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Studies on the Efficiency of Cyanobacteria on Textile Wastewater Treatment

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ABSTRACT

Releasing of textile dye effluents into general water bodies is a major environmental and health problem. Color removal, in particular, has recently become of major scientific interest, as indicated by the multitude of related research reports. During the past two decades, several physico-chemical decolorization techniques have been reported, few, however, have been accepted by the textile industries. Their lack of implementation has been largely due to high cost, low efficiency and inapplicability to a wide variety of dyes. The ability of microorganisms to carry out dye decolorization has received much attention. Cyanobacteria are considered as an important source for decolorizing dye and textile effluent. In the current study four local cyanobacteria strains ***viz***. *Anabaena fertilissima, Nostoc muscorum, Phormidium fragile and Wollea* sp., were used in the preliminary screening for their ability to grow on and the removal of the red color and the heavy metals, i.e., iron, manganese, boron, lead and arsenic from the crude effluent discharged by EL-Shafie textile factory at EL- Mahalla EL- Kobra East Delta, Gharbia Governorate, Egypt. Results revealed that all tested cyanobacteria strains were able to gradually remove the color of the crude textile effluent in parallel with increasing the incubation periods. Also, *N. muscorum* recorded the highest percentage of color removal percentage followed by *Wollea* sp., *Ph. fragile* and finally *A. fertilissima* after 28 days of incubation. All the tested cyanobacteria strains were able to remove any of Fe, Mn, B, Pb, and As in different degrees. *N. muscorum* was superior in removing all discharged heavy metals compared to the other tested cyanobacteria strains. On the other respect, all tested cyanobacteria strains had slightly raised pH of the discharged textile crude effluent, while they reduced any of EC, COD and BOD compared to the initial values of the discharged textile crude effluent. However, the research of cyanobacteria to remove color in dye wastewaters is still in the early stage, but is a promising alternative of biological treatment.

Keywords: *Anabaena fertilissima, Nostoc muscorum, Phormidium fragile and Wollea* sp. - textile wastewater-physico-chemical properties**,** heavy metals and declorization.

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INTRODUCTION

Textile industries consume large volume of water and chemicals for wet processing of textile. The chemical reagents used are very diverse in their chemical compositions, ranging from inorganic compounds to polymers and organic products [1].

The environmental problem associated with textile activities mainly arises from the extensive use of organic dyes with complex and highly varied chemical structure [2]. The textile wastewater consists of untreated dyestuffs and other chemicals that are used in different stages of dyeing, fixing, washing and other processing [3]. The textile wastewater is characterized by high Chemical Oxygen Demand (COD), strong color, high salinity, large amount of dissolved solids and suspended solids [4]. They also added that the wastewater color has many environmental problems, i.e., its effect on aesthetics and water transparency. The thin layer of discharged dyes, formed on the water surface, decreases the amount of dissolved oxygen and photosynthetic activities due to the reduced light penetration, which badly affects the aquatic flora and fauna.

Bioremediation techniques are typically more economical than those of the traditional methods such as incineration, and some pollutants can be treated on site, thus reducing exposure risks for clean-up personnel, or potentially wider exposure as a result of transportation accidents. Since bioremediation is based on natural attenuation that the public considers it more acceptable than other technologies [5].

Algae have been showed to be capable in removing color from various dyes through mechanisms such as biosorption, bioconversion and bioagulation. Some studies examined the removal of remozal Blue and reactive Black B dyes by the immobilized thermophilic cyanobacterial strain *Phormidium* sp., which showed high dye decolorization with maximum uptake yields ranging from (50 to 88%) due to all tested dye concentrations [6].

Recently, the use of microalgae in bioremediation of the colored wastewater has attracted a great interest due to their central role in carbon dioxide fixation. In addition, the algal biomass generated has a great potential as feedstock for biofuel production [7]. Moreover, it was reported that more than 30 azo compounds were biodegraded and decolorized by *Chlorella pyrenoidosa, Chlorella vulgaris* and *Oscillatoria tenuis* in which azo dyes were decomposed into simpler aromatic amines [8].

Among all, *cyanobacteria* are unique organisms which occupy and dominate a vast array of habitats as a result of several general characteristics; some belonging to bacteria and others unique to higher plants. The application of *cyanobacteria* showed immense potential in wastewater and industrial effluent treatment, bioremediation of aquatic and terrestrial habitats, chemical industries, biofertilizers, food, feed and fuel, they also, have their own importance in bioremediation, due to their simple growth requirements, nitrogen fixing capability and large biomass production [9].

Therefore, in the present study, four local cyanobacteria strains are monitored in the laboratory to study their effect on some physico-chemical properties of the discharged textile effluent collected from EL-Shafie textile wastewater at EL- Mahala EL- Kobra, East Delta, Gharbia Governorate, Egypt. As well as their ability to remove the color and heavy metals, i.e., Iron (Fe), manganese (Mn), Boron (B), Lead (Pb), and Arsenic (As) from the textile effluent. The growth of the tested cyanobacteria strains were also examined in relation to the collected effluent wastewater.

MATERIALS AND METHODS

Microorganisms and culture conditions

Four local cyanobacteria strains ***viz***. *Anabaena fertilissima, Nostoc muscorum, Phormidium fragile* and *Wollea* sp., obtained from the Agric. Microbiol. Res. Dept., Soils, Water and Environ. Res. Inst. (SWERI), Agric. Res., Center (ARC), were used in the preliminary screening for their ability to grow on and the removal of the red color and the heavy metals, i.e., iron, manganese, boron, lead and arsenic from the crude effluent discharged by EL-Shafie textile factory at EL- Mahalla EL- Kobra East Delta, Gharbia Governorate, Egypt. The collected crude discharged textile effluent was found to be polluted with a di azo dye containing only two azo groups according to the analysis done by the GC Mass Spectrum at Studies and Analysis Unit, Soils, Water and Environ. Res. Inst., Agric. Res. Center, Giza, Egypt.

The tested cyanobacteria strains were grown and maintained on BG11medium [10] in a growth chamber under white continuous illumination (3000 lux) and temperature of 25 ± 2 °C.

The initial chemical and physical properties of the tested textile wastewater are shown in Table (1).

Table (1): Characteristic of the textile wastewater

Character	Values
Color	Red
pH	7.5
EC (dSm^{-1})	1.09
COD (ppm)	20.19
BOD (ppm)	22.15

The tested crude discharge textile effluent is stored in the holding tank in the factory before being discharged into the river, which is solely generated by the dye house. The factory employs a combination of physical, chemical and biological methods for the wastewater treatment; however, the discharged effluent from the textile factory still contains color at the point of discharge. The source of effluent wastewater for this study was from the holding tank.

Declorization percentage

Decolourization percentage was calculated according to the following formula [11].

$$\text{Decolourization (\%)} = \frac{\text{Initial absorbance - Observed absorbance} \times 100}{\text{Initial absorbance}}$$

Chemical and physical analyses

The crude discharged effluent sample was examined for pH, electric conductivity (EC), chemical oxygen demands (COD), and biological oxygen demands (BOD) [12]**.** The BOD was determined according to the following formula:

$$\text{BOD mg/l} = (D_1 - D_2)/P$$

Where: D_1= Dissolving oxygen (DO) after sampling.
D_2= DO after 5 days incubation at 20 °C.
P= decimal volumetric fraction of sample used.

Heavy metals analyses

Iron (Fe), manganese (Mn), Boron (B), Lead (Pb), and Arsenic (As) were measured by using atomic absorption Model (Inductively Coupled Argon Plasma, iCAP 6500 Due, Thermo Scientific, England. 1000 mg/L multi-element certified standard solution, Merck, Germany) according to Standard Methods of Water and Wastewater Examination [12].

Cyanobacteria dry weight

Dry weight of cyanobacteria strains was determined after drying the pre-weighed filter papers at 105 °C for 24 h, using the following formula:

$$\text{Dry weight (mg/L)} = \frac{\text{(The dry weight of filter paper with cyanobacteria cells} - \text{the dry Weight of filter paper without cyanobacteria) (mg)}}{\text{Volume of cyanobacteria culture (L)}}$$

Bioremediation of the crud textile effluent by using cyanobacteria strains

Two hundred ml of the crude discharge textile effluent were placed into 500 ml Erlenmeyer flask and then inoculated with 10 ml from each cyanobacterial strain (10^{12} cfu ml^{-1}) individually. The inoculated flasks were incubated at 25 ± 2 °C for 7, 14, 21 and 28 days under continuous white light exposure (3000 Lux) in three replicates, to study the effect of cyanobacteria on some physico-chemical properties, i.e., pH and EC after 28 days only and COD and BOD(at the stated incubation periods) of the crude discharged textile effluent and to evaluate their ability to remove the, color and some heavy metals Fe, Mn, B, pb and As) from the textile effluent.

At the end of each incubation period, each flask was filtrated through the pre-weighed filter Whattman® Paper No. 1 and then the filtrate exposed to the measurement of COD and BOD and the effluent dye color concentration, which was measured spectrophotometerically at 600 nm by using UV-visible spectrophotometer Model Spectronic 21 at 600 nm [13]**.** While, heavy metals, pH and EC were only determined at the end of the experiment (28 days). While, the filter paper oven dried at 70 °C up to a constant dry weight to determine the cyanobacterial dry weight at different incubation period of 0, 7, 14 and 21 days.

RESULTS

Color removal from the crude textile effluent by cyanobacteria

Four local cyanobacteria strains ***viz***. *Anabaena fertilissima, Nostoc muscorum, Phormidium fragile* and *Wollea* sp. were tested for their ability to remove the color from the tested crude discharge textile effluent collected from EL-Shafie textile factory. Data in Table (2) revealed that all tested cyanobacterial strains were able to gradually remove the color of the crude textile effluent in parallel with increasing the incubation periods. However, increasing the incubation period from 7 to 28 days increased the ability of all the tested cyanobacterial strains to remove the color from the crude textile effluent to be the best at 28 days. *Nostoc muscorum* recorded the highest percentage of color removal percentage followed by *Wollea* sp., *Phormidiuum fragile* and finally *Anabaena fertilissima* after 28 days of incubation. The corresponding color removal percentages were 100, 99.23, 92.31 and 63.46. Furthermore, results indicated that both *N. muscorum* and *Wollea* sp. recorded the highest color removal percentages compared to both *Ph. fragile* and *A. fertilissima* after 28 days of incubation.

Table (2): Decolorization of dye color of the textile factory effluent discharged from EL -Shafie Garments Factory measured by absorbance (Nano meter ʎ 600) as affected by the presence of different cyanobacteria strains at different incubation periods

Treatment		Incubation period (days)			
		7	14	21	28
Cell free medium (Control)		00.00	00.00	00.00	00.00
Initial crude effluent		0.260	0.260	0.260	0.260
Anabaena fertilissima	Final	0.137	0.127	0.106	0.095
	**R (%)*	47.31	51.15	59.23	63.46
Nostoc muscorum	Final	0.079	0.059	0.018	0.000
	R (%)	69.62	77.31	93.08	100
Phormidium fragile	Final	0.104	0.100	0.034	0.020
	R (%)	60.00	61.54	86.92	92.31
Wollea sp.	Final	0.096	0.055	0.028	0.002
	R (%)	63.08	78.85	89.23	99.23

***R = Reduction percentage of the color concentration.**

Effect of crude textile effluent on cyanobacteria growth

Data in Table (3) indicate the growth of different cyanobacterial strains of *A. fertilissima, N. muscorum, Ph. fragile* and *Wollea* sp. in terms of dry weight (mg /l) in response of the effect of the crude textile effluent. Results revealed that all tested cyanobacterial strains succeeded to grow and increase their biomass in terms dry weight through increasing the incubation period from 7 to 28 days under continuous white illumination (3000 Lux). At 28 days of incubation, *N. muscorum* gave the highest dry weight of 12.78 mg

/l followed by and *Wollea* sp. (10.00 mg/l), *Ph. fragile* (6.00 mg /l) and 5.18 mg /l for *A. fertilissima*. However, these high dry weight values were less than those recorded by the tested cyanobacterial strains grown on the BG 11 medium (control).

Removal of heavy metals

Data in Table (3) indicate the ability of different cyanobacteria strains to remove some heavy metals from the crude textile effluent (CTE) after 28 incubation period. All the tested cyanobacteria strains were able to remove any of Fe, Mn, B, Pb, and As in different degrees. The highest removal percentage of Fe was recorded by *N. muscorum* followed by those recorded by *Wollea* sp., *Phormidium fragile* and *A. fertilissima*. The corresponding removal Fe percentages were 76.92, 67.95, 30.77 and 19.00. However, the same order achieved for the tested cyanobacteria strains in the removal of iron was true in their removal ability for any of Mn, B, pb and As. In this respect, *N. muscorum* achieved the highest removal percentages of 69.16 (Mn), 59.84 (B), 94.00 (pb) and 98.04(As) followed by those scored by *Wollea* sp. The corresponding removal percentages were 65.00 (Mn), 57.00 (B), 82.00 (pb) and 92.16 (As). While, the lowest removal percentages 0f 19.20 (Mn), 28.00 (B), 47.06 (pb) and 54.90(As) were attained by *A. fertilissima*.

Table (3): Dry weight of cyanobacteria strains grown on the crude textile wastewater at different incubation periods

Cyanobacteria strains	Dry weight (mg /l)							
	Incubation Periods (days)							
	0		7		14		21	
	Control	Crude wastewater	Control	Crude wastewater	Control	Crude waste water	Control	Crude wastewater
Anabaena fertilissima	1.34	01.34	3.65	02.50	5.87	3.98	9.86	05.18
Nostoc muscorum	5.20	05.20	9.13	07.00	12.34	09.90	16.12	12.78
Phormidium fragile	2.06	02.06	5.72	03.30	7.89	05.00	11.78	06.00
***Wollea* sp.**	2.20	02.20	06.12	04.30	9.28	07.00	13.24	10.00

Table (4): Removal of heavy metals from the textile wastewater by using different cyanobacteria strains after 28 days of incubation

Heavy metals (mg/l)	Initial metal concentration (mg/l)	*Anabaena fertilissima*		*Nostoc muscorum*		*Phormidium fragile*		*Wollea* sp.	
		Final	Removal %	Final	Removal %	Final	Removal %	Final	Removal %
Fe	0.078	0.063	19.00	0.018	76.92	0.054	30.77	0.025	67.95
Mn	0.120	0.097	19.20	0.037	69.16	0.078	35.00	0.042	65.00
B	0.254	0.182	28.00	0.102	59.84	0.154	37.00	0.110	57.00
Pb	0.034	0.018	47.06	0.009	94.00	0.016	52.94	0.006	82.00
As	0.051	0.023	54.90	0.001	98.04	0.019	62.75	0.003	92.16

Effect of cyanobacteria on physic-chemical properties of the crude textile effluent

Data in Tables (5 & 6) indicate the effect of cyanobacteria inoculation on the physic-chemical properties of the crude textile effluent, i.e., pH, EC after 28 incubation period and, COD and BOD after 7, 14, 21 and 28 days. Results in Table (5) revealed that the tested cyanobacteria strains raised slightly the pH degree for the crude textile effluent (CTE). The highest increased pH of 7.91 was for *A. fertilissima*, followed by 7.82, 7.72 and 7.71 for *Ph. fragile*, *N. muscorum* and *Wollea* sp., respectively, compared to the initial pH value of 7.50.

Due to the electrical conductivity (EC), the tested cyanobacteria strains decreased the EC values to for the CTE to be slightly less than that of the initial EC value of 1.09. In descending order they recorded 1.05 (*A. fertilissima*), 1.04 (*Ph. fragile*), 1.02 (*Wollea* sp.) and 1.01 (*N. muscorum).* These EC results reveal that *N. muscorum* was superior in decreasing the EC than the initial value compared to the other examined cyanobacteria strains.

Table (6) revealed that inoculation of the textile discharge dye wastewater with the tested cyanobacteria strains led to decrease both COD and BOD at all tested incubation periods compared to the initial COD and BOD values of the discharge dye wastewater. However, the highest percentage reduction of COD of 90.04 was achieved by *N. muscorum* followed by 85.24 (*Wollea* sp.), 79.60 (*Ph. fragile*) and 79.40 for *A. fertilissima*. While, for BOD, the highest percentage reduction of 58.78 was due to *N. muscorum* followed by those of 58.47, 57.16 and 48.71in relative to *A. fertilissima*, *Wollea* sp. and *Ph. fragile*, respectively. Moreover, *N. muscorum* was superior in reducing both COD and BOD of the discharge dye wastewater compared to the other tested cyanobacteria strains.

Table (5): pH and EC of the textile wastewater as affected by the presence of different cyanobacteria strains after 28 days of incubation

parameters	Initial values	*Anabaena fertilissima*	*Nostoc muscorum*	*Phormidium fragile*	*Wollea* sp
pH	7.50	7.91	7.72	7.82	7.71
EC(dS m-^{1})	1.09	1.05	1.01	1.04	1.02

Table (6): Removal of COD and BOD values from textile wastewater by using different cyanobacteria strains at different incubation periods

Cyanobacteria strains	COD (ppm)					BOD (ppm)				
	Incubation periods (days)									
	7	14	21	28	*Red. (%)	7	14	21	28	Red. (%)
Anabaena fertilissima	7.43	5.02	4.85	4.16	79.40	15.76	12.17	11.34	09.20	58.47
Nostoc muscorum	3.81	2.28	2.15	2.01	90.04	16.38	14.19	12.24	09.13	58.78
Phormidium fragile	5.13	4.80	4.63	4.12	79.60	15.86	13.79	13.16	11.36	48.71
Wollea sp.	7.73	6.73	4.81	2.98	85.24	13.46	12.46	10.38	09.49	57.16

Initial COD = 20.19 Initial BOD = 22.15 - *Red. = Reduction percentage

DISCUSSION

The application of cyanobacteria showed immense potential in waste water and industrial effluent treatment, bioremediation of aquatic and terrestrial habitats, chemical industries, biofertilizers, food, feed, fuel, etc. [14].

The present study aims to evaluate the ability of different cyanobacteria strains ***viz***. *Anabaena fertilissima, Nostoc muscorum, Phormidium fragile* and *Wollea* sp.To remediate the industrial textile discharge dye wastewater at El-Shafie Factory for Garments located at EL-Mahalla EL-Kobra, East Delta, EL-Gharbia Governorate, Egypt.

The study for the efficient cyanobacteria strains in dye degradation of textile effluents is in focus that will enable textile industries with their discharge become eco-friendly. When there is lack of proper technology for dye discharge removal, more information gathered on microbial bioremediation through scientific researches will provide useful technology for color removal from dye discharge effluents. The dye removal is highly concentration dependent and approximately attributed to bioconversion in presence of cyanobacteria [15] Also, stated that the decolorization was found to be due to both biological dye reduction and adsorption [16]. The increase of decolorization with increasing incubation period and decreasing the azo dye effluent concentration found to be related to the molecular structure of the dye [17], adsorption to cyanobacteria cells **[**16] and rapid degradation of the dye **[**18]. However, the rapid decolorization or the color dye effluent due to the presence of cyanobacteria strains may be caused by strong attractive force between azo dyes molecules and cyanobacteria, fast diffusion onto the external surface that followed by fast diffusion into the cyanobacterial cells to attain rapid equilibrium [19]**.** Microbial biomass and their byproducts from fermentation industries will yield useful substances for bioremediation. This study cleared that bioremediation of toxic industrial effluents by micro-algae can be an effective method for removal of textile effluents, and can substitute the conventional remediation processes. Broad screening of microbial biomass type should be undertaken for developing new technologies. The current consensus is that, for improved commercial use of micro-algae, immobilization or pellet preparations in suitable carriers will prove economical for their use. In relation to other parameters of industrial relevance, micro-algae including cyanobacteria can be highly efficient in removing the toxic components from the discharged textile dye effluents. From the results, it is evident that some micro- algae can effectively remediate the pollutants from textile industry effluent. Also, The cyanobacterial species such as *Nostoc muscorum*, *Anabaena variabilis*, *Lyngbya majuscula* and *Oscillatoria salina* were used for biotreatment [9]. A significant raise in pH value and reduction in COD, BOD, Ca, Mg, sulphate, zinc, nickel and color was observed at 25 days of treatment. These results are in harmony with those obtained in the current study, since the use of cyanobacteria in the discharged textile dye led to raise pH and to reduce COD, BOD and the concentration of heavy metals, i.e., Fe, Mn, B, Pb, and As. Moreover, the micro-alga *Chlorella vulgaris* was able to grow in TW and remove color from the textile wastewater [4]. The physico-chemical parameters such as color, odor, temperature, pH, electrical conductivity, chemical oxygen demand, biological oxygen demand, lead, chromium and zinc in the textile dyeing effluent decreased when treated with *Spirogyra gracilis* [20]. The physico -chemical parameters such as pH, OD, EC, BOD, COD, TDS and removal of heavy metals such as Mercury, Cadmium, Iron, Copper and Lead contents were monitored on 30th day of incubation. Furthermore, significant raise in pH value and reduction in COD, BOD, Ca, Mg, sulphate, zinc, nickel and Color was observed in 25 days of treatment [9]

CONCLUSION

In the current study, the tested cyanobacteria showed capability of decolorize and remove partially the existent heavy metals from the textile crude discharge effluent. Therefore, the research of cyanobacteria to remove color in dye wastewaters is still in the early stage, but is a promising alternative of biological treatment. Our results showed that the cyanobacteria evaluated can decolorize and degrade dyes and that they may also be used in other studies, such as bioremediation.

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