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Short Communication

Phycoremediation of Textile Industry Effluent by Cyanobacteria (*Nostoc muscorum* and *Anabaena variabilis*)

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ABSTRACT: Phycoremediation is the process of using algae for the removal and biotransformation of pollutants from waste water. Cyanobacteria can be an effective for costly and laborious physical and chemical methods for the treatments of textile industry effluent. In this study, untreated textile industry effluents were treated by two native species of cyanobacteria and then physical and chemical parameters of the treated water were analyzed to assess the efficiency of the treatments. Untreated waste water samples were collected from the Konabari industrial area of Gazipur City Corporation of Bangladesh. Two native species of cyanobacteria, *Nostoc muscorum* and *Anabaena variabilis* were used in this study. These two species were cultured in BG 11 media and inoculated onto the untreated waste water. Fifteen days later, pH level raised significantly, while EC (Electrical Conductivity), TDS (Total Dissolved Solids), COD (chemical oxygen demand) and BOD (Biochemical oxygen demand) parameters were found to be reduced. The levels of magnesium, calcium, sulphate, nickel and zinc were also reduced after the cyanobacterial treatment. The comparative study between two species showed that *A. variabilis* had higher efficiency in reducing the pollution load from the waste water than the *N. muscorum* species. From the results, it is suggested that native cyanobacteria has active role in the reduction of pollution level from textile industry effluent. More in-depth studies should be undertaken to establish the role of these cyanobacterial species in phycoremediation as well as to elucidate their mechanism of action.

KEYWORDS: phycoremediation, cyanobacteria, effluent, physicochemical, biological treatment.

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INTRODUCTION

Textile manufacturing sector is one of the largest industrial sectors in Bangladesh. It is centered in Gazipur – very near to the capital city Dhaka. The manufacturing process includes a number of water consuming activities like – slashing, bleaching, mercerizing and dyeing, which are in turn responsible for the major portion of waste water generation. A lot of chemicals such as ammonia, sulfide, lead, heavy metals as well as other hazardous pollutants like oil, grease, colors and many other toxic substances are added to the process for cleaning and dyeing purposes.[1] Pollution load of untreated waste water of textile industry are very significant because the physicochemical properties of these waste water are heavily degraded with much amount of organic matter, inorganic matter and heavy metals.[4]

The textile dyeing industries of Gazipur (Konabari) generate large amount of waste water on a regular basis which are being directly discharged into the surrounding canals, agricultural fields, irrigation channels, surface water – and thus finally falling into Turag and Shitalakkhya rivers.[2] As a result, a considerable portion of the available surface water is being polluted by the textile effluents. The textile and dyeing effluents may cause alteration of the physical, chemical and biological parameters of aquatic environment by continuously changing the temperature, odor, turbidity etc. This is very much alarming for public health, livestock, wildlife, fish, and other biodiversity.[3] The presence of dyes in surface and subsurface water is making them not only aesthetically objectionable but also causing many water borne diseases, like dermatitis, perforation of nasal septum and severe irritation of respiratory tract.[2,3]

Physical and chemical methods are mainly involved for the treatment of textile effluents, but these methods are very costly. Therefore in this context there has been increased interest in using biological methods for remediation of textile effluents. In recent years, the use of microalgae in bioremediation of colored waste water has attracted great interest due to their central role in carbon dioxide fixation.[5] Biodegradation of organic pollutants by bacteria are very significant, some studies have indicated that in addition to providing oxygen for aero-bacterial bio-degraders, microalgae can also degrade organic pollutants directly. A study reported that more than 30 azo compounds were biodegraded by bacteria in which azo dyes were decomposed into simpler aromatic amines.[6] Application of many cyanobacterial species has also showed huge potential in waste water and industrial effluent treatment.[7]

The objectives of this study was to investigate the effect of two *Cyanobacterial sp – Nostoc muscorum* and *Anabaena variabilis* on some selected parameters such as Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Biochemical oxygen demand (BOD), as well as on the levels of Calcium, Magnesium, Sulphate, Nickel and Zinc in the industrial waste water.

MATERIALS AND METHODS

Study area

The study area was located at the Konabari industrial area at Gazipur district adjacent to the capital city of Bangladesh, Dhaka. The area is situated beside the Tangail-Gazipur highway and the elevation of the area was approximately 10 meters. The Turag River is flowing through the study area.[8] In this study area, industrial effluents are found to be directly discharged through different channels into the river and solid wastes are dumped regularly on the bank of the river in an unscientific and unregulated manner.

Cultured media

Physicochemical properties of textile industry effluents were analyzed as per the standard methods.[9] The pure stock of two native species of Cyanobacteria, *N. muscorum* and *A. variabilis* were cultured in BG 11 media in conical flasks at 30ºC and 190 rpm for about 15 days. To facilitate algal growth the cultured environment was illuminated properly.[7] The organisms were maintained for further analysis on effluent samples.

Assessment of biodegradability

For the assessment of biodegradability, at first the physicochemical properties of untreated textile industry effluents (n=3) were analyzed as per the standard methods (0 days parameters).[9] The effluent were then autoclaved and cooled except for the study of COD and BOD. 50 mL samples of autoclaved untreated textile waste water were added to 250 mL of BG 11 media inoculated with the identified algal species separately in Erlenmeyer flask and kept under illumination at 30ºC for 15 days under aerobic condition. For the study of COD and BOD, 50 mL untreated textile effluent was directly added to 250 mL of BG 11 media inoculated with the identified algal species. For the initial 48 hours of incubation, the flasks were kept in an incubator shaker at 100 rpm for the purpose of uniform mixing of the media and effluents. Periodic monitoring of the sample was done for investigating the physicochemical properties and biodegradability of the effluents.[7]

Sample analysis

The water quality parameters such as pH were determined by the digital pH meter (Model: pH Scan WP 1, 2; made in Malaysia). Buffer solution containing pH 7.0 was used to calibrate the pH meter. Digital EC and TDS meter (Model: HM digital; made in Germany) were used to determine EC and TDS, respectively. The DO was determined by digital DO meter (Model: D.46974; made in Taiwan) where sodium thiosulphate (0.025N) was used as a reagent. The BOD was measured in two steps where initial BOD (BOD_1) was measured immediately after collection and BOD_5 was measured after 5 days of incubation in the dark condition at 20ºC. Then the total BOD ($BOD_1 – BOD_5$) was measured according to Trivedy and Goel (1984), and Huq and Alam (2005).[10,11] The COD was measured after removing algal cells by centrifuging at 3000 rpm. The atomic absorption spectrophotometer was used for determining the metals in the waste water, following wet oxidation of the effluent samples by di-acid digestion method with a mixture (3:1) of concentrated HNO_3:$HClO_4$.[7,12,13]

Statistical analysis

Statistical analyses were carried out using ANOVA followed by the Tukey post hoc test. Data are expressed as mean values. We considered a value of $P < 0.05$ to be statistically significant.

RESULTS

The physicochemical properties of untreated waste water of studied textile industry are shown in the Table 1. The pH of waste water was acidic in nature and the EC, TDS, BOD, magnesium, calcium and zinc levels were higher than the standards as set by WHO (1993).

After fifteen days of treatment, the pH of the waste water was significantly enhanced from 6.3 to 8.1 and 8.6, by *N. muscorum* and *A. variabilis* respectively (Table 2). *A. variabilis* was found to be more efficient (36.51%) than *N. muscorum* (28.58%), to increase the pH of waste water of textile industry and thus making the water less acidic (Table 3).

Table 1. The physicochemical properties of untreated waste water of textile industry.

Parameters	Mean Values (n = 3)	WHO standards (1993)
pH	6.3	7-8
EC (µS/cm)	3500	400-1400
TDS (mg/L)	5100	400-1200
COD (mg/L)	560	--
BOD (mg/L)	110	50
Magnesium (mg/L)	74	50
Calcium (mg/L)	102	75
Sulphate (mg/L)	300	--
Nickel (mg/L)	8.9	--
Zinc (mg/L)	14	5

The electrical conductivity (EC) of waste water was significantly reduced from 3500 (0^{th} day) to 2800 (5^{th} day), 2100 (10^{th} day) and 1600 (15^{th} day) µS/cm by *N. muscorum*, while *A. variabilis* significantly reduced the EC from 3500 (0^{th} day) to 2700 (5^{th} day), 2100 (10^{th} day) and 1500 (15^{th} day) µS/cm (Table 2). The remedial efficiency rate (Table 3) was 54.29% and 57.14% by *N. muscorum* and *A. variabilis* respectively.

Table 2. Variability in physicochemical properties of waste water of textile industry during phycoremediation by *N. muscorum* and *A. variabilis*.

Parameters	**0th day**	***Nostoc muscorum***			***Anabaena variabilis***		
		5th day	**10th day**	**15th day**	**5th day**	**10th day**	**15th day**
pH	6.3	6.8	7.4***	8.1***	7.1*	7.9***	8.6***
EC (µS/cm)	3500	2800***	2100***	1600***	2700**	2100***	1500***
TDS (mg/l)	5100	4500*	3900***	3200***	4400**	3700***	3000***
COD (mg/l)	560	490*	430***	380***	470*	400***	360***
BOD (mg/l)	110	90*	65***	50***	85***	60***	48***
Magnesium (mg/l)	74	70	66	60*	68	62*	57**
Calcium (mg/l)	102	98	93**	88***	95	90**	86***
Sulphate (mg/l)	300	270	255	230	265	235	205
Nickel (mg/l)	8.9	8.4	7.9**	7.3***	8.2	7.6*	7.1**
Zinc (mg/l)	14	11.2	9.8	7.9	11.4	10.1	7.6*

All data expressed as mean values (n =3). *, P < 0.05; **, P < 0.01; ***, P < 0.001 vs. 0th day.

Table 3. Phycoremediation efficiency of *Nostoc muscorum* and *Anabaena variabilis*.

Parameters	***Nostoc muscorum*** **$[(E_0 - E_{15})/E_0]\times100$**	***Anabaena variabilis*** **$[(E_0 - E_{15})/E_0]\times100$**
pH	28.58	36.51
EC (µS/cm)	54.29	57.14
TDS (mg/l)	37.25	41.18
COD (mg/l)	32.14	35.71
BOD (mg/l)	54.55	56.36
Magnesium (mg/l)	18.92	22.97
Calcium (mg/l)	13.73	15.69
Sulphate (mg/l)	23.33	31.67
Nickel (mg/l)	17.98	20.22
Zinc (mg/l)	43.57	45.71

The untreated waste water contained high level of TDS contents (5100 mg/L) which after 5 days of treatment was reduced to 4500 and 4400, respectively by *N. muscorum* and *A. variabilis* (Table 2). At 10th and 15th days it was significantly reduced to 3900, 3200 and 3700, 3000 by *N. muscorum* and *A. variabilis* respectively (Table 2). *A. variabilis* showed higher removal efficiency (41.18%) than *N. muscorum* (37.25%) (Table 3).

The study showed that *N. muscorum* and *A. variabilis* has high potential for maintaining the BOD and COD contents of water (Table 3). After 15 days of treatment, the BOD contents of water were significantly reduced from 110 to 50 and 48 mg/L, (Table 2) respectively by *N. muscorum* and *A. variabilis*. The COD contents were significantly reduced from 560 to 380 and 360 mg/L (Table 2) after 15 days of treatment, by *N. muscorum* and *A. variabilis* respectively. In case of BOD the efficiency rate was 54.55% and 56.36% for *N. muscorum* and *A. variabilis* respectively, whereas for reducing COD efficiency rate was 32.14% and 35.71% by *N. muscorum* and *A. variabilis* respectively (Table 3).

At the final stage that means after 15 days of treatment, *N. muscorum* significantly reduced the levels of magnesium, calcium and nickel. Sulphate and zinc levels were also reduced, but the reduction was not significant (Table 2). In case of *A. variabilis*, after 15 days of treatment significant reduction was observed for magnesium, calcium, nickel and zinc levels, whereas the reduction of sulphate was not found to be significant (Table 2). *A. variabilis* was found to be the more efficient between the two species for the reduction of these ion levels (Table 3).

DISCUSSION

Phycoremediation is a novel technique that uses algae to clean up untreated industrial discharges. It takes advantage of the alga's natural ability to take up, accumulate and degrade the constituents that are present in their growth environment. Photosynthesis can be effectively exploited to generate oxygen from waste water remediation by algae. The potential of the two tested Cyanobacterial sp. such as *A. variabilis* and *N. muscorum* to reduce the pollutants of effluent samples collected from textile industry has been studied and compared. The study only focused the effect of added inocula of *A. variabilis* and *N. muscorum* to reduce the pollutants of effluent sample. To remove the effect of the internal Cyanobacterial sp. those naturally present in the effluent, the samples were autoclaved and cooled before the treatment with the test species. But in case of COD and BOD parameters, textile effluent was directly treated with inocula because the values might be altered after autoclave. So the reduction of COD and BOD levels was due to the combined effect of added inocula and natural sp. of Cyanobacteria within the effluent.

Analysis of various physio-chemical parameters before and after treatment revealed that the tested Cyanobacterial sps. could effectively remove the pollutants from textile industry effluent and thus improve the water quality. An alkaline environment with a range of pH from 7.5 to 8.4 is good for the growth of algae, and between 6.0 and 7.2 is optimum for fish eggs.[14] This study observed that by using cyanobacteria the pH of waste water can be raised to get the water from acidic to alkaline. The results also showed that the efficiency rate of *A. variabilis* (36.51%) was higher than *N. muscorum* (28.58%), to increase the pH of waste water of textile industry. These results were similar with previous reports.[7] Water containing large amount of EC is not suitable for aquatic environment. Both the *Cyanobacteria sps.* were found to have potential role in reducing the EC contents in waste water. Fifteen days of treatment with each *Cyanobacteria sp.* reduced the EC level (1600 and 1500 µS/cm) to very close to the standards set by WHO (400-1400 µS/cm). These results are also supported by previous studies.[15]

The Total Dissolved Solids (TDS) is also an important chemical parameter of water, which mainly indicate the presence of various minerals including ammonia, nitrate, nitrite, phosphate, sulphates, metallic ions, alkalis, acids etc. in both colloidal and dissolved forms.[18,19] Both the test species showed potential role in reducing the TDS contents in waste water, while *A. variabilis* showed higher removal efficiency than *N. muscorum*. Though the reduction rate was statistically significant, the 15 days treatment was not enough to reduce the TDS contents within the WHO standard range. These results are also reported by some previous studies.[16,17]

The biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are important parameters to determine water quality. The BOD and COD are very much affected by the pollution load resulting from textile industries.[20] From the investigation, it was found that a significant reduction of BOD and COD from the industrial waste water is possible by *N. muscorum* and *A. variabilis,* which has been also supported by Gupta and Suhas (2009).[22] The BOD of the effluents was reduced to within the standard levels approved by WHO.

Various types of salts are needed for maintaining the good quality of water but when it exceeds the permissible level, it becomes deleterious for aquatic environment. The results also depicted that magnesium, calcium, sulphate, nickel and zinc were removed effectively and markedly from the industrial waste water by *N. muscorum* and *A. variabilis*. A study conducted by Gonclaves *et al* (2000) also reported the similar efficiency.[23]

Overall, all the 10 parameters tested in this study were found to be significantly reduced by both *N. muscorum* and *A. variabilis*. The 15 days treatment was enough to bring the pH and BOD levels within WHO standards. The EC level was also brought down very close to the WHO standard range. These are very promising results which calls for elaborated studies on these Cyanobacteria species to further elucidate their function in phycoremediation.

CONCLUSION

The treatment of waste water involves various methods including physical, chemical and biological but all the process are not satisfactory. From the study it was found that biological treatment by Cyanobacteria like, *N. muscorum* and *A. variabilis* has the significance in reducing pollution load from waste water and they have high efficiency reduction rate. Establishment of the use of these Cyanobacteria sp. for the bioremediation of industrial wastes can make the effluent treatment process easier and cheaper. This can in turn, encourage more and more industries for the treatment of the waste water before discharging into environment.

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