Textile dyes used in Textile industries extracted from specific fibres.

1.4.2. Phase 2: survey development phase

To conduct a systematic survey, google scholar is used as a tool and most relevant articles from Elsevier, Springer, and IEEE conference proceedings are selected. Key words used in the search were textile effluents, dye removal and adsorbents. For the discourse in the present article, more focus is given on the collection and analysis of recent journals published in the last 10 years.

1.4.3. Phase 3: survey dissemination phase

With the abundance of data thus collected, it was then segregated under different categories and sub-categories for effective communication to the practitioners and researchers. Articles were clubbed together on the basis of treatment methods such as physical, chemical and biological treatment. Under the categories of modern treatment methods, it is further classified on the basis of mechanism of sensing, employing modern sensor technology. In the later part of the article, references are clubbed under organic and inorganic adsorbents with analysis of content under each category.

Recent literature outlining the modern methodologies and analysis strategies for the removal of dyes from textile effluents are tabulated with their outcomes in Table 1.

The review article starts with presenting a brief introduction to textile dyes, and their classification and also presents the need for removal of textile effluents. It intends to provide the state-of-art methods for removal of dyes from textile effluents with the support of modern enabling technologies with relevant approaches and future perspectives.

Section 1 narrates about types of dyes and the impact of textile effluents outlets from industries. Section 2 deals with the different treatment techniques for the extraction of dyes from textile effluents. Section 3 discusses the modern enablıng technologıes and methodologıes for dyes removal from textile effluents. Section 4 summaries role of adsorbents for the removal of dyes from textile effluents. Finally, Section 5 summarizes the survey with the scope for researchers to work in this area in the conclusion part.

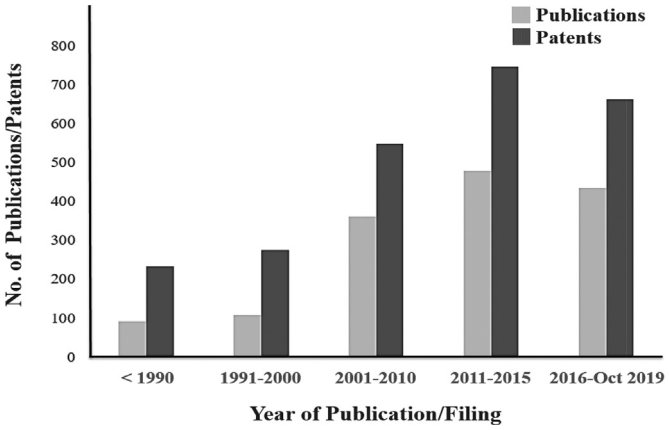


Fig. 2. Publication/Patent Filing trend in the field of Textile Effluents Treatment.

2. Materials and methods for removal of textile dyes by different treatments

Different wastewater treatment methods are adopted for removing textile dyes such as biological, chemical and physical treatments. Fig. 2 shows few predominant methodologies that can

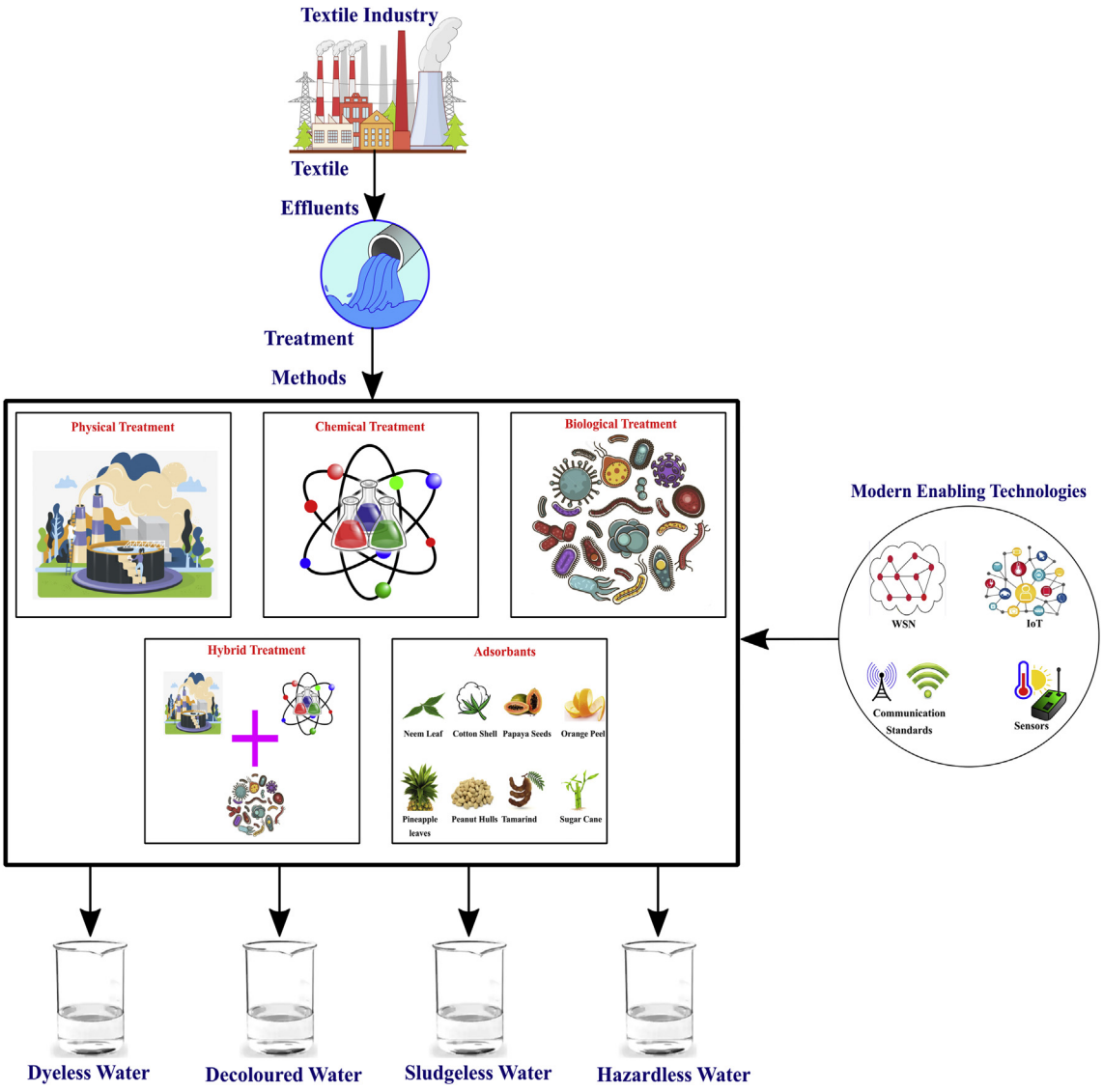


Fig. 3. Treatment methods for removal of dyes from textile effluents.

be deployed for the removal of dyes from textile effluents by using various treatments. Selection of the methods depends on the composition and types of waste-water.

2.1. Chemical treatment

The chemical treatment of dye wastewater consists of chemicals like PAC, BacEnz, and poly. The chemical PAC has the property in which sludge will rapidly settle in the borosilicate beaker. The chemical Poly has the property of in which it will give the bright blue color and the BacEnz has the property of in which it will split the water into dyes. These chemicals are influenced by the Meerbergen et al. (2017) found that the decolorization of reactive dye is carried out by chemical treatment method. The chemical treatment is carried out by Fenton's reagent in which the azo dyes are decolorized. Mostly the Fenton's reagent plays a major role in it. In chemical treatment, the sludge and the dye wastewater gets separated. Natarajan et al. (2018), also found that dye removal is carried out by photocatalytic processes. The photocatalytic process, for the degradation of dyes, dwells on generation of electron hole pairs, surface area and band gap. It provides a higher surface area with higher adsorption. Lin and Lin et al. (1993) reported that the treatment is carried out by chemical coagulation method. In chemical coagulation method mainly the effluents are taken and it is tested by chemical oxygen demand method. The ozonation method is carried out for removing dyes for better industrial ecology establishment. The combination of sludge and the chemical coagulation process provides effective use of chemical treatment. Lin and Lo (1996) found that the treatment is carried out by foam flotation method. Experiments conducted like pH, COD and flow rate and other operating conditions (Gurbuz et al., 2019). Papic et al. (2000) show that removal of reactive dyes is carried out by chemical coagulant. The jar test is conducted for the overall coagulation process. Yonar et al. (2005) show that the removal of COD is carried for the removal of color. In addition to that, the operating costs are also determined in the various advanced oxidation processes. Poly Aluminum Chloride (PAC) based treatment of textile effluents are compact, easy to control, economical and compact. Poly chemical is added after pouring PAC chemicals into the wastewater. The poly chemical has the property of coagulation process. Once the chemical enters into the wastewater the coagulation process takes in which it influences the separation of sludge

Table 1
Earlier works on water quality assessment using modern methodologies.

Previous Work	Application	Type of Analysis/Methodology adopted	Outcomes	Challenges
Dahm et al. (2014)	Water quality management	Principal Component Analysis (PCA)	Dissolution of aquifer minerals and coal deposition	Aquifer recharge need to be done
Bertone et al. (2016)	Risk assessment	Bayesian Network model	Analysis of water quality at extreme weather conditions	Management of diverse weather conditions
Grace et al.(2016)	Water treatment	Using ash, rice husk, wood wastes etc.,	Performance assessment of materials done	Choice of appropriate filters and precautionary measures
Mativenga et al. (2018)	Water quality management	Concentration independent processing method	Deterioration of water quality is observed	Concentration independent processing is needed
Fan et al. (2018)	Aquaculture	Pinch Analysis and mathematical programming methods	Future integration of water systems	Regeneration units are needed
Li et al. (2019)	Aquaculture	Aqua phonic system	Converted nutrients from the aquaculture system	Choice of mixing ratio in nutrients
Liu et al. (2019)	Crop production	Usage of micro-nano bubble water	Quality enhanced crop production	Management of drip irrigation system

and the wastewater. BacEnz is the chemical that is added after the poly chemical in the chemical treatment process. BacEnz has the effect of separating all the detrimental effects which is present in the wastewater. The sludge separation may also have carried out by the BacEnz chemical. Once the chemical enters into the wastewater it influences the detrimental effects and also the response time of separating the sludge and wastewater is very quick. It is a non-oxidizing type, which is compatible with the polyamide thin film composite material. Water-based antifoam comprising a mixture of surface active agents and can be used for wastewater process.

2.2. Biological treatment

The decolorization effect is the process carried out in biological treatment. This treatment requires the mixing of materials like cow dung and jaggery in proper proportion and also for the development of bacteria these ingredients have stirred the material with the help of stirrer. A funnel is provided on the top of the fish tank for pouring cow dung. The temperature is also maintained around 32 °C for the development of *Pseudomonas aeruginosa* bacteria. The observations can be done once in five days. It can be seen that after giving aeration to the fish tank there is more microorganisms formed in which the decolorization effect also arises at the day of 20. The method and system of the invention uses a fish tank in which decolorization effect of textile wastewater can be observed. Here in my invention new ingredients are added, they are cow dung, jaggery. Cow dung has the property like creation of more bacteria and jaggery has the property of influencing bacteria like Pseudomonas. After carrying out the chemical treatment of dye wastewater add cow dung and jaggery in the fish tank. For about 4 L of dye wastewater from the chemical treatment add cow dung for about 1000 g and add jaggery for about 500 g and the handling system of cow dung is carried out by funnel and jaggery is mixed in proper ratio and it is added into the fish tank. The system is cost-effective and uses a simple system and enhances the decolorization effect. Sarayu and Sandhya (2012) reported that the effective method for decolorization is carried out in biological treatment. The chemicals such as biocides and stain repellents are used for softening and wetting of fabrics which is present in wastewater.

Chung and Stevens (1993) surveyed the degradation of azo dyes by measuring them using anaerobes. The study was performed by isolating bacteria strains in cell mediums that are suspended and including various azo dyes. They concluded from their studies that those dyes are not reactive. Chinwetkitvanich et al. (2000) experimented using bath effluents with reactive dye. His research consolidated the initial color concentration is reduced in fiber reactive dyes and also the effect of the co-substrate is also reduced by USAB reactors. Different dye experiments are performed using various colours and dyehouse effluents, which possess black, blue and red colours. Pagga and Brown (1986) chose 87 different commercially available dyestuffs for the study. Few of them are in pure form while other organic substances are a type of wetting agent. The test was performed in a USAB reactor in which it was designed for adsorption of wastewater treatment. The samples are collected and tested for the simulation after treating them for 42 days, it was observed from their structures and other functions, in which it is mostly biodegradable one in performing short time aerobic tests. Shaul et al. (1991) collected 18 dyes for the study among them 15 of them are acid azo dyes. Sludge and effluent samples are collected by undergoing pilot scale treatment, for determining the fate of the dye in the sludge process.

Pearce et al. (2003) used two types of textile effluents, one from the municipal water with textile effluents and the other with finished water that contains Reactive Navy 106. Zissi et al. (1997) experimented the process of biological oxidation, by batch processing. It was observed along with the by product formation, the inhibitions of cellular growth rates and utilization of glucose. Fitzgerald and Bishop, (1995) observed the complete degradation of the azo dyes by using three lab scale reactor systems. The metabolic intermediates are also identified, that was resulted from the anaerobic treatment. O'Neill et al. (2000) used reactive azo dyes for investigating the degradation of Procion Red by using sequential treatment with the support of UASB reactor and activated sludge tank.

2.3. Physical treatment

Reverse osmosis (RO) is the process in which the water moves through higher concentration to lower concentration. By carrying out this treatment, pure water is obtained in which the pH is measured as 7 and it is a stable one for drinking purpose. In a sequential stage the waste-water enters into five stages with a reverse osmosis process to extract clean water. Drewes et al. (2003) studied the treatment of wastewater from industrial wastes using reverse osmosis process Usage of reverse osmosis membranes is being practiced as a prominent technology over several years. But membrane fouling is observed as a major impediment in such processes. Tordoff et al. (2000) investigated the advanced water reclamation, in which the effluents outlet of treatment plants has organic matters. The RO membrane contributes organic fouling with the presence of the organic matter in effluents. Amjad (1993) studied the treating methodology for different types of effluents from industries using RO and ultrafiltration, which are the popular processes that used membrane based separation from the effluents. Chain and DeWalle (1977) investigated the effluents directly discharged in groundwater and soil using RO and NF. This process

doubles the flux quantity than the conventional procedures. It keeps the levels of inorganic and organic species at the same level. Schwinge et al. (2002) investigated with different configurations and shapes of membranes for obtaining optimal performance. Experimental and numerical observations were made by altering different variables in the optimization process. Brian (1965) calculated the polarization of salt concentration.

2.4. Hybrid treatment

Hayat et al. (2015) say that the decolorization of dyes in wastewater is carried out by biological and chemical treatment in which COD, turbidity are effectively removed of about 85% in wastewater treatment plants. Aljuboury et al. (2017) found that the Fenton process can be used for the removal of wastewater treatment. By adding Fenton's reagent in chemical treatment, there is the removal of chemicals in wastewater treatment. Chu et al. (2012) say that the waste-water is treated using iron powder and hydrogen peroxide for the removal of ions. Prato-Garcia and Buitron (2013) say that the evaluation is carried out by the dosing strategies method for the removal of Fenton process in which the azo dye mixtures is carried out. Meric et al. (2005) say that the acute toxicity is removed by using Fenton's reagent in which by using chemical treatment the ions are removed. Kuo et al. (2014) say that the treatment of wastewater is carried out by dispersed dye factories. The design data is calculated by number of dispersed dye are adsorbed in which kinetic coefficients were determined by the retention times. The results obtained are BOD in which it is utilized as a substrate coefficient and also the maximum sludge removal concentration is also calculated. dos Santos et al. (2004) reported that the textile waste-water is characterized as based on different operations involved in it. The operations are sizing, desizing, scouring, wool carbonizing, wool felting, bleaching, finishing, rinsing and dyeing.

Marcucci et al. (2002) says that the textile effluents are reused and treated by the low cost method called ultra-filtration method. The ultrafiltration method guarantees a constant permeate and operates at low pressure. For the dyeing process, RO permeate can be reused through which the water treatment can be carried out. Ledakowicz et al. (2001) investigates advanced oxidation methods such as biodegradation, detoxification and decolorization for better industrial ecology. The waste-water can be treated both in biological and chemical treatment in which it acts as an integrated path described by Monod type of kinetic measurements results of biodegradation are also described. Walker and Weatherley (1997) say that the by activated carbon method acid dyes adsorption can be performed. This work was carried out by a Northern Ireland printing plant. In a system of fixed bed columns, for treating the effluents this activated carbon is used. This model is also used as an adsorption method and a useful mechanism for comparison of bed depth models operating using different variables used for carrying out the process.

3. Adsorbents for removal of dyes in textile effluents

Adsorbents are small porous materials on a small microscopic level. They act like a sponge to stick to other materials. Selective components can be effectively removed from solid, liquid or gas adsorbents based on requirements. Those specially selected components of adsorbents can be utilized to purify, or remove contaminants from various industrial ecology segments. Adsorbents can be classified as organic and inorganic adsorbents in general, despite they show natural, synthetic, industry/agro/domestic waste properties. Fig. 4 shows the major categories of adsorbents used for dyes removal in the effluent treatment.

3.1. Organic adsorbents

Organic adsorbents are employed to remove various organic pollutants found in textile effluents. Due to high stiff limitation on the organic contents from textile industry outlets, it is mandatory to expel dyes from effluents before it is released into the water stream.

3.1.1. Unburnt carbon

Unburnt carbon particles are released from various carbon fuels such as coal, wood, and release of petroleum products in the environment. When those carbon fuels are burnt incompletely, carbon monoxide gases are released in the atmosphere and pollutes the environment. Those unburnt carbon which results in the incomplete combustion of hydrocarbons. Unburnt carbon is a residual particle which is obtained after the pyrolysis of a fuel such as coal, cenospheres and petroleum coke. Abbaszadeh et al. (2016) say that the unburnt carbon is used as an adsorbent in which the adsorption efficiency is about 100 mg. Zubrik et al. (2017) investigated the biomass in multistage pyrolysis. Followed by that, by performing pre-carbonization, better development of the porous activated carbon is obtained. Vargas and Halog (2015) investigated the emission reductions in fly ash in the cement industry.

3.1.2. Activated carbon

Carbon Processed to have low volume of pores is called activated charcoal or activated carbon. Such kinds of carbon are used as adsorbents while it increases the surface area during chemical reaction. Rashidi and Yusup (2017) implemented a technique for carbon dioxide adsorption with the support of activated carbon precursors using a kernel shell. By using the oxidation agent CO_2 and one step activation process, the activated carbon has been formed based on the kernel shell. Chen et al. (2018 a,b) Dzunic investigated the activated carbon in which it can be recycled from tea and palm shell wastes for the desalination of salt water.

3.1.3. Areca husk carbon

Areca nut is the fruit in which it is obtained from areca palm. This areca nut is dried under sun and it is crushed properly to form areca husk carbon. Consumption has many harmful effects on health and is carcinogenic to humans. Yusriah et al. (2014) say that the agro wastes can be recycled by proper characterization of its morphological, mechanical, physical and thermal properties in which the agro waste. It was found that the thermal stability of BNH fibre is affected by variable amounts of lignin, hemicellulose, moisture, and cellulose in the fibre at its stages of maturity. Binoj et al. (2016) say that characterization and also the parameters of fruit husk fibres. High cellulose content can be improved using high tensile strength. Padmaraj et al. (2013) say that the reinforced biodegradable composite materials are used for treatment of areca fiber. Fiber surface treatment is carried out by improving the adhesion properties of fiber and matrix to reduce the water adsorption.

3.1.4. Neem leaf powder

Neem leaf powder is extracted from neem. It is used as an antioxidant one. Neem leaf for leprosy, skin ulcers, and liver problems. The leaf is also used for birth control and to cause abortions. Mattos et al. (2017) investigated the neem bark in which from the neem bark the neem leaf powders are extracted in which it acts as a slow release biocide. Neem bark extract used in biogenic silica nanoparticles provides green and non-bio-accumulating release of biocide. Agarwal et al. (2015) experimented about the oxidation stability of biodiesel in which when there is an increase in oxidation the adsorption capacity is also increased.

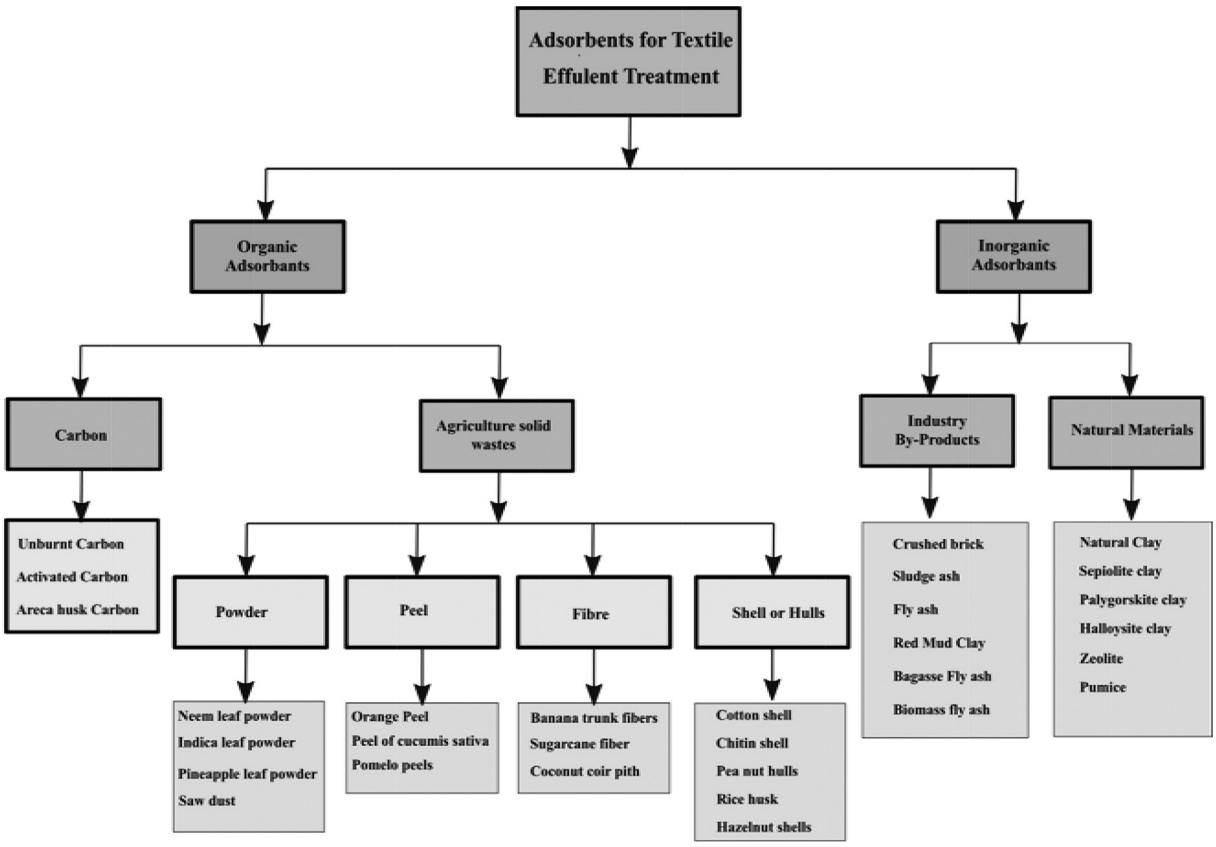


Fig. 4. Classification of adsorbents for textile effluent treatment.

3.1.5. Saw dust

Sawdusts are one of the inexpensive substrate materials obtained from the process like sawing, milling, planning of woods which is carried out in woodworking operations. It is composed of fine particles of wood. Careddu et al. (2014) investigated the recovery of saw dust in which it results in high value-added products. By recovering the sawdust, the marble processing plants can be improved. Analysis was performed with five factories and it culminates the feasible utilization of sawdust products and they provide inexpensive treatment of textile effluents.

3.1.6. Orange peel

The orange peel is obtained from orange fruit. It belongs to the family of Rutaceae. This orange fruit is also called sweet orange. The orange pulp is an excellent source of vitamin Lam et al. (2017) say that the pyrolysis conversion is carried out by converting orange peel into activated carbon in which there is an improvement in making dye adsorbent. Wu et al. (2017) emphasized that usages of essential oil extracted from citrus fruit peels provide one of the best solutions as dye adsorbent.

3.1.7. Banana trunk fibers

Banana trunk fibers are a category of natural fibers that provide very high strength, and they can be combined very easily along with the cotton fibers and other categories of synthetic materials. Banana fibers provide a wide range of benefits for various industries and are used as fertilizer, but only few parts of banana fiber products are remaining being wasted. Jandas et al. (2013) say that the banana fiber to be surface treated in which the fiber can be used as a nanocomposite for some disposal applications. He also says that the surface treatments can be made by mechanical, thermal and biodegradability in which the fibers can ~~be~~ form biocomposites.

3.1.8. Sugarcane fiber

Utilization of Sugarcane natural fiber in performing the construction tasks are most widely used in building materials. However, by using waste materials of sugarcane fibers it can be used as adsorbents and it can be used as biofuel, it can also regularize intestinal problems and when combined with a fat diet, it can also control diabetes. de Madeiros et al. (2017) say that the sugarcane bagasse is an efficient one in the gasification process.

3.1.9. Cotton shell and neem bark

Cotton shells are one of the best adsorbents of dyes. The botanical name of cotton is Gossypium in the Family Malvaceae. Cotton shell has a lot of useful products in the manufacturing of Yarn. Neem bark extracts have been used for a long time, to manufacturing different products, ranging from oral care to skin care. It provides dental and digestive support for pets and peoples. It also supports healthy gums, teeth and skin health. Cholake et al. (2017) say that the composite panels and automotive panels can be used as agricultural waste. Mattos et al. (2017) say that the neem bark is used as an adsorbent in which it is mixed with nanoparticles where neem bark is used as a biocide.

3.1.10. Chitin shell

Chitin shell is an excellent adsorbent in which it is a biopolymer and generally biodegradable one. Lu et al. (2018) say that the scalable recycling of oyster shells can be improved by mechanochemical properties in which it is useful for oil treatment methods. Elanchezhiyan and Meenakshi et al. (2016) say that for removal of

oil from the emulsion of oil-water, synthesized version of mental incorporated chitin is highly useful.

3.1.11. Tamarind

This tamarind fruit is sour in taste which is used for traditional medicinal purposes and its peel is the best adsorbent. Binoj et al. (2017) say that the discarded fruit fiber acts as a polymer composite material which is highly bio reinforced and eco-friendly. Thermal stability as well the aquatic properties of the adsorbents have been estimated by the temperature degradation and the textile effluents absorption characteristics.

3.1.12. Pineapple leaf powder

The botanical name of pineapple leaf powder is Ananascomosus. Pineapple are cultivated from possibly flowering of 5–10 months and fruiting of six months. Pineapple leaf powder is the best adsorbent of dyes. The biosorption process is carried out in pineapple leaf powder. Chowdhury et al. (2011) say that biosorption technique is used for aqueous solution in which decolorization technique is used and also thermodynamic analysis and parameters are defined by pineapple leaf powder.

3.1.13. Corncob

A corncob also called a cob of corn in which it is the best adsorbent of dyes. Corn cob is most sensitive to drought conditions. Corn cob is very effective in adsorption of dyes. Corn is the best antioxidant one when it is cooked. Memon and Khan (2018) say that the eco-friendly and sustainable corn cob is used for utilization of corncob ash.

3.1.14. Pomelo peels

Pomelo fruits are rich in citrus and they possess numerous health benefits by providing a better body immune system. The fruit is abundant with vitamin C, as well as vitamin B. Pomelo includes a large amount of potassium. Wu et al. (2017) say that pretreatment process is carried out from the citrus fruit peel waste. Pomelo peels have the best adsorbent of dyes.

3.1.15. Pea nut hulls

Peanut hulls are obtained from crushing peanuts. Crushing peanuts for oil and meal remains a major use for crops, but direct utilization for food has been steadily increased. Nikkhah et al. (2015) say about environmental impacts of peanuts in which it also acts as an adsorbent. EIA is conducted in which it is very helpful for conducting some assessment techniques for adsorbents of dyes.

3.1.16. Indica leaf powder

Acalyphaindica is the botanical name of indica leaf. Indica leaf is dried under sun and grinded thoroughly to form an Indica leaf powder. This Indica leaf powder has traditional medical uses, especially as an emetic, purgative and scabicide. Binoj et al. (2017) say about a comprehensive characterization of discarded fruit fiber in which it is very helpful for polymer composite. Thermal stability and aquatic properties are obtained by water adsorption characteristics.

3.1.17. Peapods

Peapods are obtained from the husk of a pea. Each pod contains several peas. Pea pods are botanically fruit, since they contains seeds. The immature peas are used as a vegetable, fresh and frozen. Naudin et al. (2014) say that the life cycle assessment is studied for pea wheat intercrops by handling a new method for studying its impacts on co-products. Intercrops represents the interesting application of handling the new products.

3.1.18. Rice husk

Rice husk is also called as rice hulls. It covers the hard protecting surface of grams. The rice husk is the best adsorbent of dyes. Dunnigan et al. (2018) say that the pyrolysis method is carried out for the production of biochar particles. Mohammadi et al. (2017) say that the climate change and health effects of rice husk also mainly affects the pyrolysis systems. Mor et al. (2016) say that for removing the phosphate from the effluents, the agro waste rice husk ash is highly useful.

3.1.19. Hazelnut shells

Hazelnut shells burn at high temperature, do not decompose readily and are best adsorbent. Hazelnut shells are lightweight, long-lasting, attractive and discourages growth of weeds. When hazelnut shells are used properly, mulch reduces the need for chemical fertilizers. Tozsin et al. (2014) say that the effect of marble wastes is calculated by hazelnut shells. Castro and Swart (2017) say that the hazelnut shells can be used as an adsorbent for supply chains. The hazelnut crops protect the environment and also its quality and productivity are increased to a reasonable extent.

3.1.20. Yellow passion fruit waste

Oil extracts from Passion fruit seeds have a large amount of unsaturated fatty acids and they highly reduce the microbiological and chemical alterations of during the product's final stage. Abdullah et al. (2016) say that the ultrasonication treatments provide oil palm fruit bunch fibers for cellulose and also for improving composite properties. Efficiency of empty fruit bunch and palm pressed fiber is used as a substrate for the cultivation of yellow passion fruit waste (Ali et al., 2013).

3.1.21. Coconut coir pith

Coconut coir pith is extracted from the coconut husk. It is very useful for making products like floor mats, doormats, brushes, and mattresses. Coconut coir is used both in agriculture and horticulture (Jose et al., 2019). Coir is an allergen, as well as latex and other materials which are used frequently in the treatment of coir. Arena et al. (2016) say that the life cycle assessment studies are carried out in activated carbon in which coconut coir pith is used as an adsorbent.

3.1.22. Rubber seed coat

While carrying out a latex manufacturing process using rubber seeds, in acidic conditions or in the presence of enzymes the glycosides and cyanogenic releases prussic acid. Chin et al. (2014) say that the gasification of rubber seed shells is used as polyethylene mixtures. Kinetic studies are also studied on the basis of high density of polyethylene. The synergistic effect of the biomass and plastic waste mixture are investigated in which there will be a number of pyrolysis processes processed during each stage.

3.1.23. Apple pomade and wheat straw

Apple pomade is an extract made from apple in which it is the best adsorbent of red dyes. Wheat straw is also an extract from the wheat, and by products of similar such cereal plants dry stalks cultivation are used as adsorbent. Weinwurm et al. (2017) say that wheat straw can be used for extraction and another reaction modelling. Abdelmoez et al. (2014) say that the water technology involved in wheat straw hydrolysis produces value-added products.

3.1.24. Castor seed hull

Castor seeds are acrid, thermogenic, digestive, and cathartic. Castor seed hull is the best adsorbent for dyes. The botanical name of the castor seed hull is Ricinus Communis. The pure consumption of the seeds already has poisonous effects and can lead to death.

Guil-Guerrero et al. (2017) expressed that biodiesel can be produced from the seed oils extracted from wild plants available in Mediterranean basin in which it is helpful for adsorption. Biodiesel properties with empirical and experimental data are adequately examined. Biodiesel fuels of very high-quality are obtained at last.

3.1.25. Other materials

The peel of cucumis sativum fruit is widely used as an adsorbent of dyes. They may have a pollenizer cultivar interplanted. El Khaled et al. (2017) say that the control system is used for calculating the impedance value in which the fruits and vegetables waste can be recycled by cleaner quality control systems. Abbaszadeh et al. (2016) performed treatment in the lead-contaminated water and used as an adsorbent from locally available papaya seeds in which the peel is used as a biowaste.

3.2. Inorganic adsorbents

3.2.1. Natural clay

Clay combines few minerals and moderate traces of organics and metal oxides, and certain geological deposits of clay also have phyllosilicate minerals. Burland (1990) experimented the undrained strength of stiff fissured clay that is operational and it is observed to be consistent in strength. It is resulted from the fissures present in the material and the brittle nature of intact materials. Leroueil et al. (1990) say that for varve sedimented clays, the vertical permeability reduction is smaller than the horizontal permeability, and also it is observed that the permeability anisotropy increases with compression.

3.2.2. Crushed brick

Crushed brick is obtained from bricks in which it is useful to make different pavements and walls in construction. Kazmi et al. (2018) investigated the thermal performance and also he described the eco-friendly bricks in which it is helpful for concrete materials. Thermal conductivity relation of the bricks with other mechanical and physical properties are also explored.

3.2.3. Sludge ash

Sludge ash is obtained from the burning of sewage sludge. The collection of solids is known as raw sludge . The sludge is dried in the sun and it is burnt properly by incineration methods and the sludge ash is obtained from it. Chen et al. (2018)a,b investigated that the sewage sludge ash and the sludge are reused for producing concrete blocks. For controlling the content of water lodged in the concrete mixes, dry mix compaction methods are being used. Zhang et al. (2018) investigated the usage of zeolite for warm mix asphalt as sewage sludge ash. For optimizing the synthesis conditions, the design was experimented with orthogonal conditions. Chakraborty et al. (2017) investigated the sewage sludge in which it is an excellent replacement method and it is also used as construction material.

3.2.4. Fly ash

Fly ashes are extracted from combustion of coal products that compose fine particles from the boiler outlet combined with flue gases. Musci et al. (2018) say that fly ash is a best adsorbent in which when it is reinforced with geopolymer to produce a waste tire. From the fly ashes and used tires by synergetic application valuable materials for constructions can be produced. Novais et al. (2018a) say that for removing the methylene blue from textile effluents, usage of biomass fly ash geopolymer will be a much more effective choice.

3.2.5. Bagasse fly ash

Bagasse fly ash is obtained from burning of bagasse. It is obtained by crushing ~~of~~ sugarcane. The bagasse is dried under the sun and it is burnt to form bagasse fly ash. Noor-ul-Amin et al. (2016) say that the geopolymer from bottom ash is obtained from mainly sugar industries. The bagasse fly ash is mainly obtained from burning of sugarcane fibers. Embong et al. (2016) say that the pretreatment process is carried out by a solar drying process in which it is effective in the ash of sugarcane bagasse.

3.2.6. Biomass fly ash

All the vegetable wastes are burnt and the biomass is produced in which fly ash is a best adsorbent for dyes. This biomass fly ash is the best adsorbent for dyes. Biomass ashes from wood and herbaceous sources may be considered a natural pozzolan depending on their composition. Novais et al. (2018a) say that biomass fly ash geopolymer is very effective and methylene blue is removed by waste-waters. Novais et al. (2018b) report that biomass fly ash based geopolymer will boost methane for the adsorption and also could be used for anaerobic digestion.

3.2.7. Sepiolite clay

Sepiolite clay is a soft white clay mineral, often used to make tobacco pipes. Sepiolite clay is used in oil drilling and also for car litter. In construction sepiolite can be used in lime mortar as a water reservoir. Nikolic et al. (2017) investigated that the organo modification is performed by adding sepiolite nano composites in which it results in the performance criteria. Marrakchi et al. (2016) examined that the dye adsorption of blue and reactive orange is obtained by adding sepiolite composite in which the cross-linked clay is used for it. Santos and Boaventura (2008) developed that the different types of textile dyes are adsorbed using sepiolite clays in which the textile dyes are adsorbed.

3.2.8. Palygorskite clay

Palygorskite clays are a composite of attapulgite clay. It physically binds to acids and the digestive tract. Palygorskite can be added to lime mortar with metakaolin for period-correct restoration of mortar at cultural heritage sites. Yang et al. (2018) say that the adsorption of various ionic dyes is carried out by palygorskite clay. The clay is taken in a solidified form and various adsorption tests are performed. Xue et al. (2010) say that the reactive dyes are adsorbed by means of aqueous solution which is by the use of palygorskite clay.

3.2.9. Red mud clay

Iron oxide composition of alkaline wastes are found in red mud clay extracted from the production of alumina. Kismir and Aroguz (2011) say that the green color dyes are absorbed by Saklıkent mud. Adsorption characteristics of the dyes onto Saklıkent mud is also based on the rise in temperature. First order kinetics models of adsorption are best described for lower temperatures and Second order kinetics models of adsorption are best described for higher temperatures. Liu et al. (2011) say that red mud clay has metal oxides with porous structures and it is composed of fine particles that are effectively used as adsorbents for removing bacteria, anoions, organics and heavy metals.

3.2.10. Halloysite clay

Halloysite is a clay mineral with hydrothermal alteration of alumina-silicate minerals. Zhao and Liu (2008) say that the adsorption using the halloysite clay is mostly dependent on temperature, pH value and the concentration of the solution. Adsorption kinetic using the halloysite clay follows the kinetic model of pseudo-second-order that confirms the chemisorption of

methylene blue on halloysite nanotubes.

3.2.11. Zeolite

Zeolites are minerals that are formed as a result of volcanic ash changes in a water environment. Clinoptilolite is one of the most abundant in the world in terms of natural zeolites. Various ions present in zeolite (clinoptilolite) and modified-zeolite are known as exchangeable ions. These ions can easily be replaced by other cations in aqueous solutions without disrupting the alumino silicate structure. It has been supported by numerous scientific researches in which zeolite and modified-zeolite are capable of being used for removal of dyes from effluents (Almasian et al., 2015;).

3.2.12. Pumice

Pumice, a category rock that is erupted from volcanoes. Its surface has got a lot of pores with irregular and oval shapes. Because of its large surface area, the pumice is used as a biofilm material especially wastewater treatment. Scientific researches on the use of pumice show that pumice could be an appropriate adsorbent for dye removal from wastewater. Samarghandi et al. (2012) showed that pumice stone can be used in azo dyes removal from textile effluents. Fiallos et al. (2017) experimented the use of pumice stone as a biofilter material and found positive results. Samarghandi et al. (2012) showed that pumice can be used as cheap adsorbent in textile wastewater by acidic modification.

3.2.13. Adsorbent properties & factors affecting adsorbents

Usually granular form is acceptable and powder is palatalized. Granular form of charcoal, activated carbon and rubber granules may show better properties as adsorbents.

The effect of adsorbent depends mainly on large surface area per unit volume and increase in pore volume (Dubinin, 1982;). The porosity of adsorbents is one of the main factors in adsorption. The smallest pores in adsorbents (the micropores) are comparable in size with adsorbed molecules. As a result of the superposition of the fields of dispersion forces from opposite walls of the micropores, adsorption energies in micropores are relatively high. Volatilization and increase in mesoporous volumes of adsorbent particle surface leads to high adsorption capacity and long effective adsorbent life (Dubinin, 1982; Orlandi et al., 2017).

Adsorbents are affected by factors such as pH, dosage and time. The electrostatic attraction is increased by low pH, where the positive adsorbent surface is increased. When the excess adsorbent dosage is used, a significant portion of the adsorption sites remains unsaturated. This obviously leads to low specific adsorption capacity. When the adsorbent dosage was lowered, the number of active sites saturated with dyes increased; therefore, specific uptake also increased. The decrease in dye removal with time may be due to aggregation of the dye molecules around the adsorbent particles.

4. Modern enabling technologies and methodologies supporting removal of dyes from textile effluents

Because of the toxic material composition in the textile industry effluents as well the challenging conditions of breaking down the bonding of few dyes used in textiles, usage of conventional techniques needs a flavor of modern technological support. Environmentalists and researchers have taken those issues as serious concern to put forward modern techniques for supporting the textile industry in managing their outlets in an effective manner.

Elaborated discussion on the outcomes of the literature on water quality assessment are given as follows. Dahm et al. (2014) studied the water quality compositions using Principal Component Analysis (PCA) on composite geochemicals. It is revealed from the observations that the water quality is related to aquifer recharge, dissolution of aquifer minerals and coal deposition (Mativenga et al., 2018). Bertone et al. (2016) analysed the quality of water under extreme weather conditions. By considering the colour of the water, turbidity and Cryptospordium, a conceptual model was developed using Bayesian Network model. Risk assessment on water resources was observed for different scenarios of weather conditions (Bertone et al., 2016). Grace et al. (2016) studied the usage of waste materials such as ash, rice husk, wood wastes etc., for performing water treatment. They also performed few precaution measures to avoid contamination of water due to metals and other wastes used for treatment. Appropriate filters were used during water treatment based on their adsorption potential. Wehn et al. (2018) Compiled a systematic review of water innovation and their dynamics. It includes the study of the category of innovation, level of analysis performed on water bodies, measurement types and various stages of innovations carried out.

Mativenga et al. (2018) collected and analysed the water quality data for a period of 8 years. They examined the level of pH, turbidity, amount of sulphates, manganese and concentration of dissolvable solids in drinking water. A concentration independent processing method is proposed to observe the deterioration of water quality. Fan et al. (2018) analysed the water treatment systems by introducing regeneration and treatment units. Pinch Analysis and mathematical programming methods are used for integrating water systems, treatment systems and regenerative systems. It guides to provide a best outline for future integration of water systems. Li et al.(2019) proposed an aqua phonic system for improving the quality of water and for enhancing its nutrition contents. Here converted nutrients from the aquaculture system is mixed with ammonium and nitrate with a specified ratio. It enhances the growth of aqua plants and thereby creates a better quality water and environment for rearing fishes.

Jose et al. (2019) presented a simple and economical method using coconut fibre. Here electrocoagulation is performed for removing the harmful chemicals and biomass in a safe manner. Purity and Efficacy are tested by observing the conductivity reduction in water, change in its colour, pH, sledge quantity in water and many more parameters (Li et al., 2019). Wang et al. (2019) proposed an optimized model for overcoming the serious demands for quality water. Here the mixture of ground water and reuse sewage water are considered and water resource allocation is performed by using an optimized strategy. Based on the observed measures, water quality is simulated finally (Wang et al., 2019). This model provides an optimal solution for quality water allocation to the required multiple agents. Liu et al. (2019) investigates the usage of micro-nano bubble water along with ground water for estimating the efficacy of water usage, yield and quality of crops. This provides a better solution for saving water and increasing the yield of the crops. It also provides quality enhanced crop production using a drip irrigation system.

The modern enabling techniques for water quality monitoring utilizes smart sensors interfaced to modern controllers and interconnected using wireless standards for monitoring the quality of water. Fig. 5 outlines the modern enabling technologies for supporting better water quality monitoring and treatment. It includes a set of sensors, a range of networking methodologies and controllers for decision making. IoT also deployed as enhanced technology for water quality monitoring and control systems using the Internet as backbone networks supporting remote monitoring and control in recent days (Damor and Sharma 2017). Literatures supporting the implementations of modern enabling techniques are discussed as follows.

4.1. Sensors based devices for monitoring systems

Cloete et al. (2016) implemented a real-time water quality monitoring system using Raspberry Pi. Here in his experiment he connected Raspberry Pi with pH sensor, temperature sensor, turbidity sensor, DC power supply. All the functions are done by the raspberry chip and the output is measured by the wifi module. The pH sensor performs the functions like removing the disinfectants in which it is carried out by colorimetric method (Nasirudin et al., 2011). Temperature sensor is a solid-state technique in which it determines the temperature level in bimetallic strips and also thermostats in which automatic cut-off temperature is carried in which it reaches the maximum level. Saravanan et al. (2018) say that the water quality monitoring system has evolved in the environment area. Mainly water quality monitoring is carried out and different parameters like pH of the water and other fluid contamination are measured. The main reason for taking pH is to check whether the water is contaminated or not. The design and development of a water quality system is monitored and the Arduino system is evolved in it. Bhardwaj et al. (2015) used modern sensors for observing the water quality. These sensors provide good response time, high selectivity, high sensitivity and they are highly insensitive to electromagnetic interference. But they also require regular maintenance, and additional power for ensuring their expected operation in the environment.

4.2. Wireless sensors devices

Chen et al. (2011) reported that using low power protocols along with field programmable gate arrays, a wireless sensor network could be deployed for integrating them along with the microbial fuel cells. In this paper energy harvesting systems are used in which energy provided is efficient to sensor module system. Daigavane and Gaikwad (2017) reported that the water quality monitoring systems are used in which different types of sensors used they are temperature, pH, turbidity, flow sensor are used in which it can be measured. The sensors are interfaced using Arduino board for collecting the data and performing analysis. The developed system is used for monitor water quality automatically, and it is highly economical. Manju et al. (2017) says that the proposed system is designed by integrating it with different sensors for continuous monitoring of the plant's environment and quality of water. Using the Internet of Things (IoT) framework, water quality and other parameters collected using the sensors are accessed remotely. Sridharan (2014) discussed about the usage of wireless sensor network (WSN) for monitoring quality of water. The system integrates a large number of sensor nodes connected through a wireless network. The water monitoring system setup emphasizes on economic aspects along with easy installation, handling as well as maintenance of the system. Usage of wireless sensor networks for monitoring purpose, reduces the overall system system monitoring cost with minimum facilities and reduced labor cost. The WSN system also provides better flexibility in terms of long distance coverage and remote communication.

4.3. Optical sensors

Skarga-Bandurova et al. (2019) reported that for monitoring the quality of water, remote sensing technique and internet of things techniques are used. Their work presents a low cost module for monitoring the quality of the water. Developed system also detects several pollutants from the body sources. This system uses the Arduino as the main system in which the temperature sensor, conductivity, turbidity are measured and the output data is sent to the computer and the output is measured by the cloud computing system. Kedia (2015) says that sensor cloud models are used for improving the water quality and creating awareness about it. A pseudo algorithm system is used in an optical sensor for synchronization with sensor cloud and its applications.

4.4. Smart sensors

Geetha and Gouthami (2016) observed that a water quality monitoring system is evolved for giving smart solutions. This paper presents detailed information about smart water quality monitoring systems. Energy efficient systems are also monitored using the internet of things. Five parameter like conductivity, temperature, pH, turbidity and water level are measured using the Arduino software. Saseendran and Nithya (2016) say that using IoT technology and wireless sensor nodes, water usages are tracked and continuously monitored using WSN. Data collected through wireless networks are used for tracking the wastage and efficient

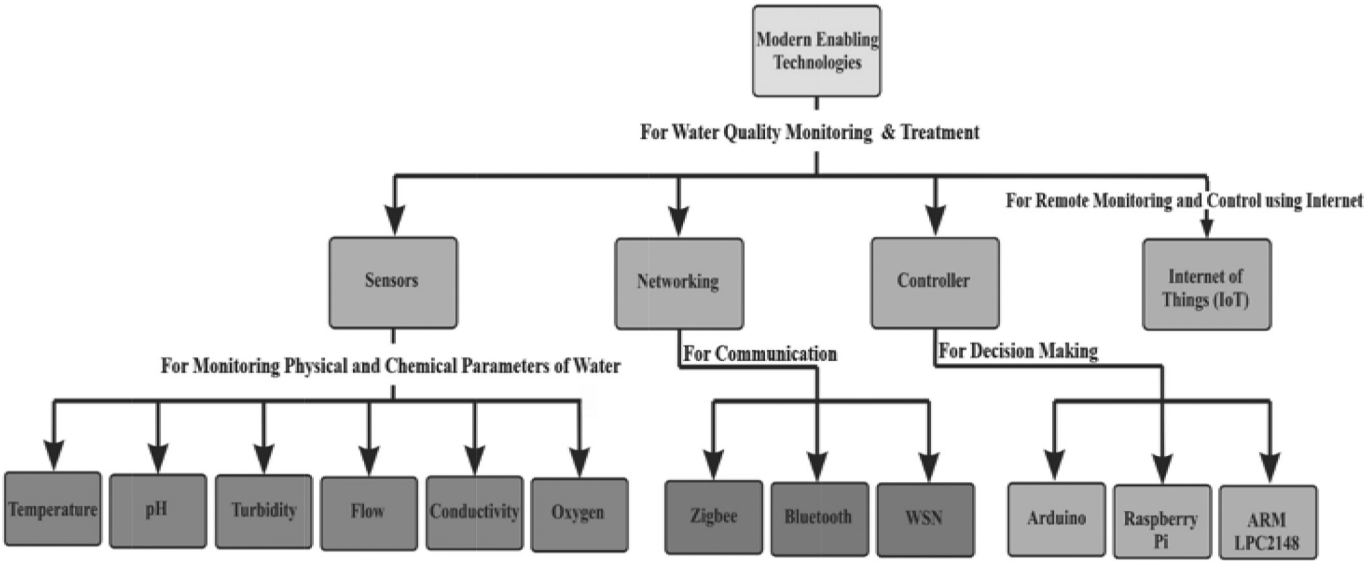


Fig. 5. Modern enabling technologies for water quality monitoring and treatment.

utilization of water resources.

4.5. Real time monitoring devices using arduino

Damor and Sharma (2017) commented that the IoT is evolving in which the approach of the internet of things Devices connected using IoT enables energy efficient processes. Arduino Uno Board and Raspberry Pi are used in which the sensors for all the treatment are placed and at last cloud computing system is evolved for the result of real time monitoring systems. Nasirudin et al. (2011) observes water quality parameters from the lakes, rivers and other freshwater resources and real time data are collected using WSN. Various water quality sensors are deployed at distributed water body locations to monitor the quality. The developed system also used green energy sources for optimized power utilization by effective utilization of solar energy (Poonam et al., 2016). Collected data is transmitted to sub base stations through a network coordinator node and GSM network to the server for monitoring purposes.

4.6. ZigBee and microcontroller

Poonam et al.(2016), commented that the water analysis system is done by using sensors for monitoring the water quality and connected through zigbee modules for remote transfer data are used for transferring the data to cloud. LPC2148 controller is used in which the water quality system is monitored for environment observing, ecosystem monitoring which can be viewed anywhere across the globe. Raich (2013) says that water quality system is monitores temperature, pressure, conductivity, flow rate as well as other physical and chemical parameters. The system uses Arduino and the advanced level of raspberry pi systems are used for calculating the cloud computing data to be transferred for each treatment process. Zhang (2011) uses efficient and low cost PIC microcontroller for handling waste-water, by configuring it to operate under robust environmental conditions. The developed system eliminates human intervention and thereby protects their health againt the waste-water. The system is programmed to automate the functions needed for sample collection from the effulents.

4.7. Remote sensing and IOT based systems

Vijayakumar and Ramya (2015) reported that the water parameters are monitored using a real time system designed using Raspberry Pi B+ core controller and a Wi-Fi module to configure it as an IoT system. These IoT based devices are economical, efficient and they are capable of transmitting and receiving the data through Wi-Fi modules. Murphy et al. (2015) developed an autonomous optical sensor of low cost for monitoring the water quality and different range of parameters. The robust and simple optical sensor has two photodiodes and they acts as detectors of mutiwavelengh optical signals. The quality of the sensor is strong enough for improved measurement of water quality. Robles et al. (2014) proposed an IoT based system for integrating a smart water management using decision support mechanisms for monitoring the water quality aiming at better business prospects, even at the subsystem level of implementation. Ramesh et al. (2017) developed an IoT based system for observing the contamination level and the quality of water. The hydrocarbons are detected using the metal contacts and the soil probes. In addition to that, the pH value oxygen content, turbidity and conductivity are monitored from various water bodies.

Most of the IoT based water quality monitoring and control system uses the general architecture shown in Fig. 6. Edge node at the local monitoring scene integrates the data from the controllers for enabling Internet connection. The remote end includes cloud services for storage and performing analytics for deciding on the quality of water and taking appropriate control actions.

Murray et al. (2012) proposed an IoT based water quality monitoring system. ARM processor is used for collecting data from monitoring nodes through the sensors. Collected pH, turbidity and conductivity parameters are sent through wireless links and Internet to remote stations. Observed data from remote stations can monitor the quality of water in visual format using the MATLAB software. This low powered economical solution supports future research on remote water quality monitoring services. Daigavane and Gaikwad (2017) proposed a system with an Arduino board as a core controller and a Wi-Fi module for monitoring the quality of water. This low cost IoT based system provides real time monitoring of chemical and physical parameters of water. Sensor data is collected through Wi-Fi modules connected to the Internet. Sun et al. (2012) proposed a method for quality information extraction from sensors interfaced with IoT devices. They explored energy efficiency of the devices and integrated the critical sensor data based on time and vital requirements for the applications. Performances were analysed by using the sensors in a water quality monitoring system. Kartakis et al. (2016) incorporates IoT technology along with localization algorithm and graph theory for detecting water leakages and bursts. Vibrational data are acquired and non-intrinsic sensors are used for observing the anomalous behaviour in the water systems. Appropriate solutions were provided with the support of IoT technology.

5. Discussion

The Textile and Clothing segment market and industries manufacturing them are having great economic impact in the world. It also adds up a lot of threats to the natural resources. Mostly, the colorful clothes and textiles people wear are printed with the materials that impact the environment. Raw materials used to make fabrics are collected from crops such as cotton, flax and hemp required plenty of water. Those crops are highly valuable, and few farmers use a lot of pesticides and herbicides that may pollute the environment. Rayon fabrics are made from wood pulp, which are treated with harmful chemicals and those effluents find the path into the environment. Synthetic or man-made fabrics such as nylon and polyester are made from petrochemicals and fossil fuels and it makes them utilize a lot of water. Nylon manufacturing also creates greenhouse gases, which are harmful for the environment. Dyes in synthetic fabrics textiles are not biodegradable and they may pollute the environment to a larger extent.

Detailed survey of existing publications to treat those textile effluents are done to observe the technology involved. Physical, chemical, biological, adsorbent based and modern technologies supporting the effluents treatment for better industrial ecology are elaborated with detailed surveys from recent publications. Each treatment part elaborates the methodologies followed and effective means of waste water treatment.

It also observed that sustainable pollution free environmental conditions could be easily achieved and well monitored and controlled with the support of modern enabling technologies such as IoT, modern communication technologies and wireless sensor networks. Literatures outlining the modern methodologies using IoT for water quality monitoring and control are tabulated with their outcomes in Table 2.

Cloud based models could be used for monitoring the water quality (Kedia 2015) . The water quality measured by sensors are uploaded to cloud services and the data is directed to local and government authorities. The embedded design solution with the

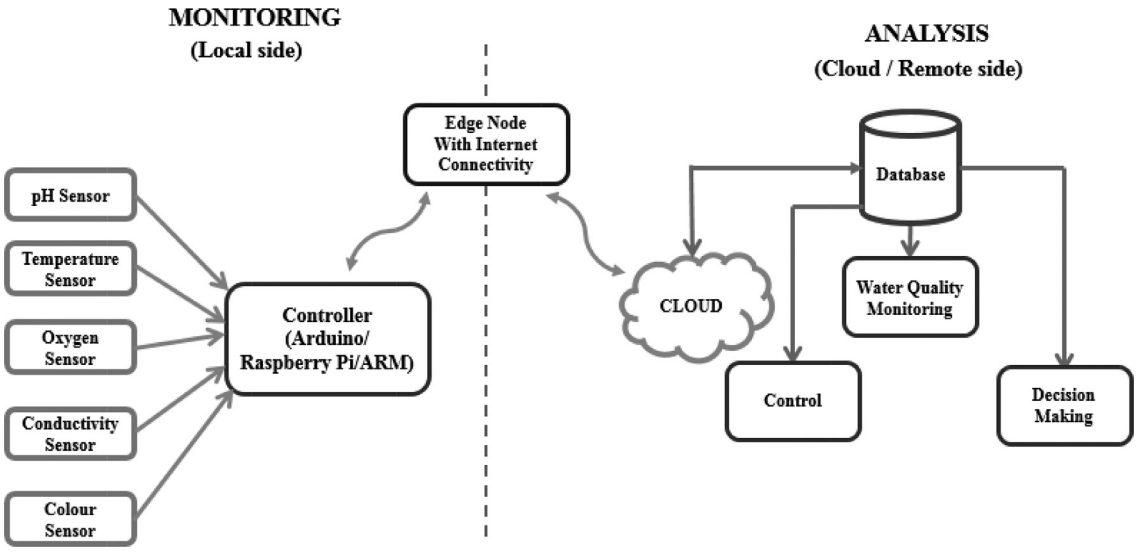


Fig. 6. General Architecture of IoT based water quality monitoring and control system.

choice of networking methods are considered for disseminating the awareness of the water quality to the public. Different wireless communication methodologies for communicating the quality of water through IoT framework (Cloete et al., 2016). Raspberry Pi module is integrated with cloud computing infrastructure for visualizing the water quality parameters from a remote browser connected through the Internet. Lom et al. (2016) emphasized the importance of Industry 4.0 for smart cities. IoT acts as a backbone for Industry 4.0. For any smart city, a clean environment is an essential factor. The dependence on the Internet of Everything (IoE) for natural resources such as water, oil etc is rapidly increasing. With growing demand, IoT and IoE will be a good support for societal development.

In the present scenario, the textile industries that would meet the requirements of Industry 4.0 would actually survive. So, artificial intelligence based techniques, effective ways in planning, implementation of internet of things based devices, multi-objective optimization techniques for the process of dyeing are indispensable. But only few researchers have tried out these studies in unconventional methods with promising results. Implementation of these modern techniques helps us to reap huge benefits with cost reduction in water treatment. Besides, consumption of water would be reduced to a greater extent.

6. Conclusion

The present exhaustive survey on the textile effluent management technologies has a major influence on water quality, targeting to enlighten multi-sector decision making towards achieving cleaner manufacturing environment. Developing countries are still in early stages due to deficit funds, incapability of adopting suitable methodologies, poor systems coordination and high-operational costs of conventional wastewater treatment plants. The strategic implementation of integrated classic textile effluent treatment know-hows with modern enabling technologies have the potential to bridge these challenges delivering a viable sustainable route towards localization, implementation, and monitoring of water systems on real time basis. The authors are optimistic that coordinated operations would lead to the optimization of resources by reducing the water consumption and the treatment costs, whilst minimizing the environmental pollution. Such automated operations would certainly provide way for the development of smart cities in the near future.

This review article deals with a variety of dyes used in textile industries and their alarming consequences. Different textile effluent treatment methods, modern approaches and devices are summarized and compared. There is a lack of common platform for pooling different classical methods of treatment of textile dyes along with different modern promising approaches. Researchers and practitioners gain a good overview of the scope of the possibility of maintaining industrial ecology for sustainability. Sustainability could be often achieved by combining suitable combinations of diverse approaches. Besides, the full potential of an exhaustive list of adsorbents are explored and compared. Low cost high

Table 2
Comparison of IoT technology based water quality assessment approaches.

Previous Work	Application	Type of Analysis/Methodology adopted	Outcomes	Challenges
Murray et al. (2012)	Water quality monitoring	ARM Processor and IoT devices	Low power economic solution.	Choice of monitoring nodes and sensors
Daigavane et al. (2017)	Monitoring of nutrients in water.	Arduino boards with Wi-Fi modules and IoT devices	Low cost IoT based system for real time	Extraction of chemical and physical parameters
Kedia et al. (2015)	Water networking methods	Cloud based model	Design solution for providing awareness about water quality to the public.	Choice of networking methods
Cloete et al. (2016)	Remote water quality monitoring	Raspberry Pi module based IoT frameworkṁ	Visualizing the water quality parameters from a remote.	Cloud integration strategies
Kartakis et al. (2016)	Behaviour analysis of the water systems.	localization algorithm and graph theory	Observing the anomalous behaviour in the water systems.	Optimization of localization process

performing adsorbents hold promising benefits for industrial applications.

Advanced IoT based technology with artificial intelligence offers a huge scope of unlimited possibilities and that are yet to be explored in full. The scope of the work could also be still extended with the survey of machine learning, artificial intelligence, neural networks, and deep learning approaches for eliminating the harmful pollutants, dyes and sludge from effluents in order to ensure sustainable pollution free environment and better industrial ecology. Implementation of techniques such as automation, data exchange, the Internet of things, cloud computing in textile effluent treatment would ensure Industry 4.0 standard with promising results.

CRediT authorship contribution statement

N. Rajesh Jesudoss Hynes: Conceptualization, Investigation, Visualization. **J. Senthil Kumar:** Methodology, Writing - original draft. **Hesam Kamyab:** Writing - review & editing. **J. Angela Jennifa Sujana:** Writing - review & editing. **Omar Ali Al-Khashman:** Formal analysis. **Yasemin Kuslu:** Formal analysis. **Antoaneta Ene:** Writing - review & editing. **B. Suresh Kumar:** Writing - original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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