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Okara: A Low-Cost Adsorbent for Textile Waste Water Treatment

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Abstract

We are living in the era of expeditiously increasing population and industrialization and water is used in almost all industrial sectors such as food, pharmaceutical, metallurgy, chemical, textile industry and leather industry etc. which produces different kind of effluent. There are several methods used for removing pollutants from wastewater, among them the adsorption method is best as it removes diverse species of pollutants. Textile effluent is one of the major problems for aquatic as well as human life, contains several kinds of dyes, chemicals & hazardous substances that needs to be removed before further use. If the effluent is discharged into the environment without any treatment process, it will cause serious issues related to environmental as well human health. In various waste water treatment plants that are used for treating wastewater through adsorption, cellulosic, lignin based carbon materials, chemically or biologically activated carbonaceous of different biomass origin are used as adsorbent. This paper reviews the possibility of Okara (soyabean milk waste), being a cellulosic biomass and shows some adsorption capacity, as a low-cost adsorbent for treatment of the waste water generated from the textile industries.

1. Introduction

Water is an utmost precious natural resource and basic necessity for almost all forms of life existing on around the globe. In the current scenario, as we are facing an unbalanced and drastic increase in population, demand for water is also escalating logarithmically. Instead of population rapid industrialization and unrestricted use of water are not only pushing us towards the water crisis but also pollute the water bodies (Gurjar *et al.,* 2007). Industries are major producers of hazardous contaminants as by-product/waste/effluents. Synthetic dyes are not only extensively used in the textile industry but also of several other industries such as, tannery, paper and pulp, plastic, and many others. An estimate of over 100,000 commercial dyes with an approximate production of 7×10^5 –1×10^6 tons per year worldwide are part of waste water generated with approx 10–20% of the dyes are released into the environment during manufacturing and usage (Gao *et al.,* 2015). A large fraction, usually around 30% of the applied reactive dyes, is wasted because of dye hydrolysis in the alkaline dye-bath (Papic *et al.,* 2009). Moreover, the presence of very small amounts of dyes in water is highly visible and even results in bad smell and most of them are carcinogenic, if entered in the living systems. Thus, the effluents of hazardous dyes have created a global concern. The treatment of dyes wastewater is not easy due to dyes' complex structure, toxicity, high thermal, and photo-stability. Hence, removal of dyes from wastewater is desirable and the development of clean-up technologies for the treatment of water contaminated with dyes is of major interest.

Water is available up to a limit that's why people are focusing on its sustainable use, recycling and its treatment through several techniques such as; filtration, boiling, solar disinfection, chlorination, sedimentation, coagulation, ozonation, aeration, adsorption, phytoremediation (Thathola *et al.,* 2019) etc. but due to several advantages over other techniques adsorption is considered as a prominent method of water treatment. Though activated carbon is the most effective and efficient known adsorbent for textile wastewater treatment and many synthetic high quality adsorbents such as Powder and granulated activated carbon, magnetic carbon beads, carbon dots and carbon nano-tubes (Tadda *et al.,* 2016) are in use but all these are expensive so to reduce the cost of adsorption based treatment researchers are developing and studying other natural adsorbents such as; kaolinite, montmorillonite clay, fly ash and perlite (Sengupta and Bhattacharya, 2011). However, agricultural residues (cellulosic biomass) are also having adsorptive removal capacity and many studies have

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shown it. Some of the widely used natural and low-cost adsorbent or as activated carbon precursors such as; coir pith, coconut husk, banana pith, spent tea, ground coffee husk, de-oiled soya (Gupta and Suhas, 2009), etc have shown the satisfactory results in Azo dyes removal. This paper is an attempt to explore the possibility and feasibility of utilizing okara, the residue left from ground soy beans produced soy milk and tofu, as economic and effective adsorbent for the removal of dyes from wastewaters (Gao *et al.,* 2015)

2. Natural Polymers as Adsorbent to Treat Textile Waste Water

The wastewater treatment has become a serious concern worldwide. There are number of technologies have been evolved to treat the water, however, an efficient as well as high self-decomposing ability of the material used in the treatment process should be the main criteria for selection. Natural polymers have more advantages over inorganic compounds as they produce denser and more compact flakes and may reduce the required inorganic coagulant dosage and produce smaller quantities of sludge (Renault *et al.,* 2009). Plants derived coagulants, particularly cultivated in the local regions or rural communities, have the advantage of being a sustainable development initiative. Currently, the growing world concern with environmental issues has raised the interest in the natural polyelectrolytes' research because they are low-cost, an abundant source, highly biodegradable, low toxicity, usually have a large number of surface charges, which increases the efficiency of the coagulation process, have an environment-friendly behavior when compared to inorganic coagulants and synthetic polymers (de Souza et al., 2014). The use of natural polyelectrolytes can reduce wastewater treatment costs when crops can be grown and processed locally (Sanghi *et al.,* 2006). Therefore, they offer a great potential for the development of alternative materials (Freitas *et al.,* 2015).

3. What is Okara?

Soybean or Soyabean is an edible bean of legume species native to East Asia. It is a protein-rich bean directly consumed by humans in their meals. Many kinds of fermented, non-fermented and animal meal products are produced from the soybean but its soya-milk and soya-oil are the two major products. As soybean milk or soymilk doesn't contain lactic acid so it is being consumed by lactose intolerant patients as an alternative to milk and its products. Therefore, the demand of soymilk and soymilk derived products eg. tofu is increasing day by day (Wight and Cillieeries, 1989). As soymilk is a versatile and remarkable product low calorie, high protein and less cholesterol it has also gain so much of importance among diet conscious people. Okara is a wet residue or leftover slurry of soya-milk production process. This is also called soyabean waste, tofuza (in China), bean curd waste or tofuashu (in Japan). Okara is a byproduct obtained during processing soybean for soymilk and tofu. About 1.1 kg of fresh okara is produced from every kilogram of soybean processed for soymilk and contains 27% protein (db), oil, and soluble and insoluble fibers (Vishwanathan et al., 2011). The most common method of utilization of okara is in the form of animal feed in many developed countries. But there are many tofu-consuming countries unable to utilize okara and have resorted to burning them as waste and dump as landfill. Major component of the okara is dietary fibres (42.8-52.1%) along with some considerable amount of protein (23.14-33.4%) and fats (7.81-12%). Detailed proximate composition of okara is given in table 1.

Table 1: Okara proximate composition (proximate analysis g/100gm)

S. No.	Compound	Amount				
		Hee *et al.*, 2010	Wight and Cillieres, 1989	Redondo-Cuenca and Jose, 2008	Mateos-aparacio and Redondo-Cuenca, 2010	Ahlawat *et al.,* 2018
1	Proteins	27	25.4-28.4	28.5	33.4	23.14
2	Fibres & car-bohydrates	53	56.6-63.4	60.6	58.2	49.27
3	Fats & oils	12	9.3-10.9	9.8	8.5	7.81
4	Ashes	8	3.0-3.7	4.5	3.7	3.8

Around 1.4 kg of wet okara is produced from 1kg of soyabean used for milk production and in tofu preparation 1kg soyabean produces around 1.2 kg of okara (Toole *et al.,* 1999). Even we also get okara after soyabean oil production but that we got in dried and consolidated form. As soyabean products industry is transforming and growing due to its demand. The amount of this waste is also increasing at an escalating pace. Around 3,910,000 tons of okara is being produced in China, Korea and Japan. According to a study in year 2004 approximately 310,000 tonnes of okara was obtained by tofu production in Korea and most of it was dumped or burned due to unavailability of proper utilization techniques (Hee *et al.,* 2010) (Table 2).

4. Okara: A potential Adsorbent in Waste Water Treatment

Okara usage in animal fodder is well known from ancient times but this much amount of okara consumption in animal fodder is not possible. Many other studies have also been done but

Table 2: Annual production of okara (Li *et al*., 2012)		
S. No.	Country	Amount (tons/year)
1	Japan	800,00
2	China	2,800,00
3	Korea	3,10,000

not dealing effectively with okara utilization; researchers are focusing on the utilization of this okara in different areas and techniques such as; in fermented foods, floor production, prebiotics, protein separation etc. In wastewater treatment these by-products are used as a low-cost natural adsorbent. Waste okara has been used in many adsorption studies for the efficient removal of heavy metals, pharmaceutical and personal care compounds, Azo dyes, etc. okara has shown upto 88.7%, 87.2% and 86.2% removal efficiency in removing chloroform, dichloromethane and benzene respectively (Adachi *et al.,* 2005). Microscopic structure of okara is hollow rod-shaped fibres with high surface area which is a necessary feature for adsorbent. Due to variety of components present in okara it also contains variety of functional groups on its surface such as; CHO, CO, COOH etc which are further responsible for the attachment of different contaminants on the bases of their surface charge. So, it shows very good results in removing azo dyes such as methylene blue, methyl orange, eriochrome black-T, reactive brilliant blue and rhodamine-B dyes from textile industry-based effluent. In general, Azo dyes removal occurs at optimal pH range 5-8 but okara shows the dye removal capacity even on pH 2.0 (Taylor *et al.,* 2015) which is a major advantage of okara over other natural adsorbents. Besides it okara also contains cellulose and hemi-cellulose so it can also be used as a raw material in activated carbon preparation and it can replace the existing raw materials used in activated carbon production to be a potential raw material for the same. Okara is novel adsorbent, has active sites for contaminants binding, inexpensive, and effective in adsorptive removal so it can be used as a natural adsorbent in textile industry based effluent treatment (Azo dyes removal). Gao *et al.* (2015) conducted an experiment with Okara as adsorbent for RBB dye and compared its efficiency with other adsorbents (Table 3).

Table 3: Adsorption capacity for the removal of reactive dyes from aqueous solutions by some low-cost adsorbents			
Adsorbent	Dye	Q^0 (mg/g)	Reference
Modified basic oxygen furnace slag	RBB	60	Xue *et al*., 2009
Cross-linked chitosan/oil palm ash composite beads	RBB	416.7	Hasan *et al*., 2008
Wheat bran	RBB	97.1	Lcek *et al*., 2007
Waste metal hydroxide sludge	RBB	275	Santos *et al*., 2008
Pinus sylvestries Linneo	Reactive Red 195	6.69	Asakal and Ucun, 2010
Sepia pen	Reactive Green 12	3.46	Figueiredo *et al*., 2000
High lime flyash	Reactive black 5	7.184	Eren and Acar 2007
Barley straw	Reactive black 5	25.4	Oei *et al*., 2009
Fly ash	RBB	135.69	Dizge *et al*., 2008
Okara	RBB	68.7	Gao *et al*., 2015

5. Conclusion

Okara, a low cost and novel cellulosic biomass which can be used effectively for textile effluent treatment. It shows effective removal of many dyes besides, it has also found an excellent adsorptive removal capacity even in extreme acidic conditions. So, it can be used as a low-cost natural adsorbent for the adsorptive removal of dyes from textile effluent. Okara can be a prominent entity in wastewater treatment if used wisely as a natural adsorbent or activated carbon precursor. It can also be used in potable and domestic waste water treatment with some modifications or collaborations with other treatment techniques to enhance the waste water treatment efficiency.

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