Chapter 11
Ionic Liquid Modified Activated Carbon for the Treatment of Textile Wastewater

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Contents

Abstract The dependency on water has increased three times more than the increase in population. It has led to a rise in health problems and has limited the development as well as the growth of the world in terms of agricultural and economy. It has become mandatory to treat the wastewater of textile industry and make it pure in order to meet the demands of the people in the future. Various treatment processes have also been applied to convert wastewater into a suitable form where the linking of the innovative technology-oriented process with the conventional process has proved to be appropriate. For the treatment of textile wastewater, the application of ionic liquid modified activated carbon has yielded fruitful results, showing good properties in terms of selectivity, stability and favourable adsorption

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capabilities in comparison with other materials. In the present book chapter, the significant ionic liquid modified activated carbon along with their uses for wastewater treatment is described.

Keywords Textile · Wastewater · Ionic liquid · Textile industries · Dye

11.1 Introduction

Textile is a fabric or a type of cloth which is made of filament or yarn. Textile is a flexible material consisting of a network of natural (wool, cotton, silk, etc.) and artificial (rayon, nylon, polyester, etc.) fibres. The word textile originates from the *Latin* word Taxtilis and the *French* word Texere, which means 'to weave,' and originally it means woven fabric. Textile is formed by different processes like knitting,weaving, crocheting, felting, tufting and knotting. Textile includes threads, ropes, cords, braids, embroidery, net and laces. Thus textile includes threads, ropes, cords, braids, embroidery, nets and laces. Basically *textile* is any material made of interlacing fibres, including *carpeting* and *geotextiles*. Textile production can be increased by industrialization and using some advanced techniques nowadays (Schwartz 2008).

The maximum amount of wastewater effluents is generated from the textile industry because of the application of water for various operations of wet processing. The effluents of such industry include substances such as dyes, acids and so on (Paul et al. 2012; Sharma et al. 2018). Hence, it has been observed that the textile industry uses high quantity of water in comparison with other industries that release even maximum pollutants as well. It is seen that the textile industry employs approximately 200 L of water per kg of fabrication process, every day (Ding et al. 2010). As per the estimation made by the World Bank, the dyeing and finishing work for fabrics are releasing about 17–20 % of effluents in terms of wastewater (Kant 2012).

In India, owing to the leading demands of cotton fabric and polyester, the consumption of dyes and its stuff is very high, nearly 80% of 1,30,000 tonnes (Naik et al. 2013). Such dyes lead to a severe hazardous impact on the photosynthetic activity within the plants. It also affects the aquatic life in terms of less light penetration and consumption of oxygen (Javadian et al. 2014). It is fatal to various marine organisms as it releases different metals and even chlorine which are dangerous. The suspended substances may choke the gills of the fish which may lead to death. It reduces the ability to make food and oxygen in the algae. The dyes are reported to be severe for even the municipal treatment of wastewater (Naushad et al. 2016; Sophia et al. 2019).

Currently, the heterocyclic and aromatic forms of dyes are applied in the industry. The complex and certain structural dyes are leading to complication in the degradation process in any form of matrix and wastewater (Ding et al. 2010). The toxic substance released from the textile industry and mineralization of dyes has become a challenging task and concern to overcome pollution (Arfin et al. 2019).

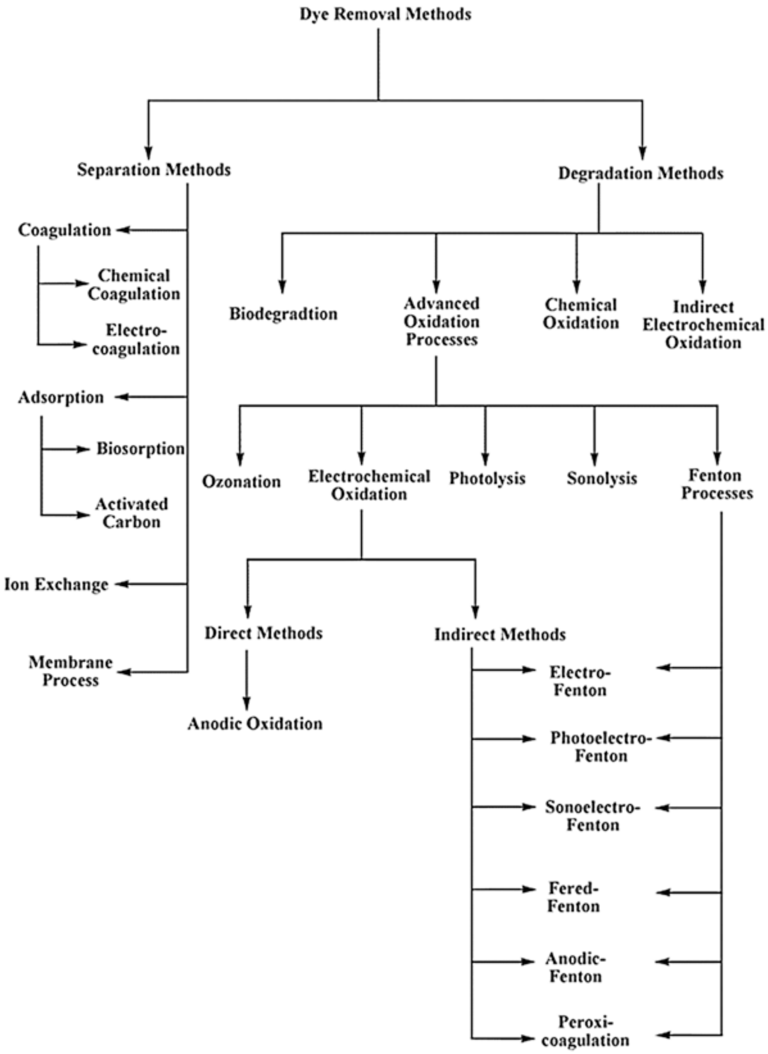

Fig. 11.1 Treatment process of dyes in textile wastewater

With the more quantity of complex material possessing the maximum amount of color, a high concentration of organic changes the features of dyes. With the presence of high BOD/COD, colours and salts, the wastewater dyes of cotton release hazardous pollutants. The coloured water leads to the scarcity of light significant for the growth and development of marine organism resulting in environmental imbalance. Colour and toxic substances should not be present to lessen the cost of the treatment process of river water for consumption purpose. Hence, various treatment processes are formulated and implemented before discharging wastewater into the water bodies in a precise manner which is given in Fig. 11.1.

For the treatment of textile wastewater, different physico-chemical approaches are used, namely, flocculation, chemical precipitation and ion-exchange method (Alqadami et al. 2016). But such approaches are unfavourable as they include expensive costing and even generate secondary waste. In comparison with different techniques, adsorption is the most applicable and even possesses less pollutant. Currently, more interest is generated towards the study relative to absorbents with low-cost materials, namely, tree bark, alum sludge and so on (Clave et al. 2004). The most often applied are the activated carbon, kaolin and silicon polymers. Each adsorbent signifies for selective adsorption of the dye particles. But among all, the activated carbon is considered as the best material. The activated carbon (AC) can remove COD up to 91.15%, and the chroma was reduced up to 92.17% within the reactor meeting the target of the standard wastewater level, and it can even be used again in the form of washing. Since the AC is selective to the adsorbed dye, it is capable enough to remove water-soluble dyes, namely, azo dyes, reactive dyes and basic dyes. But it is unable to absorb the insoluble dyes and the suspended solids present in the dyes. Since the AC possesses high regeneration cost, it is not used directly in original dyeing of textile. Therefore, it is used in low concentration. Ionic liquids (ILs) gathered a lot of attention in the field of engineering and modern chemistry in the industrial application. Lemus et al. (2012) reported that structural characteristics and chemical surface of AC can be modified to adsorb different structures of IL. This property has viability for adsorption of IL according to thermodynamics. Farooq et al. (2012) investigated about the adsorption of hydrophilic IL through AC which stated that both thermodynamics and kinetics of IL adsorption were dependent on AC adsorbent.

11.2 Types of Textile

Sources of textile material are mainly of four types:

- Animal (wool, silk)
- Plant (cotton, jute)
- Mineral (glass fibre, asbestos)
- Synthetic (polyester, nylon)

The first three types of sources are natural, and the fourth source made by the use of petroleum, i.e. artificially. A textile's better property or grade depends on several factors, such as the type of raw material used for making yarn, smoothness of yarn or fabrics, density, etc. (El-Molla and Schneider 2006).

11.3 Location of Textile Industries in India

In India, textile industry is another way to generate vast employment among people both skilled and unskilled, which stands as the second largest industry after agriculture. As per analysis, 2,500 weaving factories and 4,135 finishing factories of textile were present in 2010.

In India, cotton industries are situated in Kanpur, Kolkata, Ahmadabad, Rajkot, Indore, Surat, Vadodara, Nagpur, Mumbai, Solapur, Chennai, Coimbatore and Madurai.

Silk industries are situated in Srinagar, Anantnag, Jammu, Murshidabad, Kolkata, Gokak, Bengaluru, Mysore, Chennai, Coimbatore and Madurai.

Wool industries are situated in Srinagar, Amritsar, Ludhiana, Panipat, Kanpur, Allahabad, Shahjanwan, Mirzapur, Jamnagar, Amalner, Jalgaon, and Bengaluru.

Jute industries are situated in Kanpur, Gorakhpur, Shahjanwan, Katihar, Rajgarh, Darbhanga, Guntur, Vishakhapatnam and Cuttack (Sharma 1949).

11.4 Textile Wastewater

Water treatment is a major problem in the industries (Arfin and Rangari 2018; Arfin et al. 2016). According to standard quality, purifying industrial wastewater must be required before reuse for different purposes; we required some advanced techniques for purification, and these techniques should be efficient and cheap. This treatment required some additional cost for recycling as a product. It can be proved economically more feasible if it takes the low cost of intake water and low discharge cost. Textile industries consume 200 L water per kg of fabrics on an average per day. According to the observation of the World Bank, after finishing and dyeing processes, textile industries produce 17–20 % industrial wastewater.

Textile industries utilize about 80 % of the total amount of the product of 1,30,000 tonnes of dye, in India, because of the high demand of polyester and cotton, and globally these wastewater dyes show a negative impact on photosynthesis process in plant and also on aquatic life due to less penetration power of sunlight. Sometimes these wastewater dyes may be lethal for certain marine life due to the presence of metal and harmful chemicals. And sometimes the particles which are suspended in wastewater may cause blockage into the gills of fishes, and it may lead to death. They also reduce the capability power of algae to make their food. This type of contamination can be detected through municipal wastewater during treatment, for example, ultraviolet decontamination.

Heterocyclic and aromatic dyes are utilized in industries at present. The complex structure of the dye is generally creating difficulty in the process of degradation of

Table 11.1 Textile industrial standards in water pollution

S. No.	Parameters	Standards
1	pH	6.9
2	BOD	30 ppm
3	COD	250 ppm
4	TDS	2000 ppm
5	Sulphide	2 ppm
6	Chloride	500 ppm
7	Calcium	75 ppm
8	Magnesium	50 ppm

dyes. The manufacturing, mineralization and toxicity of dyes in textile industries are major challenges for the environment, so we can say that understanding wastewater treatment from a textile is ecologically noteworthy (Holkar et al. 2016). The textile industries' standard parameters are given in Table 11.1. Wastewater characterization of various textiles are given in Table 11.2 (Bisschops and Spanjers 2003).

11.5 Activated Carbon

Activated carbon (AC) is highly porous, complex and carbonaceous in structure and absorptive; carbon atom contributes in its structural composition. Activated carbon comprises pores which form a network of channels (Waghmare et al. 2015a, b; Waghmare and Arfin 2015). These channels are created inside rigid disordered layers present between atoms of carbon. Pores network linked with the help of chemical bonds. Uneven stack arrangement creates pores due to crevices, perforation, cleft, etc. created between layers of a carbon atom. The high porosity of activated carbon provides about 500 m^2 of surface area per gram of activated carbon; this is determined with the help of adsorption of nitrogen gas.

Various raw materials used in the manufacturing of activated carbon are:

- Coconut shell
- Hard and soft wood
- Peat
- Olive pits
- Lignite coal
- Bituminous coal

The mechanism used in the manufacturing of activated carbon is chemical activation or activation by steam which is at high temperature available from various raw materials. Commercially available forms of this activated carbon are:

(a) Granular activated carbon
(b) Powder activated carbon
(c) Pelleted activated carbon

Table 11.2 Values of wastewater characterization of different textiles

Parameters	Processes	Wool	Cotton	Synthetic	Not Specified
COD	Desizing	–	950–20000	–	10000–12000
	Scouring	5000–90000	8000	–	
	Bleaching	–	288–13500	–	–
	Dyeing	7920	1115–4585	620	–
	Printing	–	–	1515	
					785–49170
BODs	Desizing	–	–	–	200–5200
	Scouring	2270–60000	100–2900	500–2800	–
	Bleaching	400	90–1700	–	–
	Dyeing	400–2000	970–1460	530	–
	Printing	–	–	590	600–1800
Colour (AMDI)	Desizing	–	64–1900	–	–
	Scouring	2000	694	–	–
	Bleaching	–	153	–	–
	Dyeing	2225	1450–4750	1750	–
	Printing	–	–	–	1450
Total solid	Desizing	–	–	–	7600–42900
	Scouring	28900–49300	–	–	–
	Bleaching	910	2300–14400	–	–
	Dyeing	–	–	–	<50000
	Printing	–	–	150–250	–
Total suspended solid	Desizing	–	18–800	–	400–4000
	Scouring	1000–26200	184–17400	600–3300	–
	Bleaching	900	130–25000	–	–
	Dyeing	–	120–190	140	–
	Printing	–	–	–	125–9500
Total dissolved solids	Desizing	–	530–6900	–	–
	Scouring	–	–	–	–
	Bleaching	–	4760–19500	–	–
	Dyeing	–	–	–	55
	Printing	–	–	–	–
Carbon (DOC)	Desizing	–	250–2750	–	–
	Scouring	5800	–	–	–
	Bleaching	–	320	–	–
	Dyeing	–	–	–	–
	Printing	–	–	–	–
Total Kjeldahl nitrogen	Desizing	–	70	–	–
	Scouring	–	–	–	–
	Bleaching	–	40	–	–
	Dyeing	–	–	–	–
	Printing	–	–	164	30–1765

(continued)

Table 11.2 (continued)

Parameters	Processes	Wool	Cotton	Synthetic	Not Specified
NH_4N^-	Desizing	–	9–19	–	–
	Scouring	604	–	–	–
	Bleaching	–	8–19	–	–
	Printing	–	-	129	20–370
Total P	Desizing	–	4–10	–	–
	Bleaching	–	6–60	–	–
	Printing	–	–	21	–
PO_4	Scouring	89.3	–	–	–
Sulphide	Scouring	0.2	–	–	–
	Dyeing	–	325–900	–	–
Sulphate Cl^-	Bleaching	–	–	–	90–100
	Dyeing	–	1750–26500	–	26000
Oil and grease	Scouring	–	580–5000	–	–
Cr^{2-}	Scouring	–	5-0	–	–
pH	Desizing	–	8.8–9.2	–	6–8
	Scouring	7.6–10.4	7.2–13	8–10	–
	Bleaching	6	6.5–13.5	–	–
	Dyeing	4.6–5	9.2–10.1	11.7	–
	Printing	–	–	–	5–8.5
Turbidity	Desizing	–	–	–	930
Waste usage (fabric/kg)	Desizing	–	–	–	12.5–35
	Scouring	4–77.5	2.5–43	17–67	–
	Bleaching	–	30–50	–	–
	Dyeing	40–150	38–143	38–143	–
	Printing	250–520	–	–	20–300

11.5.1 Granular Activated Carbon

Due to the large particle size of granulated AC in comparison with that of powdered AC, thus granulated AC's external surface is small. In processes where adsorbate's diffusion is a primary requirement, granulated AC would be important. Thus, they are preferred in case of adsorption of gases due to their high diffusion rate.

Various applications of GAC involve water treatment, separating components and deodorization.

11.5.2 Powdered Activated Carbon

The composition of PAC involves crushed particles of carbon. Of this 95–100 % will pass through a mesh sieve of a particular designation. GAC is retained on mesh sieve of size 0.297mm. ASTM classified PAC as a particle with size of 0.177mm. In

Table 11.3 Various sources of activated carbon with applications in pollutant removal

S. No.	Source of activated carbon	Activated with	Pollutants removed	References
1.	Sugarcane bagasse	$ZnCl_2$	Basic dye	Fabon et al. (2013)
2.	Bituminous coal	Phosphoric acid	Remazol dye	Teng et al. (1998)
3.	Rice husk	Microwave activated	Dibenzothiophenes	Kumagai et al. (2009)
4.	Coconut husk	Microwave activated	Cyanosine	Gupta et al. (2010)
5.	Nutshell	Microwave-assisted KOH activation	Alkali metal compounds	Foo and Hameed (2011)
6.	Lemongrass	Microwave-assisted activation	Methylene blue	Singh and Tesheing (2014)
7.	Sawdust	Steam pressure	Direct dye	Malik (2004)
8.	Coal	Microwaved	Methylene blue and iodine	Xiao et al. (2015)
9.	Cocoa shells	Microwave activated	Dyes	Kadirvelu et al. (2003)
10.	Grape peel	Microwave-supported activation	Methylene blue	Ma et al. (2018)
11.	Cassava peel	Microwave activated	Dye	Rajeshwarisivaraj et al. (2001)

dedicated vessel, PAC is not used. PAC is directly added to process units; these units include clarifiers, gravity filters, mix basins, etc. (Li et al. 2014).

11.5.3 Pelletized Activated Carbon

Pellets are AC compacted into shaped cylinders and have a wide assortment of employments removing contaminants such as mercury. GC C-40 is an example of virgin activated carbon. It is derived from the types of bituminous coal and converts into pelletized form. It shows high surface area and activity.

The source of activated carbon and its application are listed in Table 11.3.

11.6 Ionic Liquids

Ionic liquids (ILs) are ionic species made up of an inorganic anion and organic cation having a melting point less than 100 °C. Figure 11.2 shows the list of few cations and anions of ILs. The constituent of IL varies independently possessing linear alkyl chain and moieties to be functionalized as highly branched, cyclic and aromatic one. It also has a large amount of structure variability. The low melting point of IL is because of the large size of anion and cation and least symmetry

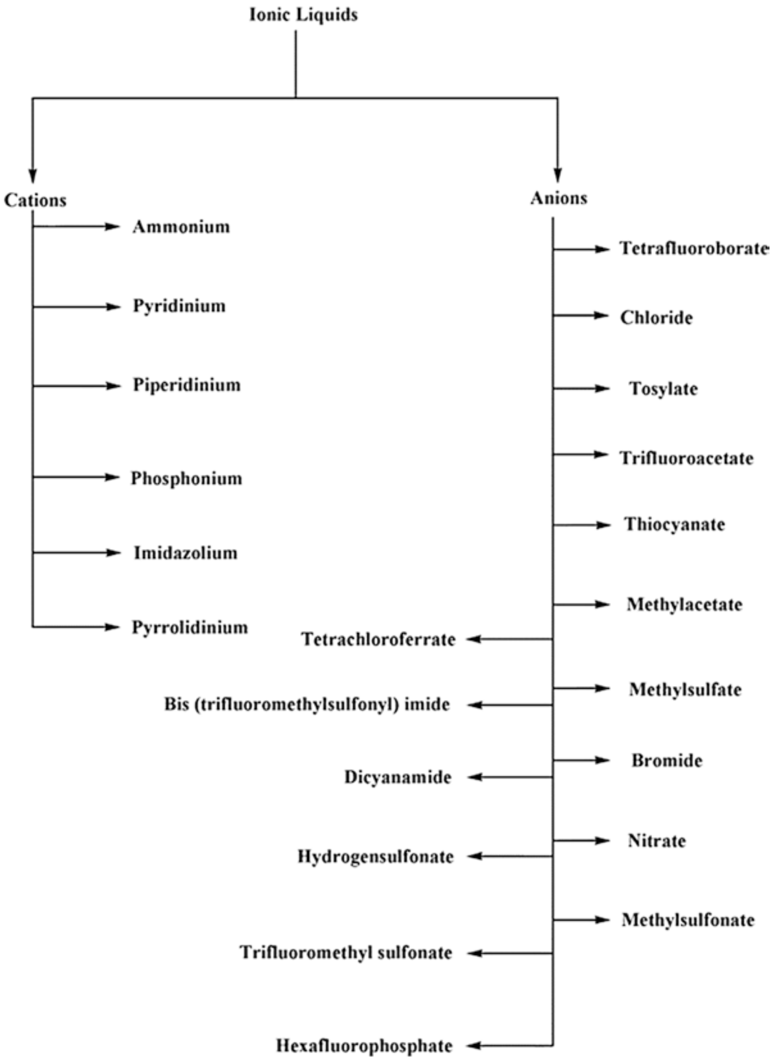

Fig. 11.2 Classic ionic modules of ILs

(Naushad et al. 2012). IL is emerging as a new class of synthesized mixture. It possesses various distinctive physical and chemical properties. Traditional solvents which lead to various environmental damages like ozone depletion, photochemical smog, global warming, etc. are replaced by environment-friendly IL. They are utilized in diverse spheres of industries, synthesizing units which utilize it as a solvent; used as a separating unit at the pilot level of lab work, it assisted in developing various materials which are useful in removing various pollutants that are otherwise

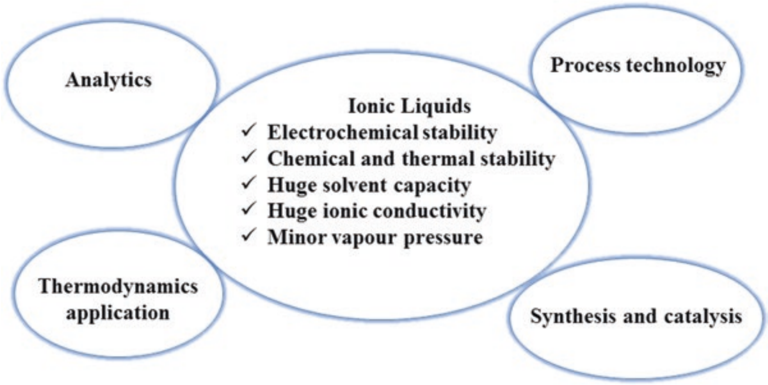

Fig. 11.3 Sketch diagram of ILs and its uses

hard to be removed by conventional methods. To cope up with the increasing demand of IL, it is requisite to study its properties in detail so that IL with desirable properties and composition could be developed further to assist in further industrial processes and material development. Along with desirable properties like electrochemical, ecological, spectrometric, etc., it is necessary for IL to be non-toxic and environmentally friendly when produced at a large scale (Rogers and Seddon 2003).

As the important objective of the current book chapter is related to the research on IL–AC system, the focus is put on the analysis of interaction among the IL and AC. The thermodynamic study of IL adsorption on AC processing various nature, texture of pores generates information about their application in treatment of aqueous effluents with IL. The anion and cation attains the spectrum of IL. The adsorption emphasises the relation between the physical and chemical nature and the adsorption capacity.

Paul Walden reported about the physical characterization of ethylammonium nitrate for the synthesis of first IL in 1914 (Sugden and Wilkins 1929). It could not gather the interest of the research due to various drawbacks. But in the recent year, it is attracted to the field of IL and considered as significant one. After two decades the first patent on IL was published (Graenacher 1934). In the main patent, content was regarding organic salt possessing the ability to solve a problem related to cellulose and change in reactivity. This published patent could not even gather the interest in the scientific fields.

Hurley and Wier synthesized chloroaluminate with IL to generate interest for electrochemistry in comparison with organic and inorganic chemistry in 1948. However, this publication did not generate any noteworthy interest in the scientific community (Hurley and Wier 1951).

In the current scenario, the industrial and commercial application is very astonishing in terms of variety and quantity that arises from industry and academics which is shown in Fig. 11.3.

11.6.1 ILs' Behaviour Towards

ILs are categorized as the green solvents where some of the IL possess thermal and chemical stability and even highly soluble in water. IL may be risky for the environment because of its toxic effects and biodegradable nature. Its synthesis and application in the industry may lead to the formation of waste stream with large amount of ILs in the effluents (Petkovic et al. 2011). Such effluents can also be problematic due to the demand of suitable solution. Hence, to decrease the pollutants of ILs, the efficient strategy is required to remove ILs from aqueous streams.

11.6.2 IL-Based Materials

The IL-based materials bring forward the two types of advanced material mainly based on IL and AC known as supported IL and AC. But according to the application aspect, the use of IL possesses various limitations in mass transfer ratio owing to various physical features, namely, viscosity and high density. And such negative features have led to the innovation of a novel advanced material based on the concept of IL combined with solid support. The combination of IL with solid support is appreciable and favourable to further application. The IL–AC and its application in dye are listed in Table 11.4.

Poole and Poole (2010) have suggested that IL has been proved to be a favourable green solvent applied for chemical processes in reducing the waste in the solvent form by decreasing the dangerous vapours, and it has also been regarded as an eco-friendly material. Welon (1999) have also reported that they possess the property of high solvation. They hold negligible vapour pressure and reduce contamination from the environment by the process of evaporation and are regarded as

Table 11.4 Various IL–AC with applications in dye removal

S. No.	IL–AC	Pollutants removed	References
1.	MimGO sponge	DR 80	Zambare et al. (2017)
2.	Ionic liquid–crafted zeolite	Methyl orange	Xing et al. (2016)
3.	PDVB-IL	Orange II	Gao et al. (2013)
4.	IL@Fe3O4	Reactive black 5	Poursaberi and Hassanisadi (2013)
5.	SAILBO	Malachite green	Elhamifar et al. (2016)
6.	Mt–BMIM	Anionic dye	Belbel et al. (2018)
7.	ILNS	Congo red and reactive blue	Lawal et al. (2017)
8.	Fe_2O_3–cellulose–ionic liquid	Congo red	Beyki et al. (2016)
9.	TCPIL/$CuFe_2O_4$/BNONS	Methylene blue	Arumugam et al. (2018)

significant predictable organic solvents. Leclercq and Schmitzer (2009) suggested that it is an effective replacement for predictable organic surfactants due to its specificity, yielding and high rate.

Lawal and Moodley (2015, 2016) reported about the amaranth dye removal by using the montmorillonite modified with the IL. The material modified is a mixture of macroporous and mesoporous substance generally hydrophobic possessing large pore for trapping the contaminants. The removal percentage reached the maximum of more than 90 % at 2 pH. The Langmuir isotherm best described the adsorption behaviour with a capacity of 263.2 mg/g and the kinetic was described by pseudo-second order. At different concentration, the column experiment employing the Thomas model observed adsorption capacities to be 393.64, 580.89 and 603.60 mg/g. The outcome made it clear that ionic liquid modified montmorillonite served to be the best option for the adsorption technique of the dye from the wastewater of the textile industry.

Lawal and Moodley (2016) performed the adsorption studies for determining the efficiency of IL modified by kaolin. Kaolin modified with IL was put on characterization where adsorption studies were carried out by making use of column and batch processes to remove acid red and phenanthrene. The column models showed that it fitted well for Thomas and Yoon-Nelson isotherm, and the value of R^2 was near to the unit level for both the solutes. The Freundlich and Langmuir isotherms were responsible for describing phenanthrene adsorption showing the capacity of 263 mg/g along with the π–π interactions to be mean sorption. Hence, ILs are applied as a modifier of the adsorption to remove acid red and phenanthrene.

Yan et al. (2015) investigated the use of activated carbon modified with IL for removing methylene blue. The functional group content of the AC surface altered due to modification technique. The absorbance of AC and MAC was used to evaluate the modification. The adsorption process was described by adsorption kinetic models and fitted well with pseudo-second order.

11.6.3 Adsorption Mechanism

Figure 11.4 clarifies about the adsorption mechanism of DR80 on the surface of mimGO sponge. When we go through the structure of DR80, it is basically a dye with a large number of azo linkages along with many anionic sulfonic acid ions and an aromatic ring. The mimGO sponge is hierarchical possessing cationic imidazolium ionic liquid having amide linkages along with hydroxyl functionalities. The presence of π–π interaction among the phenyl ring available in DR80 and mimGO surface also illustrates the adsorption process. Since the hydrogen bond and the π–π interaction are formed in the unmodified GO, there is the unavailability of electrostatic interaction in between the sulfonic acid group of DR80 and nitrogen group of mimGO. Such absence infers that there are low absorption rate and low adsorption capacity as well.

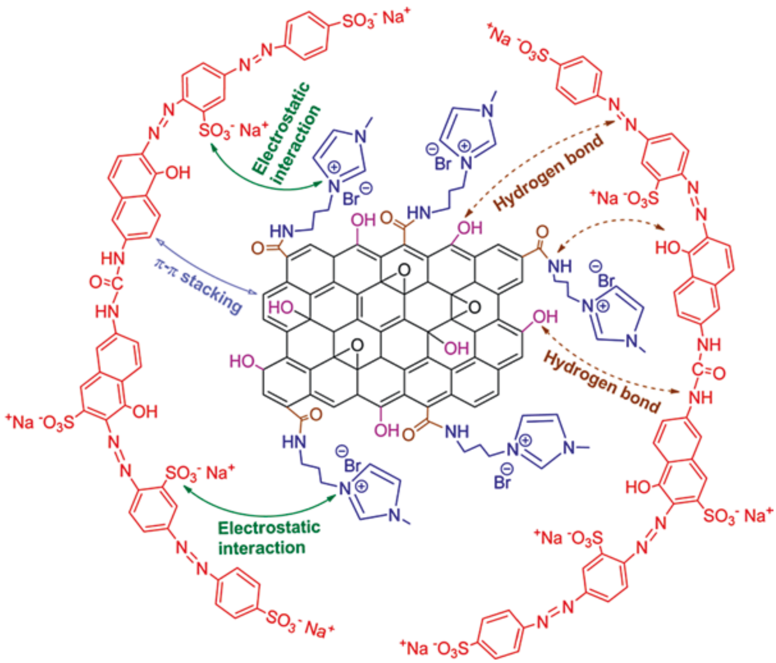

Fig. 11.4 Adsorption mechanism of DR80 on the mimGO sponge. (Reprinted with permission from (Zambare et al. 2017) ©ACS)

11.6.4 Characterization

The scanning electron microscopy (SEM) was performed to exhibit the size of particle and morphology of the surface of SAILBO as shown in Fig. 11.5. Figure 11.5 (a) shows the order of particle in uniform worm-like morphology, and Fig. 11.5 (b) demonstrates about the diverse morphology to compare it with the availability of SAILBO. The result made it clear that adsorption of MG molecule can be either with or without the SAILBO.

The single nanosheet within the composite is shown in Fig. 11.6 (a) and (b). The image of high-resolution transmission electron microscopy (HRTEM) showed that BNONS has sheets which are multilayered with the outer diameter in between 20 nm and 2.5 nm. But it is observed that the HRTEM image is not specific as there is a large electron concentration, and ILs interrupt during the focusing process on the microscope. It is later found that the diameter of the sheet increases between 20 nm and 50 nm just after the modification of IL. It states that there is IL coating on the BNONS surfaces.

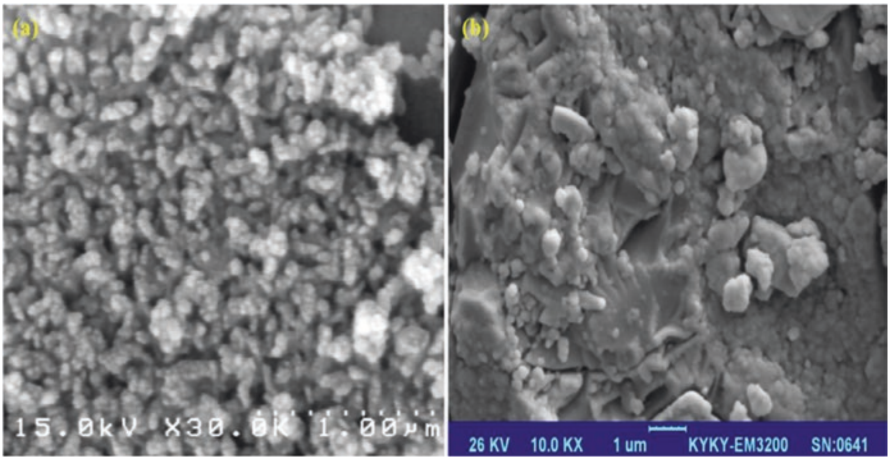

Fig. 11.5 SEM image SAILBO (**a**) before and (**b**) after the adsorption of MG. (Reprinted with permission from (Elhamifar et al. 2016) ©Elsevier)

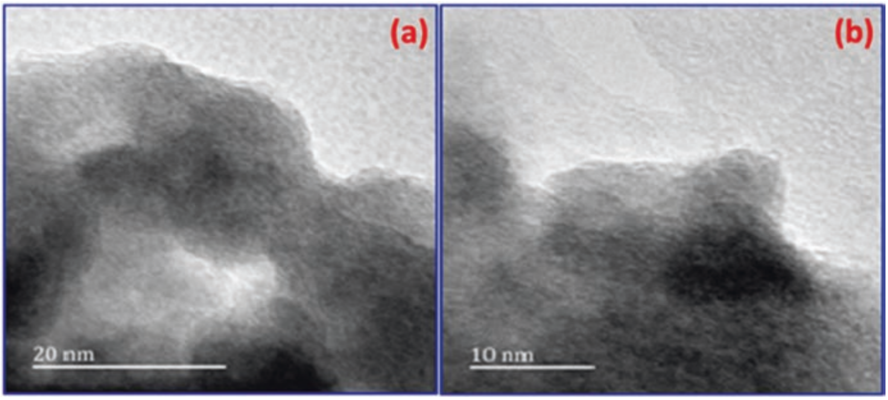

Fig. 11.6 HRTEM images of TCPIL/$CuFe_2O_4$/BNONS nanomaterial at (**a**) 20 nm and (**b**) 10 nm. (Reprinted with permission from (Arumugam et al. 2018) ©Elsevier)

11.7 Conclusion and Future Perspectives

The population increase and unstable rise in the industrialization are giving a serious threat to the safe drinking water on a worldwide level (Arfin and Rafiuddin 2009, 2011; Arfin and Yadav 2012; Arfin et al. 2011, 2012). Therefore, to avoid the scarcity of water, wastewaters from the textile industry can be used as an alternative, but they require proper treatment and purification before using for different purposes which can be a challenging task. Various methods are used for such treatment where innovative technology-oriented process along with conventional process has proved to be the best option. For wastewater treatment, such ionic liquid modified activated carbon is adopted and shows favourable results in the adsorption of dyes and micropollutant.

It has been found that the water industries are advancing the development techniques and providing a cost-efficient system to develop the source of wastewater treatment. Therefore, such advancement in large scale ionic liquid modified activated carbon have proved the way for successful use.

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References

Alqadami AA, Naushad M, Abdalla MA et al (2016) Adsorptive removal of toxic dye using Fe3O4−TSC nanocomposite: equilibrium, kinetic, and thermodynamic studies. J Chem Eng Data 61(11):3806–3813. https://doi.org/10.1021/acs.jced.6b00446

Arfin T, Rafiuddin (2009) Transport studies of nickel arsenate membrane. J Electroanal Chem 636(1):113–122. https://doi.org/10.1016/j.jelechem.2009.09.019

Arfin T, Rafiuddin (2011) An electrochemical and theoretical comparison of ionic transport through a polystyrene-based cobalt arsenate membrane. Electrochim Acta 56(22):7476–7483. https://doi.org/10.1016/j.electacta.2011.06.109

Arfin T, Rangari SN (2018) Graphene oxide-ZnO nanocomposite modified electrode for the detection of phenol. Anal Methods 10(3):347–358. https://doi.org/10.1039/C7AY02650A

Arfin T, Yadav N (2012) Impedance characteristics and electrical double-layer capacitance of composite polystyrene-cobalt-arsenate membrane. J Ind Eng Chem 19(1):256–262. https://doi.org/10.1016/j.jiec.2012.08.009

Arfin T, Jabeen F, Kriek RJ (2011) An electrochemical and theoretical comparison of ionic transport through a polystyrene based titanium-vanadium (1:2) phosphate membrane. Desalination 274(1-3):206–211. https://doi.org/10.1016/j.desal.2011.02.014

Arfin T, Falch A, Kriek RJ (2012) Evaluation of charge density and the theory for calculating membrane potential for a nano-composite nylon-6,6 nickel phosphate membrane. Phys Chem Chem Phys 14(48):16760–16769. https://doi.org/10.1039/C2CP42683H

Arfin T, Bushra R, Mohammad F (2016) Electrochemical sensor for the sensitive detection of o-nitrophenol using graphene oxide-poly(ethyleneimine) dendrimer-modified glassy carbon electrode. Graphene Technol 1(1):1–15. https://doi.org/10.1007/s41127-016-0002-1

Arfin T, Sonawane K, Saidankar P, Sharma S (2019) Role of microbes in the bioremediation of toxic dyes. In: Shahid-ul-islam (ed) Integrating green chemistry and sustainable engineering. Scrivener Publishing LLC, Beverly, pp 441–470

Arumugam V, Sriram P, Yen T-J, Redhi GG, Gengan RM (2018) Nano-material as an excellent catalyst for reducing a series of nitroanilines and dyes: triphosphonated ionic liquid-$CuFe_2O_4$-modified boron nitride. Appl Catal B 222:99–114. https://doi.org/10.1016/j.apcatb.2017.08.059

Belbel A, Kharroubi M, Janot J-M, Abdessamad M, Haouzi A, Lefkaier IK, Balme S (2018) Preparation and characterization of homoionic montmorillonite modified with ionic liquid: application in dye adsorption. Colloids Surf A 555:219–227. https://doi.org/10.1016/j.colsurfa.2018.08.080

Beyki MH, Bayat M, Shemirani F (2016) Fabrication of core-shell structured magnetic nanocellulose based polymeric ionic liquid for effective biosorption of Congo red dye. Bioresour Technol 218:326–334. https://doi.org/10.1016/j.biortech.2016.06.069

Bisschops I, Spanjers H (2003) Literature review on textile wastewater characterisation. J Environ Technol 24(11):1399–1411. https://doi.org/10.1080/09593330309385684

Clave E, Francois J, Billon L, Sebe G, Jeso BD, Guimon MF (2004) Crude and modified corncobs as complexing agents for water decontamination. J Appl Polym Sci 91(2):820–826. https://doi.org/10.1002/app.13179

Ding S, Li Z, Wangrui (2010) Overview of dyeing wastewater treatment technology. Water Resour Prot 26:73–78

Elhamifar D, Shojaeipoor F, Roosta M (2016) Self-assembled ionic-liquid based organosilica (SAILBO) as a novel and powerful adsorbent for removal of malachite green from aqueous solution. J Taiwan Inst Chem Eng 59:267–274. https://doi.org/10.1016/j.jtice.2015.07.036

El-Molla MM, Schneider R (2006) Development of eco-friendly binders for pigment printing of all types of textile fabrics. Dyes Pigments 71(2):130–137. https://doi.org/10.1016/j.dyepig.2005.06.017

Fabon MB, Legaspi GJ, Leyesa K, Macawile MC (2013) Removal of basic dye in water matrix using activated carbon from sugarcane bagasse. International Conference on Innovations in Engineering and Technology, pp 198–201. https://doi.org/10.15242/IIE.E1213568

Farooq A, Reinert L, Leveque J-M, Papaiconomou N, Irfan N, Duclaux L (2012) Adsorption of ionic liquids onto activated carbons: effect of pH and temperature. Micropor Mesopor Mat 158:55–63. https://doi.org/10.1016/j.micromeso.2012.03.008

Foo KY, Hameed BH (2011) Preparation and characterization of activated carbon from pistachio nut shells via microwave-induced chemical activation. Biomass Bioenergy 35(7):3257–3261. https://doi.org/10.1016/j.biombioe.2011.04.023

Gao H, Kan T, Zhao S, Qian Y, Cheng X, Wu W, Wang X, Zheng L (2013) Removal of anionic azo dyes from aqueous solution by functional ionic liquid cross-linked polymer. J Hazard Mater 161:83–90. https://doi.org/10.1016/j.jhazmat.2013.07.001

Graenacher C (1934) Cellulose solution. Patent number 1943176.9 Jan 1934

Gupta VK, Jain R, Shrivastava M (2010) Adsorptive removal of cyanosine from wastewater using coconut husks. J Colloid Interf Sci 347(2):309–314. https://doi.org/10.1016/j.jcis.2010.03.060

Holkar CR, Jadhav AJ, Pinjari DV, Mahamuni NM, Pandit AB (2016) A critical review on textile wastewater treatments: possible approaches. J Environ Manag 182:351–366. https://doi.org/10.1016/j.jenvman.2016.07.090

Hurley FH, Wier TP (1951) Electrodeposition of metals from fused quaternary ammonium salts. J Electrochem Soc 98(5):203–216. https://doi.org/10.1149/1.2778132

Javadian H, Angaji MT, Naushad M (2014) Synthesis and characterization of polyaniline/γ--alumina nanocomposite: a comparative study for the adsorption of three different anionic dyes. J Ind Eng Chem 20:3890–3900. https://doi.org/10.1016/j.jiec.2013.12.095

Kadirvelu K, Kavipriya M, Karthika C, Radhika M, Vennilamani N, Pattabhi (2003) Utilization of various agricultural waste for activated carbon preparation and application for the removal of dyes and metal ions from aqueous solutions. Bioresour Technol 87(1):129–132. https://doi.org/10.1016/S0960-8524(02)00201-8

Kant R (2012) Textile dyeing industry an environmental hazard. Nat Sci 4(2012):22–26. https://doi.org/10.4236/ns.2012.41004

Kumagai S, Shimizu Y, Toida Y, Enda Y (2009) Removal of dibenzothiophenes in kerosene by adsorption on rice husk activated carbon. Fuel 88(10):1975–1982. https://doi.org/10.1016/j.fuel.2009.03.016

Lawal IA, Moodley B (2015) Synthesis, characterisation and application of imidazolium based ionic liquid modified montmorillonite sorbents for the removal of amaranth dye. RSC Adv 5(76):61913–61924. https://doi.org/10.1039/C5RA09483F

Lawal IA, Moodley B (2016) Column, kinetic and isotherm studies of PAH (phenanthrene) and dye (acid red) on kaolin modified with 1-hexyl, 3-decahexyl imidazolium ionic liquid. J Environ Chem Eng 4(3):2774–2784. https://doi.org/10.1016/j.jece.2016.05.010

Lawal IA, Chetty D, Akpotu SO, Moodley B (2017) Sorption of Congo red and reactive blue on biomass and activated carbon derived from biomass modified by ionic liquid. Environ Nanotechnol Monit Manag 8:83–91. https://doi.org/10.1016/j.enmm.2017.05.003

Leclercq L, Schmitzer AR (2009) Supramolecular effects involving the incorporation of guest substrates in imidazolium ionic liquid networks: recent advances and future developments. Supramol Chem 21(3-4):245–263. https://doi.org/10.1080/10610270802468421

Lemus J, Palomar J, Heras F, Gilarranz MA, Rodriguez JJ (2012) Developing criteria for the recovery of ionic liquid from aqueous phase by adsorption with activated carbon. Sep Purif Technol 97:11–19. https://doi.org/10.1016/j.seppur.2012.02.027

Li WG, Gong XJ, Wang K, Zhang XR, Fan WB (2014) Adsorption characteristics of arsenic from micro-polluted water by an innovative coal-based mesoporous activated carbon. Bioresour Technol 165:166–173. https://doi.org/10.1016/j.biortech.2014.02.069

Ma L, Jiang C, Lin Z, Zou Z (2018) Microwave-hydrothermal treated grape peel as an efficient biosorbent for methylene blue removal. Int J Environ Res Public Health 15(2):239. https://doi.org/10.3390/ijerph15020239

Malik (2004) Dye removal from wastewater using activated carbon developed from sawdust: adsorption equilibrium and kinetics. J Hazard Mater 113(1-3):81–88. https://doi.org/10.1016/j.jhazmat.2004.05.022

Naik DJ, Desai HH, Desai TN (2013) Characterization and treatment of untreated wastewater generated from dyes and dye intermediates manufacturing industries of Sachin industrial area, Gujrat, India. J Environ Res Develop 7(4A):1602–1605

Naushad M, ALOthman ZA, Khan AB, Ali M (2012) Effect of ionic liquid on activity, stability, and structure of enzymes: a review. Int J Biol Macromol 51:555–560. https://doi.org/10.1016/j.ijbiomac.2012.06.020

Naushad M, Abdullah ALOthman Z, Rabiul Awual M et al (2016) Adsorption of rose Bengal dye from aqueous solution by amberlite Ira-938 resin: kinetics, isotherms, and thermodynamic studies. Desalin Water Treat 57:13527–13533. https://doi.org/10.1080/19443994.2015.1060169

Paul SA, Chavan SK, Khambe SD (2012) Studies on characterization of textile industrial waste water in Solapur city. Int J Chem Sci 10:635–642

Petkovic M, Seddon K, Rebelo L, Pereira C (2011) Ionic liquids: a pathway to environmental acceptability. Chem Soc Rev 40(3):1383–1403. https://doi.org/10.1039/C004968A

Poole CF, Poole SK (2010) Extraction of organic compounds with room temperature ionic liquids. J Chromatogr A 1217(16):2268–2286. https://doi.org/10.1016/j.chroma.2009.09.011

Poursaberi T, Hassanisadi M (2013) Magnetic removal of reactive black 5 from wastewater using ionic-liquid grafted-magnetic nanoparticles. Clean Soil Air Water 41(12):1208–1215. https://doi.org/10.1002/clen.201200160

Rajeshwarisivaraj, Sivakumar S, Senthikumar P, Subburam V (2001) Carbon from cassava peel, an agricultural waste, as an adsorbent in the removal of dyes and metal ions from aqueous solution. Bioresour Technol 80(3):233–235. https://doi.org/10.1016/S0960-8524(00)00179-6

Rogers RD, Seddon KR (2003) Ionic liquids-solvents of the future? Science 302(5646):792–793. https://doi.org/10.1126/science.1090313

Schwartz P (2008) Structure and mechanics of textile fibre assemblies. Woodhead Publishing, Cambridge, pp 1–264

Sharma TR (1949) Location of industries in India. Hind Kitabs Ltd, Bombay

Sharma A, Sharma G, Naushad M et al (2018) Remediation of anionic dye from aqueous system using bio-adsorbent prepared by microwave activation. Environ Technol (UK) 39(7):917–930. https://doi.org/10.1080/09593330.2017.1317293

Singh H, Tesheing BD (2014) Removal of methylene blue using lemon grass ash as an adsorbent. Carbon Lett 15(2):105–112

Sophia AC, Arfin T, Lima EC (2019) Recent developments in adsorption of dyes using graphene based nanomaterials. In: Naushad M (ed) A new generation material graphene: applications in water technology. Springer, Cham, pp 439–471. https://doi.org/10.1007/978-3-319-75484-0_18

Sugden S, Wilkins H (1929) The parachor and chemical constitution. Part XII. Fused metals and salts. J Chem Soc 0:1291–1298. https://doi.org/10.1039/JR9290001291

Teng H, Yeh TS, Hsu LY (1998) Preparation of activated carbon from bituminous coal with phosphoric acid activation. Carbon 36(9):1387–1395. https://doi.org/10.1016/S0008-6223(98)00127-4

Waghmare SS, Arfin T (2015) Fluoride removal from water by mixed metal oxide adsorbent materials: a state of the art review. Int J Eng Sci Res Technol 4(9):519–536

Waghmare SS, Arfin T, Manwar N, Lataye DH, Labhsetwar N, Rayalu S (2015a) Preparation and characterization of Polyalthia longifolia based adsorbent for removing fluoride from drinking water. Asian J Adv Basic Sci 4(1):12–24

Waghmare S, Arfin T, Rayalu S, Lataye D, Dubey S, Tiwari S (2015b) Adsorption behaviour of modified zeolite as novel adsorbents for fluoride removal from drinking water: surface phenomena, kinetics and thermodynamics studies. Int J Sci Eng Technol Res 4(12):4114–4124

Welton T (1999) Room-temperature ionic liquids, solvents for synthesis and catalysis. Chem Rev 99(8):2071–2084. https://doi.org/10.1021/cr980032t

Xiao X, Liu D, Yan Y, Wu Z, Wu Z, Cravotto G (2015) Preparation of activated carbon from Xinjiang region coal by microwave activation and its application in naphthalene, phenanthrene, and pyrene adsorption. J Taiwan Inst Chem Eng 53:160–167. https://doi.org/10.1016/j.jtice.2015.02.031

Xing X, Chang P-H, Lv G, Jiang W-T, Jean J-S, Liao L, Li Z (2016) Ionic-liquid-craft zeolite for the removal of anionic dye methyl orange. J Taiwan Inst Chem Eng 59:237–243. https://doi.org/10.1016/j.jtice.2015.07.026. 1876–1070

Yan JY, Shang JJ, Fu Y, Li DQ, Liu ZY (2015) Modification of activated carbon by basic ionic liquid, [Bmim]OH: a feasibility study. Chem Eng Technol 41(5):907–912. https://doi.org/10.1002/ceat.201600500

Zambare R, Song X, Bhuvana S, Prince JSA, Nemade P (2017) Ultrafast dye removal using ionic liquid-graphene oxide sponge. ACS Sustain Chem Eng 5(7):6026–6035. https://doi.org/10.1021/acssuschemeng.7b00867