Current Trends in
Fashion Technology & Textile Engineering
ISSN: 2577-2929

Mini-Review
Volume 2- Issue 5 - February 2018
DOI: 10.19080/CTFTTE.2018.02.555598

Curr Trends Fashion Technol Textile Eng

Color Removal in Textile Wastewaters using Natural Adsorbents as a Sustainable way of Treatment

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Submission: January 16, 2018; **Published:** February 06, 2018

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Introduction

Water plays a vital role in the proper functioning of the Earth's ecosystem and at the same time it is the most exploited natural resource, which is limited. Sustainable treatment of wastewaters and recycling methods are important issues for getting fresh water in the coming decades [1].

Consumption of textiles is the largest end-use market for dyestuffs [2] leading to high consumption of dyes. The conventional secondary wastewater treatments applied to textile effluents are not efficient for color removal therefore dyestuffs will enter in the aquatic environment. They may cause adverse acute or chronic effects on all forms of life [3]. The presence of dyes in the aquatic environment reduces the absorption of sunlight and consequently the photosynthetic activity. Also the public perception of water quality is greatly influenced by color, which is visible even for very low concentrations [4].

There are various tertiary water treatment methods however some of them are economically challenging [1]. The adsorption process has been proven to be one of the most promising approach for water treatment [1] due to its low cost and ease to implement. The most used commercial adsorbent is activated carbon. The search for more economic alternative adsorbents leads to the study of natural materials.

A huge variety of natural low cost adsorbents, such as clay minerals, layered double hydroxides, feathers, shells and pens, have been proven to act efficiently in removal of textile dyestuffs.

Color removal by low-cost natural adsorbents

Clay minerals are known to be good adsorbents for cationic dyes. Stawiński, et al. [5] developed an efficient adsorbent by acid activation of a clay mineral, vermiculite, using nitric and citric acid. Later on the same author [6] found out that the performance of such prepared material can be significantly enhanced when an additional step comprising rinsing in diluted NaOH is added to the treatment. Finally the developed adsorbents were tested in multi component system and in constant flow column systems [7] providing evidence of their high efficiency and possibility of regeneration and reuse. A hydrotalcite-based material capable of removing anionic dyes for wastewater was tested by Stawiński, et al. [8]. Its adsorption capacity was significantly increased by thermal treatment, which allows also the regeneration of the spent adsorbent.

Table 1: Results of adsorption experiments of textile dyes onto natural adsorbents (the maximum adsorption capacities are based on Langmuir's model adjustment).

Material	Capacity (mg g^{-1})		Reference
	CI Basic Red 46	*CI Basic Blue 9*	[6]
NaOH modified vermiculite	155±11	161±5	
	CI Basic Red 46	*Reactive dye**	[8]
Hydrotalcite	4.8±0.3	179±5	
Thermally modified hydrotalcite	31±5	291±8	
	CI Basic Red 46	*CI Basic Blue 9*	[5]
Vermiculite	44±1	53±10	
Nitric/citric acid modified vermiculite	60±2	66±3	

	*CI Reactive Yellow 39***		
Gallinaceous feathers (*Gallus gallus*, Cobb 500)	300		[10]
Gallinaceous feathers strain Label	200		[9]
	*45-55% CI Basic Green 4 and 35-40% CI Basic Red 14***		
Gallinaceous feathers	47±8		[11]
	*CI Reactive Blue 220***		
Eucalyptus bark (from *Eucalyptus globulus*)	90***		[12]
	CI Reactive green 12	*CI Direct green 26*	[13] [14]
Anodonta cygnea shell	0.4±0.1	11.3	
Sepia officinalis pen	3.5±0.4	56	
Loligo vulgaris pen	44±27	5±1	
Anodonta cygnea shell demineralised in HCl	34±6	....	
Sepia officinalis pen demineralised in HCl	120±3	....	
Loligo vulgaris pen deproteined in NaOH	270±40	37±9	

*Levafix Amber CA from Dystar, unknown CI; **simulated textile effluent; ***best value recorded in this study.

Adsorption of dyes onto feathers of gallinaceous was extensively studied by Figueiredo & Freitas [9] and Freitas, et al. [10] that investigated adsorption kinetics and equilibrium of the adsorption and Sousa, et al. [11] extended this search to adsorption experiments in fixed-bed column. Eucalyptus bark (from *Eucalyptus globulus*) has demonstrated also relatively good potential for color removal [12]. Also natural waste materials containing chitin (*Anodonta cygnea* shell and *Sepia officinalis* and *Loligo vulgaris* pens) were tested in batch and continuous (packed column) system for removal of textile dyes by Figueiredo, et al. [13], Figueiredo, et al. [14]. The detailed results of the investigations described above are presented in (Table 1), where it is shown the applicability of natural materials to adsorb several classes of dyestuffs with different charges, anionic (e.g. reactive and direct) and cationic (basic) dyes.

Conclusion

Natural low-cost materials, some of them waste products, can be successfully applied for removal of dyes from industrial wastewaters. The adsorption capacities are satisfactory and removal efficiency is good, moreover they may be enhanced on a way of various modifications of the materials. Some of the adsorbents may be subjected to simple regeneration process and reused. The utilization of natural materials offers promising perspectives for their use as alternatives to activated carbon. In the cases when natural materials are also wastes their use as adsorbents is also a way for their valorization. These studies contribute to the economical and sustainable treatment of textile effluents.

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How to cite this article: Wojciech Stawiński, Sónia Figueiredo, Agnieszka Węgrzyn, Olga Freitas. Color Removal in Textile Wastewaters using Natural Adsorbents as a Sustainable way of Treatment. Curr Trends Fashion Technol Textile Eng . 2018; 2(5): 555598. DOI: 10.19080/CTFTTE.2018.02.555598

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