The Use of Microalgae in Bioremediation of the Textile Wastewater Effluent

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Abstract: The run off of the textile dye effluents into Public water bodies is a major environmental and health problem. Color removal, in particular, recently becomes a substantial scientific interest, as revealed by the multitude of related research reports. During the past two decades, many physico-chemical decolorization techniques have been cleared, few, however, have been accepted by the textile industries. Their lack of implementation has been largely due to the high cost, low efficiency and ineffectively to a wide variety of dyes. The capacity of microorganisms to carry out dye decolorization has received much attention. Microalgae are considered as an important source for decolorizing the textile dye effluent. In the current work five local microalgae strains nameely *Anabaena flos aquae, Nostoc elepsosporum, Nostoc linkia, Anabaena variabilis and Chlorella vulgaris*, were y screened for their efficiency to grow on and the removal of the red color and the heavy metals, i.e., Chromium, lead, iron, copper, Molybdenum and arsenic from the textile wastewater effluent discharged by The textile factory located at the six October City, Industrial Region, Giza Governorate, Egypt. Results revealed that all tested microalgae strains were able to remove the color of the textile wastewater effluent after 4 weeks incubation periods under continuous illumination. Also, *N. elepsosporum* recorded the highest percentage of color removal percentage followed by *C. vulgaris*, *A. Variabilis, N. linkia* and *A. flos aquae* after 4 weeks of incubation. All the tested microalgae strains were able to remove Cr, Pb, Cu, Mo and As in different degrees. On the other respect, all tested microalgae strains raised pH and DO of the textile wastewater effluent, while they reduced EC, COD and BOD compared to the initial values of the initial values recorded by textile wastewater effluent. However, the more work should be done to confirm the ability of microalgae to be considered as a promising alternative of biological treatment to reduce the pollution load resulted from the textile wastewaters proposed to be drained into the public water bodies.

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1. Introduction

The textile industry represents one of the most important sectors in Egypt. It consumes a huge amount of water during production of the textile through several processes that include desizing, bleaching, mercerizing, dying, printing and finishing. These processes of the textile industries resulted in different inorganic, organic, dispersant, leveling agents, acids, alkalis and moreover, large amounts of water are consumed **(Imtiazuddin et al., 2012).** The wastewater produced from this industry exposes environmental problems when discharged into water bodies such as canals, lakes and rivers because it contains several toxic materials such as ammonia, sulfide, lead, heavy metals and other hazardous pollutants like dyes, oil and grease **(Talukder et al., 2015).** They also added that when the water bodies are loaded with the textile wastewater effluent, it may cause hazardous changes of the physicochemical and biological properties of these water bodies such as dissolved oxygen (DO), biological oxygen demands (BOD) and chemical oxygen demands (COD). Releasing these hazardous materials into the aquatic systems represent high threat to the living system due to altering the pH and the increase of both COD and BOD. To reduce the hazards of the textile wastewater, several methods are used in the treatment of the textile effluent before drainage. The treatment of textile effluent involves mainly physical and chemical methods, which are often very costly **(Robinson et al., 2001)**. They added that several physico-chemical methods have been widely used for removal of heavy metals from industrial wastewater, such as ion-exchange, activated charcoal, chemical precipitation, chemical reduction and adsorption. Bioremediation is one of the latest approaches that is both eco-friendly and cost effective **(Gupta et al., 2000). Kulshreshtha et al. (2014)** declared that bioremediation is considered as one of the safer, cleaner, cost effective and ecofriendly technology for decontaminating sites, which are contaminated with wide range of pollutants. The term bioremediation has been introduced to describe the process of using biological agent to remove toxic waste from environment. The process of bioremediation uses various agents such as bacteria, fungi, algae and higher plants as major tools in treating heavy metals present in the environment. Bioremediation, both ***In situ*** and *ex-situ* have also enjoyed strong scientific growth, in part due to the increased use of natural attenuation, since most natural attenuation is due to biodegradation. Bioremediation and natural attention are also seen as a solution for emerging contaminant problems. Microbes are very helpful to remediate the contaminated environment.

The use of microalgae as bioremediation agent for the colored wastewater has received a great attention because of their substantial role in carbon dioxide fixation. In addition, the algal biomass produced has a great efficiency as feedstock for biofuel production **(Huang et al., 2010)**. Moreover, **Zhang et al. (2006)** revealed that *Chlorella vulgaris, Chlorella pyrenoidosa* and *Oscillatoria tenuis* were able to biodegrade and decolorized more than 30 azo compounds in which azo dyes were degraded into simpler aromatic amines [8].

Therefore the aim of this work is to use different microalgae strains namely *Phormidium fragile, Nostoc elepsosporum, Nostoc linkia, Anabaena variabilis* and *Chlorella vulgaris* in bioremediation of colored textile wastewater effluent.

2. Materials and Methods

Textile wastewater effluent (TWWE)

The textile wastewater effluent **(TWWE)** was collected from a textile factory located in the industrial region of Six Octber city, Giza Governorate, Egypt. It was stored in a holding tank before discharge into the river. The factory utilzes a combination of physical, chemical and biological methods to treat the wastewater (**TWWE)** still with a red color and polluted with some heavy metals and azo dyes at the discharge point. The textile wastewater effluent was analyzed for its initial physico-chemical parameters.

Microalgae strains and culture media

Two local microalgae strains namely *Anabeana flos aquae* and *Chlorella vulgaris* obtained from the culture collection of Agric. Microbiol. Res. Dept., Soils, Water and Environ. Res. Inst. (SWERI), Agric. Res., Center (ARC), Giza, Egypt. Moreover, three other microalgae isolates were isolated from soil of the respective Governorate of **EL-Behira**, **EL-Gharbia** and **Kafr EL- Sheikh and** identified according to **Desikachary (1959)** as *Nostoc elepsosporum, Nostoc linkia* and *Anabaena variabilis,* respectively. These microalgae strains were screened for their efficiency to grow and decolorize and remove heavy metals, i.e., Chromium (Cr), lead (Pb), iron (Fe), copper (Cu), molybdenum (Mo) and arsenic (As) from the tested textile wastewater effluent.

The tested microalgae strains (cyanobacteria) strains were grown and maintained on BG11medium (**Allen and Stanier (1968)** in a growth chamber under white continuous illumination (3000 lux) and temperature of 25 ± 2 ˚C. While the green alga *Chlorella vulgaris* was grown and maintained on Bold's Basal medium **(Bischoff and Bold, 1963)** under the same condition.

Bioremediation of the textile wastewater effluent by using different microalgae strains

Two hundred ml of the textile wastewater effluent (TWWE) were kept into 500 ml Erlenmeyer flask and then inoculated with 10 ml from each microalga strain (10^{12} cfu ml^{-1}) individually. The inoculated flasks were incubated at 25 ± 2 ^{o}C for 4 weeks under continuous illumination using white cool light bulb exposure (3000 Lux) in three replicates, to study the effect of 5 microalgae strains on some physico-chemical properties, i.e., water reaction (PH), electric conductivity (EC), dissolved oxygen (DO), Chemical oxygen demands (COD) and biological oxygen demands (BOD) after 28 days incubation periods of the TWWE and to evaluate their ability to remove the, color and some heavy metals (Cr, Pb, Fe, Mn, Cu, Mo and As) from TWWE.

After 4 weeks incubation, each flask was filtrated through the pre-weighed filter Whattman® Paper No. 1 and then the filtrate exposed to the measurement of DO, COD and BOD. The decolorization was determined by measuring the color absorbance spectrophotometerically at 600 nm using UV-visible spectrophotometer Model Spectronic 21 **(Sadettin and Donmez, 2006).** Also, heavy metals, pH and EC were determined. While, the filter papers were oven dried at 70 ^{o}C up to a constant dry weight to determine the microalgae dry weight.

Decolorization percentage

The decolorization percentage was calculated according to the following formula adopted by Mahalakshmi et al. (2015):

Decolorization (%) = <u>Initial absorbance - Observed absorbance ×100</u>

Initial absorbance

Physicochemical analyses

The filtrate of the microalgal treated TWWE was examined for pH, EC, DO, COD, and BOD **(APHA, 2005)**. The BOD was determined according to the following formula:

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 ^{o}C.

P= decimal volumetric fraction of sample used.

Heavy metals analyses

Chromium (Cr), lead (Pb), Iron (Fe), copper (Mn), Boron (B), Lead (Cu), Molybdnum (Mo) 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 **(APHA, 2005)**.

3. Results

Initial physicochemical analyses of the textile wastewater effluent (TWWE)

Data in Table (1) indicates some initial physicochemical analyses of TWWE which was generally characterized by low dissolved oxygen (0.6 mg L^{-1}) and high BOD (96 mg L^{-1}), and COD (430 mg L^{-1}) with salinity and pH values of 2.90 dSm^{-1} and 9.5, respectively. Furthermore, the heavy metals such as chromium, lead, iron copper, molybdenum and arsenic content in TWWE were very high. Thus, the collected TWWE indicate highly pollution.

Effect of textile wastewater on the growth of different microalgae strains

Microalgae growth was tested to evaluate the enhancing or inhibitory effect of the pollutants on both cyanobacteria and\or the green alga (their resistance or sensitivity) to certain the most effective promising bioremediation strain. Data on Table (2) revealed that all the tested microalgae strains can grow and withstand the exposure to the TWWE up 4 weeks incubation. However, their dry weights was less than those recorded by those cultured on the standard media (control treatments) after 4 weeks incubation. The highest dry weight for the microalgae strains when grown on the TWWE was 11.45 mg L^{-1} for *Nostoc elpsosporum* followed by 9.08 mg L^{-1} (*Anabaena variabilis*), 8.92 mg L^{-1} (*Chlorella vulgaris*), 8.16 mg L^{-1} (*Anabaena flos aquae*), and 7.89 mg L^{-1} (*Nostoc linkia*). On the other hand, the reduction percentage of growth of the tested microalgae upon their exposure to the TWWE can be arranged as 19.37, 18.35, 15.13, 13.86 and 12.12 % for *Anabaena flos aquae, Anabaena variabilis, Nostoc elpsosporum, Nostoc linkia* and *Chlorella vulgaris.*

Table (1): Some initial physicochemical characteristic of the untreated textile wastewater effluent

Characters	Values	WHO Standard (2006)
Color	Red	---
pH	9.5	6.5
EC (dSm^{-1})	2.9	0.4 -1.4
DO (mg L^{-1})	0.60	---
COD (mg L^{-1})	430	---
BOD (mg L^{-1})	96	50
Mg (mg L^{-1})	130	50
Ca (mg L^{-1})	146	75
NO_3^- (mg L^{-1})	1.18	---
$SO_4^=$ (mg L^{-1})	77.8	---
Cr (mg L^{-1})	6.18	0.1
Pb (mg L^{-1})	10	5.0
Fe (mg L^{-1})	140.2	5.0
Cu (mg L^{-1})	8.14	0.2
As (mg L^{-1})	3	0.1
Mo (mg L^{-1})	2.6	0.01

Table (2): Effect of textile wastewater effluent on the growth of microalgae grown under continuous illumination for 4 weeks incubation

Microalgae strain	Control Normal culture media	Textile wastewater effluent	Reduction (%)
	mg L^{-1}		
Anabaena flos aquae	10.12	8.16	19.37
Nostoc elepsosporum	13.52	11.45	15.31
Nostoc linkia	9.16	7.89	13.86
Anabaena variabilis	11.12	9.08	18.35
Chlorella vulgaris	10.15	8.92	12.12

Initial inoculum = 10 ml microalgae culture containing 10^9 cfu ml^{-1}

Effect of microalgae treatment on some physicochemical characters of the textile wastewater effluent

Data in Table (3) indicate the effect of inoculation with different microalgae strains on the some physicochemical characters of the textile wastewater effluent after 4 weeks incubation under continuous illumination. Results postulated that inoculation with microalgae to the TWWE increased slightly pH values compared to the control treatment to be directed to higher alkalinity levels. The highest pH value of 9.95 was recorded by *Anabaena variabilis* followed by 8.85 (*Chlorella vulgaris*), 8.72 (*Nostoc linkia*), 7.92 (*Nostoc elepsosporum* and 7.75 for *Anabaena flos aquae* compared to 7.5 for the initial value (microalgae grown on their standard media).

Also, the treatment of TWWE with microalgae elevated the dissolved oxygen from 0.6 mg L^{-1}(control) to 2.75 mg L^{-1} for *Nostoc elepsosporum* followed by 2.68 mg L^{-1} for *Nostoc linkia,* 2.61 mg L^{-1} for *Anabaena variabilis* and 2.01mg L-1 for *Chlorella vulgaris* compared to 0.90 mgL^{-1} the initial value (microalgae grown on their standard media).

In contrast, treatment of the TWWE with microalgae led to reduce the EC, COD and BOD values compared to the control treatment. However, the least EC value of 0.92 dSm^{-1} for *Chlorella vulgaris* was followed by 1.01 dSm^{-1} (*Anabaena variabilis*), 1.12 dSm^{-1} (*Nostoc linkia*), 1.95 dSm^{-1} (*Nostoc elepsosporum*) and 2.03 *Nostoc elepsosporum* for *Anabaena flos aquae* compared to 2.90 dSm^{-1} for the initial value (microalgae grown on their standard media. The microalgae treatment reduced both COD and BOD values compared to those recorded by the control treatment. Both *Nostoc elepsosporum* and *Chlorella vulgaris* reduced COD by 98.00 and 97.63 % and BOD by 98.92 and 92.24 %, respectively. While *Anabaena flos aquae* recorded the least reduction of COD and BOD by 60.00 and 73.96 %, respectively. N the other respect, both *Nostoc linkia* and *Anabaena variabilis* gave percentages reduction of 75.00 and 80.00 % for COD and 85.63 and 82.00 % for BOD. All these results were in comparison to those scored by the control treatment (microalgae grown on their standard media). Generally, all the tested microalgae successfully were able to decrease the pollution load for the TWWE throw elevating both pH and DO and reduced any of EC, COD and BOD.

Table (3): Effect of different microalgae strains treatment on some physicochemical characters of the textile wastewater effluent after 4 weeks incubation under continuous illumination

Characters	Initial values	Textile wastewater effluent treated with									
		Anabaena flos aquae		*Nostoc elepsosporum*		*Nostoc linkia*		*Anabaena variabilis*		*Chlorella vulgaris*	
pH	7.50	7.75		7.92		8.72		9.95		8.85	
EC (dSm^{-1})	2.90	2.03		1.95		1.12		1.01		0.92	
DO (mg L^{-1})	0.60	1.90		2.75		2.68		2.61		2.01	
COD (mg L^{-1})	430.0	Final	172	Final	8.6	Final	107.5	Final	86.00	Final	10.20
		*R (%)	60.00	*R (%)	98.00	*R (%)	75	*R (%)	80.00	*R (%)	97.63
BOD (mg L^{-1})	96.0	Final	25.00	Final	1.04	Final	13.8	Final	17.28	Final	7.45
		*R (%)	73.96	*R (%)	98.92	*R (%)	85.63	*R (%)	82.00	*R (%)	92.24

Efficiency of textile wastewater effluent color by different microalgae strains

Five microalgae strains namely *A. flos aquae*, *N. elepsosporum, N. linkia*, *A. variabilis*, and *C. vulgaris* were evaluated for their efficiency to remove the red color of the textile wastewater effluent after 4 weeks incubation under continuous illumination (Table 4). Results revealed that all examined microalgae strains were able to remove the red color of the treated textile wastewater effluent with different percentages, when the light absorbance was measured at 600 nm. The percentages of color removal were in comparison with the absorbance of the untreated textile wastewater effluent measured at 600 nm. *Nostoc elepsosporum* scored the highest percentage color removal of 100%, followed by 96.16 % for *C. vulgaris*, 88.71%for *A. variabilis*, 79.03 % for *N. linkia* and 50.81 % for *A. flos aquae*.

Table (4): Color removal percentages from the red textile wastewater effluent treated with different microalgae strains after 4 weeks incubation under continuous illumination measured as absorbance at 600 nm wavelength

Untreated medium (control)	Untreated textile wastewater effluent	Treated textile wastewater effluent with									
		Anabaena flos aquae		*Nostoc elepsosporum*		*Nostoc linkia*		*Anabaena variabilis*		*Chlorella vulgaris*	
00.00	00.248	Final *abs.	**R (%)	Final *abs.	**R (%)	Final *abs.	**R (%)	Final *abs.	**R (%)	Final *abs.	**R (%)
		00.112	50.81	00.00	100	00.052	79.03	00.028	88.71	00.012	96.16

*Final abs = Absorbance of color residual **R= Removal percentage.

Effect of microalgae treatment on heavy metals removal from the textile wastewater effluent

Results in Table (5) indicate the residual concentration of heavy metals (Cr, Pb, Fe, Cu, Mo and As) remained in the textile wastewater effluent treated with different microalgae strains after 4 weeks incubation under continuous illumination. Results vivid that all tested microalgae strains had more or less the capacity to remove the heavy metals loaded in the textile wastewater effluent with different percentages.

For chromium, any of *N. elepsosporum* and *C. vulgaris* recorded relative high reduction percentages of 99.19, 97.57 and 90.94. While, the least percentages reduction for Chromium of 60.36 and 67.31 for *A. flos aquae* and *A. variabilis.* Generally, for Pb, Fe, Cu, Mo and As, *N. elepsosporum* had successfully reduced them recorded the highest corresponding reduction percentages of 98.80, 98.94, 99.02, 96.92 and 95.00. The percentages reduction of these metals recorded by *A. variabilis* were 94.00 (Pb), 97.94 (Fe), 91.77 (Cu), 93.46 (Mo) and 66.00 (As), followed by those of 96.40 (Pb), 96.76(Fe), 98.40 (Cu), 95.00 (Mo) and 88.33 (As) for *C. vulgaris* and 89.40 (Pb), 89.43 (Fe), 86.24 (Cu), 89.23 (Mo) and 69.33 (As). While the least reduction percentages of 73.00 (Pb), 73.10 (Fe), 82.19 (Cu), 60.77 (Mo) and 46.67 (As) were recorded by *A. flos aquae.* Subsequently, the aforementioned results pointed out that *N. elepsosporum* and *C. vulgaris* are the splendid microalgae that could remove successfully the loaded heavy metals for the textile wastewater effluent compared to the other tested microalgae strains.

Table (5): The capacity of different microalgae strains in removing heavy metals loaded in the textile wastewater effluent after 4 weeks incubation under continuous illumination

Metal type	Initial metal Concentration (mg L^{-1})	*Anabaena flos aquae*		*Nostoc elepsosporum*		*Nostoc linkia*		*Anabaena variabilis*		*Chlorella vulgaris*	
		Residual (mg L^{-1})	Reduction (%)	Residual (mg L^{-1})	Reduction (%)	Residual (mg L^{-1})	Reduction (%)	Residual (mg L^{-1})	Reduction (%)	Residual (mg L^{-1})	Reduction (%)
Cr	6.18	2.45	60.36	0.05	99.19	2.02	67.31	0.15	97.57	0.56	90.94
Pb	10.00	2.70	73.00	0.12	98.80	1.06	89.40	0.16	94.00	0.36	96.40
Fe	95.20	25.12	73.10	1.01	98.94	10.06	89.43	1.96	97.94	3.08	96.76
Cu	8.14	1.45	82.19	0.08	99.02	1.12	86.24	0.67	91.77	0.13	98.40
Mo	2.60	1.02	60.77	0.08	96.92	0.28	89.23	0.17	93.46	0.13	95.00
As	3.00	1.60	46.67	0.15	95.00	0.92	69.33	1.02	66.00	0.35	88.33

4. Discussion

Textile industry is one the most important and substantial manufacture sector that subsidize the Egyptian economy. This industry through the production of textile it uses different types of fibers such cotton, wool and silk and synthetic materials like polyester, nylon and acrylic and dyes **(Commission, 2002).** The textile production consumes a large amount of water during dyeing processes and produces so much colored wastewater effluent that may be released to the public water bodies such as rivers and lakes which causes one of the most serious pollution problems **(Vijayakumar and Manoharan, 2012).** Prior to discharge the textile wastewater effluent to the public water bodies, it should be treated to reduce the pollution load of these wastewater effluent (TWWE). In the present work the collected textile wastewater was evaluated initially for its physicochemical characteristics which were with high pH, COD, BOD and low DO and this means that this TWWE is highly polluted and favored the growth of microalgae. So, in the current study, different microalgae were used in the treatment of the TWWE treatment as a cost effective and ecofriendly bioremediation agents. The used microalgae of *flos aquae*, *N. elepsosporum, N. linkia*, *A. variabilis*, and *C. vulgaris* were tested for their ability to grow and survive and grow in the TWWE as well as to evaluate their effect on the physicochemical characteristics for the TWWE, their ability to decolorize and remove Pb, Fe, Cu, Mo and As from the polluted TWWE.

The tested microalgae in this study had successfully reduced EC, COD and BOD and elevate both of dissolved oxygen and pH after 4 weeks incubation under continuous illumination. In this context, **Ibraham and Nanda (2010)** reported that the treatment of textile wastewater effluent with *Oscillatoria* sp led to reduce BOD, COD and coloration by 30.4, 57.6 and 39.82 %, respectively, after 4 weeks of incubation. Also, **Vijayakumar and Manoharan (2012)** found that using both *Oscillatoria brevis* and *Westiellopsis prolifica* in dye industry effluent increased DO content and reduced BOD and COD up to 95%. They added that the effluent supported the growth of both *Oscillatoria brevis* and *Westiellopsis prolifica.* after 30 days of incubation. **Alaguprathana and Poonkothai (2015)** showed that the treatment of the textile wastewater effluent with the green alga Spyrogira gracilis decreased all the physicochemical constituents of the effluent such as EC, BOD, COD and color. **Chen et al. (2003)** reported that the increase of DO and pH and the decrease of both COD and BOD and the color removal in the textile effluent along with the treatment with microalgae may be attributed to photosynthesis carried out by the microalgae that increased the oxygen concentration of the effluent. Subsequently, this oxygen help in microbial decomposition and biodegradation of organic materials which in turn decrease both COD and BOD. **Daneshvar et al. (2007)** explained the rapid degradation of the dye from the dye effluent in presence of cyanobacteria. However, the rapid decolorization or the color dye effluent in presence of the microalgae strains may be caused by strong attractive force between the dye molecules and microalgae, fast diffusion onto the external surface that followed by fast diffusion into the microalgal cells to obtain rapid equilibrium **(Omar, 2008)**.

EL-kassas and Mohamed (2014) reported that the discharge of effluent produced during dyeing process and released in the textile effluents cause the increase of both BOD and COD for the discharged effluent. Microalgae are known to remove dyes by bioadsorption, biodegradation and bioconversion. Microalgae degrade dyes for nitrogen source, by removing nitrogen, phosphorus, and carbon from water, it can help reduce eutrophication in the aquatic environment and in turn reduce both BOD and COD. They added that the green alga *Chlorella vulgaris* can remove COD by 17.5 % from the textile effluent.

All the tested microalgae strains can successfully remove the red color of the collected TWWE after 4 weeks incubation under continuous illumination. They can be ranked according the color percentage removal in the order of *N. elepsosporum* (100%), *C. vulgaris* (96.16%), *A. variabilis* (88.71%), *N. linkia* (88.71) and *A. flos aquae* (50.81). In this concern, **Singh et al. (2010)** postulated that the use of microalgae in bioremediation of colored wastewater has attracted great interest due to their central role in carbon dioxide fixation. The mechanism for the removal of color from textile dyes effluent can be either biosorption or bioconversion, e.g., *Chlorella vulgaris* can remove 63 - 69% of the color from the mono-azo dyes by conversion into aniline. **Shah *et al.* (2001)** accounted that two main mechanisms for the removal of dyes color from solutions by biomaterials have been known: physic-chemical interaction (e. g. adsorption) and the influence of the metabolic-dependent processes (e. g. enzyme mediated degradation/decolorization). They added that 90% of the textile dye acid red can be removed by the biotreatment with the cyanobacterium *Phormidium valderianum* due to the adsorption of the dye on the alga cell surface. They explained that most of the microorganisms including cyanobacteria have a net negative charge on the surface because of the anionic nature of the functional groups making up the cell wall.

All the tested microalgae strains were able to remove any of Cr, Pb, Fe, Cu, Mo and As with different degrees from the collected TWWE. However, Heavy metal removal mechanisms include sedimentation, flocculation, absorption and cations and anion exchange, complexation, precipitation, oxidation/reduction, microbiological activity and uptake. Microalgae remove heavy metals directly from polluted water by two major mechanisms; the first is a metabolism dependent uptake into their cells at low concentrations, the second is biosorption, which is a non-active adsorption process **(Matagi et al., 1998)**. The microalgae have many features that make them ideal candidates for the selective removal and concentration of heavy metals, which include high tolerance to heavy metals, ability to grow both autotrophically and heterotrophically, large surface area/volume ratios, phototaxy, phytochelatin expression and potential for genetic manipulation **(Cai et al., 1995). Dwivedi (2012)** reported that polyphosphate bodies in algae enable fresh water unicellular algae to store other nutrients. Several researchers have established that metals such as Ti, Pb, Mg, Zn, Cd, Sr, Co, Hg, Ni and Cu are sequestered in polyphosphate bodies in green algae. These bodies perform two different functions in algae; provide a “storage pool” for metals and act as a “detoxification mechanism. The biomass of *Spirulina* strains contains different functional groups, for example, carboxyl, hydroxyl, sulfate, and other charged groups that are important for metal binding. They have great potentials in metal pollution control and the biosorption of zinc and nickel by several strains of *Spirulina*, namely, *Spirulina indica*, *Spirulina maxima*, and *Spirulina platensis*, was investigated recently **(Balaji *et ai.*, 2014).**

Conclusion

From this study it could be concluded that microalgae can be a promise in treating the wastewater drained to the public water bodies especially Nile River and its lake from the processes of the textile industry and all the industries that using dyes. The use of microalgae in wastewater bioremediation can act as cost effective and safe agent to protect the water bodies from hazard pollutant.

References

1. Alaguprathana, M. and M. Poonkothai (2015). Bio-sorption of physico-chemical constituents in textile dyeing effluent using Spirogyra gracilis Kützing. J. Algal Biomass Utln., 6: 11- 21.
2. Allen, M. M. and R. Y. Stanier (1968). Selective isolation of blue-green algae from Water and Soil. J. Gen. Microbiol., 51: 203 – 209.
3. APHA (2005). American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 21st Ed., Washington D.C., USA.
4. Bhola, V., F. Swalaha, R. R. Kumar, M. Singh and F. Bux (2014). Overview of the potential of microalgae for CO_2 sequestration. Int. J. Environ. Sci. Technol., 11: 2103-2118.
5. Bischoff, H.W. and H.C. Bold (1963). Phycological studies. 4- Some soil algae from

Enchanted rock and related algal species. Univ. Texas. Pub. N. 6318: 32-36.
6. Cai, X-H., T. Logan, T. Gustafson, S. Traina and R. T. Sayre (1995). Applications of eukaryotic algae for the removal of heavy metals from water. Molec. Mari. Biol. Biotechnol., 4: 338-344.
7. Chen, K., J. Wu, D. Lio and S.C. J. Hwang (2003). Decolorization of the textile dyes by newly isolated bacterial strains. J. Biotechnol., 101: 57-68.
8. Commission Decision (2002). The European eco-label for eextile products, 2002/371/EC of 15 May 2002. O. J. n L 133 of 18.5.2002, Criteria valid until 31 May 2007, previous criteria valid until 31 May 2003, (http://europa.eu.int/ecolabel).
9. Daneshvar, N., M. Ayazloo, A. R. Khataee and M. Pourhassas (2007). Biological decolorization of dye solutions containing Malachite Green by microalga Cosmarium sp. Bioresour. Technol., 98: 1176-1182.
10. Desikachary, T. V. (1959). « Cyanophyta ». Indian Councle of Agricultural Research. New Delhi, India. 350 -384.
11. Dwivedi, S. (2012). Bioremediation of Heavy Metals by Algae. Journal of Advanced Laboratory Res. in Biol. 3: 195-199.
12. El-Kassas Hala, Y. and Laila A. Mohamed (2014). Bioremediation of the textile waste effluent by *Chlorella vulgaris*. Egypt. J. Aqua. Res., 40: 301-308.
13. Gupta, R., P. Ahuja, S. Khan, R.K. Saxena and H. Mohapatra (2000). Microbial bisorbents: Meeting challenges of heavy metal pollution in aqueous solution. Curr. Sci., 78: 967-973.
14. Huang, G., F. Chen, D. Wei, X. Zhang and G. Chen (2010). Biodiesel production by microalgal biotechnology. Appl. Energ.,87: 38 - 46.
15. Imtiazuddin, S. M., M. Mumtaz and K. A. Mallick (2012). Pollutants of wastewater characteristics in textile industries. Lifescience Global. 554 – 556.
16. Kulshreshtha, A., R. Agrawal, M. Barar and S. Saxena (2014). A review on bioremediation of heavy metals in contaminated water. J. Environ. Sci. Food Technol., 8: 44 - 50.
17. Mahalakshmi, S., D. Laksahmi and U. Menaaga (2015). Biodegradation of dye (Congo red dye) by using green and blue-green algae. Inter. J. Environ. Res., 9: 735 - 744.
18. Matagi, S., D. Swaiand and R. Mugabe (1998). A review of heavy metal removal mechanisms in wetlands. Afr. J. Trop. Hydrobiol. Fish. 8: 23 - 35.
19. Omar, H. H. (2008). Algal decolorization of monoazo and diazo dyes. Pakistan J. Biol. Sci., 11:1310-1316.
20. Robinson, T., G. McMullan, R. Marchan, and P. Nigam (2001). “Remediation of dyes in textile effluent: A critical review on current treatment technologies with a proposed alternative,” Bioresour Technol., 77: 247-755.
21. Sadettin, S. and G. Donmez. Bioaccumulation of reactive dyes by thermophilic cyanobacteria. Process. Biochem., 41: 836 - 841.
22. Shah, V., N. Garg and D. Madamwar (2001). An integrated process of textile dye removal and hydrogen evolution using cyanobacterium, *Phormidium valderianum*. World J. Microbiol. Biotechnol., 17:499-504.
23. Singh, L.L., W. L. Chu and S. M. Phang (2010). Use of *Chlorella vulgaris* for bioremediation of textile wastewater. Bioresour Technol., 101: 7314-7322.
24. Talukder, A. H., S. Mahmoud, S. A. Lira and M. D. Abdul Aziz (2015). Phycoremediation of textile industry effluent by cyanobacteria (*Nostoc muscorum* and *Aabaena variabilis*). Biores. Commun., 1: 124 – 127.
25. Vijayakumar, S. and C. Manoharan (2012). Treatment of dye industry effluent using free and immobilized cyanobacteria. Bioremed. Biodeg., 3:2 - 6.
26. Zhang, Z. B., C. Y. Liu, Z, Z. Wu, L. Xing and P. F. Li (2006). Detection of nitric oxide in culture media and studies on nitric oxide formation by marine microalgae. Med. Sci. Monit., 12: 75-85.

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