Heavy Metal Scavenging Potential of Indigenous Microalgae of Bangladesh: A Study of Application in Textile Effluent Treatment

ABSTRACT

Aims: The aim of study was ~~is study aimed to~~ identify the heavy metals scavenging potential of indigenous microalgae (*Spirulina sp.* and *Chlorella sp.*) of Bangladesh for treatment of textile wastewater disposed in the open environment.

Study design: The capacity of improving the water quality of the textile effluent by heavy metal absorption was assessed. The quantitative determination included the comparison of physical characters (pH, TDS, EC, DO, COD) and heavy metal profile (Cr, Cd, Pb, Zn, Fe) of the textile effluent before and after treatment. Effluent treatment was carried out by individual species separately and in combination of all for a total of 25 days.

Place and Duration of Study: Major experiments were carried out at the Applied Botany Laboratory, Dhaka Laboratory, BCSIR, Dhaka, Bangladesh from January 2022 to February 2024. Quantitative estimations were carried out at Soil & Water Laboratory, Dhaka Laboratory, BCSIR, Dhaka, Bangladesh.

Methodology: The textile wastewater was characterized by means of physicochemical parameters and heavy metal concentration prior to the experimental procedure. Three treatment plans were designed, two (T_{CV} and T_{SP}) using individual species separately and one treatment (T_C) using both the species in combination. The treatment continued for 25 days. The physicochemical parameters and heavy metal conc. of the treated effluent were measured at 5-day interval till the 25th day of the experiment. Comparative analysis of the data was utilized to determine useful species for further applied studies in future.

Results: Heavy metals removal capacity of the tested species were found as follows, *C. vulgaris*: Zn > Cr > Pb > Cd >Fe and *S. platensis*: Cd> Zn > Pb > Fe > Cr, and the combination treatment: Pb > Cd> Zn > Fe > Cr. The

Keywords: *Textile effluent, Microalgae, Spirulina, Chlorella, Heavy metal scavenging, Wastewater treatment*

1. INTRODUCTION

The increasing global population has presented numerous challenges to the world economy, particularly in terms of environmental preservation and energy security. Discharged textile wastewater is known to pollute rivers, lakes, and seas worldwide [1]. There is growing concern about the substantial volume of effluents released from textile processing, which consumes large amounts of water [2]. Untreated effluent from nearby textile factories has been discharged into rivers, with major contaminants located outside the area, such as in Narayangonj, Savar, and Chattogram in some industrial areas. The annual global production of dyestuff exceeds 700,000 tonnes [3].

The textile industry uses large amounts of water for various stages of dyeing and cleaning raw materials [4]. As a result, the wastewater from textile production contains harmful heavy metals such as cadmium (Cd), chromium (Cr), and lead (Pb). These toxic metals pose threats to living organisms, including humans, due to their biotoxic effects, which can be acute, chronic, sub-chronic, neurotoxic, carcinogenic, mutagenic, or teratogenic [5]. For example, even low levels of cadmium can be extremely toxic, leading to bone defects, increased blood pressure, myocardial dysfunctions, pulmonary oedema, and in severe cases, death [6]. Studies have shown that lead is the most significant of the toxic heavy metals, being absorbed in inorganic forms, through ingestion of food and water, as well as inhalation [7]. Lead poisoning can cause inhibition of haemoglobin synthesis, kidney and joint dysfunctions, reproductive system issues, and acute and chronic damage to the central nervous system [8]. Textile wastewater is now a major source of surface water contamination, and various technologies are being developed for treating these effluents. Among these technologies, adsorption is considered one of the most promising methods [9, 10]. Recent studies have focused on the adsorptive removal of heavy metals and dyes using chitosan-based materials. [11, 12].

Four common ways to treat wastewater include physical water treatment, biological water treatment, chemical treatment, and sludge treatment. Agents used for bioremediation are bacteria, fungi, and algae [13]. Microalgae are reported in many studies to alleviate heavy metal toxicity. In recent years, the use of microalgae and cyanobacteria in the bioremediation of coloured wastewater has attracted interest due to their central role in carbon dioxide fixation. In addition, the generated algae biomass has potential as feedstock for biofuel production. Algal ability to remove dyes from wastewater can be enhanced by stimulating their growth. Living biomass of microalgae, such as *Chlorella* sp. can remove 63-69% of the colour from the mono-azo dye tectilon yellow 2G by converting it to aniline [14]. It can remove a higher percentage of colour from textile dyes than suspension cultures. Microalgae such as Chlorella sp. and *Spirulina* sp. grown respectively in CH medium and Zarrouk's medium are demonstrated to be useful in treating effluent textile wastewater [15]. Harvesting is the crucial step in the production of algal biomass, as it accounts for 20-30% of production costs. The small size of microalgae (3-30 μm) and its low concentration in the culture medium (below 500 mg/L) make the cell recovery a very challenging process. Several species of algae with varying characteristics like shape, size and motility influence their settling.

Chlorella is a microscopic green alga, spherical or ellipsoidal in shape, not much larger than a red blood cell. The name of this single-celled, non-motile water plant comes from the Greek *chloros*=green or yellow-green and *ella*=small. The cells are usually 2-12 µm in diameter, but the size can vary, even within a single population. The cells are solitary or in irregular clumps. *Chlorella* has a high growth rate, making it very interesting for research in a variety of fields [15]. There are various areas where Chlorella is used, such as to remove dyes by bio-adsorption, biodegradation, and bioconversion. *Chlorella* sp. can degrade dyes by removing nitrogen, phosphorus, and carbon from water [16].

Spirulina sp. is another organism whose role as an effective material to scavenge metal ions is exclusively examined [17, 18]. Many studies have aimed to analyze the tolerance and absorption mechanisms of toxic metals such as Cr, Cd, and copper (Cu) in *Spirulina* sp. [19]. It is also characterized by a higher capacity to remove effluents from textile wastewater [20]. Textile effluents are the causes that reduce the nutrients of water bodies. It is well known for creating biofilms on the water's surface so that the lack of sunlight causes aquatic life to suffer [21]. Many studies examined the impact of various dyes on water, concluding that higher dye concentrations inhibit the growth of Spirulina sp. and reduce its nutrient levels [22].

Bioremediation has become the primary choice for contaminated site recovery in America. It is commonly used globally for situations where previous human activity has left the location damaged and unusable without remediation [23]. With the country's population on the rise, the demand for landfills to relocate polluted material is surpassing the available supply [24]. On the other hand, biological treatment could achieve greater efficiencies in the decolourization and detoxification of textile wastewater by using native aquatic plants [25]. The use of microorganisms to break down pollutants or waste, such as oil spills, contaminated groundwater, or industrial processes makes bioremediation a very attractive solution [26].

This study focused on the growth parameter optimization of *Spirulina* sp. and *Chlorella* sp. biomass production as one of the key factors influencing heavy metal removal from industrial wastewater. There were not many studies of heavy metal scavenging in the past with a consortium condition of Spirulina sp. and Chlorella sp. We addressed fundamental physicochemical changes of textile effluent under consortium conditions, including its efficiency in scavenging Cr, Cd, Pb, zinc (Zn), and iron (Fe).

2. METHODOLOGY

2.1. Textile effluent collection

Textile wastewater was collected from the textile mills in Narayangonj, The liquid is collected successively in four 5 L gallons that have retention times of 2 to 3 days depending on water use, weather and land application practices. The gallons were anaerobic and vertically well mixed. The samples were not stratified with respect to pH, temperature, or electrical conductivity. The water also had a dark-brown color (Fig. 1).

Fig. 1. Textile wastewater samples (A) Collection area (B) Collected wastewater.

2.2. Preservation of the sample

Wastewater preservation techniques were used to stop or retard the chemical and biological changes that inevitably continue after a water sample has been collected. No preservative were used while the samples were transported to the laboratory. Around 20 L effluent sample was collected (in fresh plastic gallons). 5.0 mL of conc. HNO_3 was added to the effluent to prevent air oxidation and was preserved in 4˚C refrigerator.

2.3. Collection of microalgae

The cyanobacteria *Spirulina platensis*and *Chlorella vulgaris*was provided by the Applied Botany Laboratory, BCSIR Laboratories, Dhaka, from its specialized raceway culture ponds (Fig. 2).

Fig. 2. ***Spirulina platensis*****raceway pond at BCSIR Laboratories, Dhaka**

2.4. Culture of microalgae

Both *Spirulina platensis*and *Chlorella vulgaris* were cultured in 500 mL culture media in 1000 mL Erlenmeyer flasks at 23 ± 1˚C following aseptic conditions. The cultures were gently agitatedover an orbital shaker (SYC-2102) and exposed to white light for 24-hour photoperiod by using a cool white fluorescent light. Cell growth was monitored by determination of optical density (OD_{750}) at 750 nm. For *Spirulina* culture (Fig. 3(A)), Zarrouk's medium of pH 9.5 (as mentioned in Table 1) was used and for *Chlorella*culture (Fig. 3(B)), CH medium was used (as mentioned in Table 2). The reagents for media preparation were provided by the Applied Botany Laboratory, BCSIR Laboratories, Dhaka.

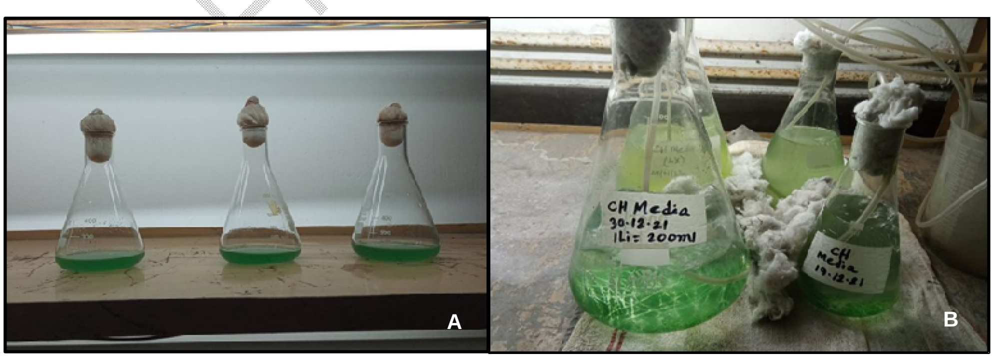

Fig. 3. Flask culture of (A) *Spirulina platensis*in Zarrouk's medium and (B) *Chlorella vulgaris* in CH medium

Table 1. Composition of Zarrouk's medium

Chemicals	Amount (g/L)
NaCl	1.00
$NaNO_3$	2.50
K_2SO_4	1.00
$NaHCO_3$	16.8
K_2HPO_4	0.50
$MgSO_4.7H_2O$	0.20
$FeSO_4.7H_2O$	0.01
$CaCl_2.2H_2O$	0.04
EDTA-$Na_2.2H_2O$	0.08
A_5 Micro Nutrient (H_3BO_3, $MnCl_2.4H_2O$, $ZnSO_4.4H_2O$, Na_2MoO_4, $CuSO_4.5H_2O$)	1.00 mL

Table 2. Composition of CH medium

Chemicals	Amount (g/L)
KNO_3	6.00
K_2HPO_4	0.24
$MgSO_4$	0.06
$FeSO_4$	0.03
$CaSO_4.2H_2O$	0.012

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2.5. Experimental design for the effluent treatment

First treatment started for 5 days. For next 10days, 15 days, 20 days and 25 days set up are ready for treatment. This set up is did on 1-2 L glass beaker in normal day lights and normal day temperature. Each set up wastewater and microalgae amounts of 1 L wastewater with 10 mL of pure microalgae like *Spirulina* sp. (T_{SP}) and *Chlorella* sp. (T_{CV}). No artificial shaker is used in this method.

First, 5 days treatment of wastewater when wastewater and algae of *Chlorella* sp. and *Spirulina* sp. composition of 1 L wastewater and total 20 mL of microalgae (T_C). It was keep on outdoor of room in normal temperature and normal day light. No artificial shaker used.

The study used fifteen glass beaker (1-2 L) representing five treatments and one control in three replicates. All aquaria were filled with 1 L of water from either textile wastewater. The control treatment consisted solely of textile wastewater in the test water. Samples of test water were taken at different periods throughout the duration of the experiment for the quantification of microalga growth (cell count) as well as for the analysis of heavy metals and physicochemical parameters.

The growth of microalgae in the five treatments was quantified in terms of cell count by using a T80 UV-visible spectrophotometer (OD_{600} PG Instruments, United Kingdom).

2.6. Physicochemical analysis of the samples

For textile wastewater analysis, 100 mL samples were taken every five days from each glass aquarium and were placed in plastic bottles. These samples shows some different condition when it was in treatment by microalgae.

2.6.1. pH

The pH meter is calibrated using standard buffer solutions of pH 4.0, 7.0, and 9.18 at room temperature. The pH of water samples is determined at room temperature. The electrode was washed thoroughly by distilled water and cleaned by tissue paper before each measurement of sample and for buffer solutions. About 100 mL of thorough sample was taken out in glass beaker. The electrode was dipped in the sample. The instrument gives direct measurement of pH. The filtered sample was used for measuring the pH using the Hach SensION 4-Thermo Fisher.

2.6.2. Salinity

The salinity of water samples is determined at room temperature. The electrode is washed thoroughly by distilled water and cleaned by tissue paper before each measurement of sample and for buffer solutions. About 100 mL of thoroughly sample is taken out in glass beaker. The electrode is dipped in the sample. Hach SensION 4-Thermo Fisher gives direct measurement of salinity.

2.6.3. Total Dissolved Solid (TDS)

The TDS of water samples is determined at room temperature. The electrode is washed thoroughly by distilled water and cleaned by tissue paper before each measurement of sample and for buffer solutions. About 100 mL of thorough sample is taken out in glass beaker. The electrode is dipped in the sample. The instrument gives direct measurement of TDS. The filtered sample was used for measuring the TDS using the Hach SensION 4-Thermo Fisher.

2.6.4. Electrical Conductivity (EC)

The conductivity cell is washed thoroughly by distilled water and cleaned by tissue paper before each measurement for sample and for KCl standard solution. All measurements of conductance are made at 25±0.1°C temperature. For calibration, the conductivity cell is immersed into the standard KCl solution. For sample measurement, 100 mL of thoroughly sample is taken out in 100 mL glass beaker. The conductivity cell is dipped in the beaker and EC is noted. The filtered sample was used for measuring the EC using the Hach SensION 4-Thermo Fisher.

2.6.5. Dissolved Oxygen (DO)

The DO meter is calibrated using standard solutions at room temperature. The electrode is washed thoroughly by distilled water and cleaned by tissue paper before each measurement of sample and for solutions. About 100 mL of thoroughly sample is taken out in glass beaker. The electrode is dipped in the sample. Instrument gives direct measurement of DO. The filtered sample was used for measuring the DO using the HACH Instrument: HQ 3 OD meter.

2.6.6. Chemical Oxygen Demand (COD)

COD of the filtered sample is measured using the reflux digestion method. 10.0 mL of sample (Sample: Distilled H_2O = 1:9) was prepared for each of the TWW samples collected. For each reaction 10.0 mL of the prepared sample was mixed with 5.0 mL of $K_2Cr_2O_7$ sol. (0.25 N), 15.0 mL of $AgSO_4$-H_2SO_4 sol. (10.0 mg/mL), and 0.02 g $HgSO_4$ in a digesting tube. Samples were refluxed for 2 h and cooled, then the volume was made up to 70.0 mL using distilled H_2O. 8 drops of Ferroin indicator were added to the mixture and titrated against standard $FeSO_4.(NH_4)_2SO_4.6H_2O$ sol. (0.25 N) until the blue-green color changes to red wine. The procedure was replicated for the blank.

2.7. Heavy metal conc?. profiling of the samples

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To determine the heavy metals Cr, Cd, Pb, Zn, and Fe, 200 mL of water sample from each setup was gently evaporated until dried. 5.0 mL of conc. HNO_3 was used to dissolve the residues with the subsequent addition of 5–10 drops of H_2O_2 to finish the digestion. 1.0 mL of this solution was used to determine the concentration of heavy metals present using an atomic absorption spectrophotometer (PerkinElmer made instrument "AAnalyst 700) and the program is run by the software AAwinlab Analyst- v4.1. On the instrument side, we must start air and acetylene manually, and switch on the instrument. After having proper pressure of air and acetylene (75 and 30 kg/cm2 respectively), ignite the burner. This covers the lamp selection and lamp setup. Calibration graphics involves setting atomization position for the required absorbance standard. Apply standard solution of 5 and 10 mg/L of a particular metal and a linear graph appears. Once the calibration curve is satisfactory, the instrument is ready for sample measurement. Aspirate the sample blank. Aspirate distilled water after every measurement. Record the concentration in mg/L that appears directly on the screen.

3. RESULTS AND DISCUSSION

3.1. Characteristics of the effluent

The sample had a TDS of 221.7 mg/L and an EC of 0.245 mS/cm among the tested parameters. The effluents' pH of 7.04 suggests that they have a slightly alkaline character. The amount of DO was 2.90 mg/L. Heavy metals, including Cr, Cd, Pb, Zn, and Fe were found in the tannery effluent, with respective values of 0.9, 0.8, 1.06, 0.7, and 0.9145 ppm. It was discovered that the effluents' TDS, and EC levels, including Pb conc. were above the threshold by an alarming amount. Even the allowed limit for the concentration of other heavy metals, such as Cr, and Cd, were exceeded.

Table 3. Physicochemical characters of the effluent

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Parameters	Effluent
pH	7.04
TDS	221.7 mg/L
EC	0.245 mS/cm
DO	2.90 mg/L

Table 4. Heavy metal conc. profile of the effluent

Heavy Metals	Effluent
Cr	<0.9 ppm
Cd	<0.8 ppm
Pb	<1.06 ppm
Zn	<0.7 ppm
Fe	<0.9145 ppm

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3.2. Physicochemical characters of the samples after treatment

The collected were analyzed for pH, TDS, EC, DO, and COD after treatments. These parameters have shown significant changes after various interventions. Improvement of the effluent after different treatments has been summarized in Table 5.

Table 5. Analysis of changes in physicochemical parameters of the samples throughout the treatments

Parameters	Treatments	Days				
		5	10	15	20	25
pH	T_{CV}	7.34	7.94	7.12	7.20	7.28
	T_{SP}	7.26	7.38	5.96	6.99	7.38
	T_{C}	7.38	7.75	7.22	7.15	7.21
TDS (mg/L)	T_{CV}	7750	455	8760	8040	6750
	T_{SP}	7250	8120	8320	6960	7310
	T_{C}	7070	792	8250	7250	7200
EC (mS/cm)	T_{CV}	15.49	0.913	17.43	16.05	13.48
	T_{SP}	14.49	16.24	16.62	13.93	15.68
	T_{C}	14.12	1.786	16.51	14.23	14.43
DO (mg/L)	T_{CV}	1.36	8.79	1.30	1.37	1.41
	T_{SP}	1.42	1.44	1.36	1.47	1.35

	T_C	1.39	8.99	1.42	1.44	1.40
	T_{CV}	519	488	413	370	301
COD (mg/L)	**T_{SP}**	511	473	404	355	295
	T_C	490	409	390	302	269

3.2.1. <u>Changes on pH level</u>

T_{SP} brought the effluent pH down to 6.99, T_{CV} brought it down to 7.12 and the T_C brought it down to 7.15. *S. platensis* showed good potential in pH reduction among all the three treatments, as observed in Fig. 4.

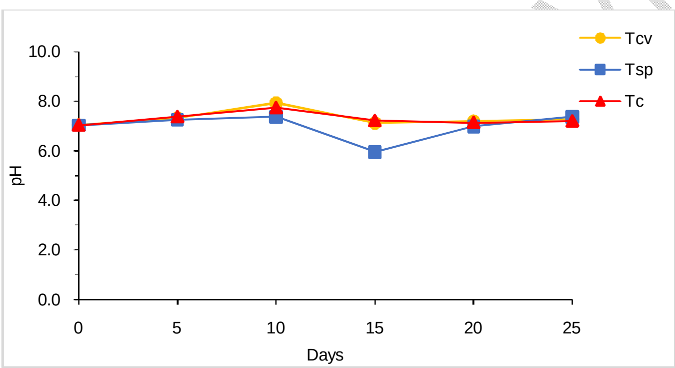

Fig. 4. Trend of change in pH level in different treatments

3.2.2. <u>Changes on total dissolved solids</u>

T_{SP} brought the TDS down to 6960 mg/L, T_{CV} brought it down to 455 mg/L and the T_C brought it down to 792 mg/L. *C. vulgaris* showed extreme TDS reduction potential among all the three treatments, as observed in Fig. 5.

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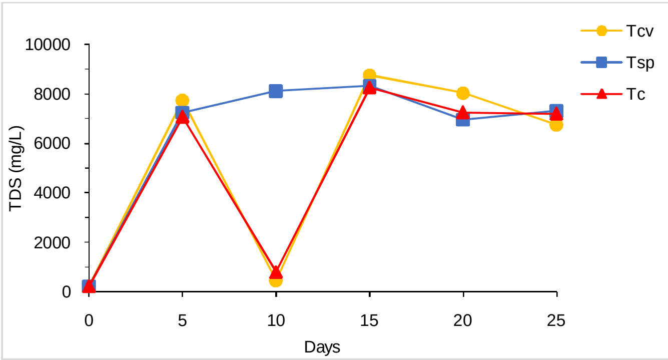

Fig. 5. Trend of change in total dissolved solids in different treatments

3.2.3. Changes on electrical conductivity

T_{SP} brought the EC down to 13.93 mS/cm, T_{CV} brought it down to 0.913 mS/cm and the T_C brought it down to 1.786 mS/cm. *C. vulgaris* also showed excellent EC reduction potential among all the three treatments, as observed in Fig. 6.

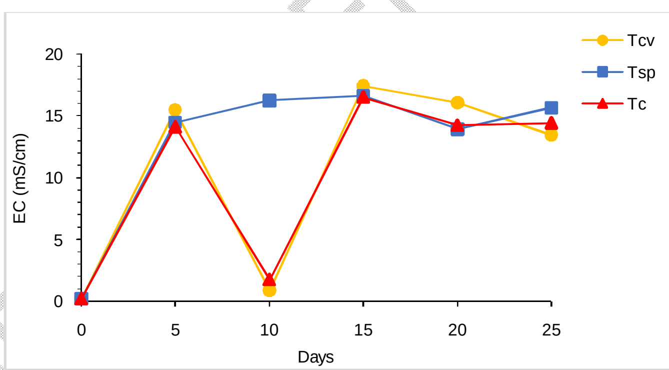

Fig. 6. Trend of change in electrical conductivity in different treatments

3.2.4. Changes on the level of dissolved oxygen

T_{CV} increased the DO level up to 8.79 mg/L and the T_C increased it up to 8.99 mg/L. *C. vulgaris* also showed excellent potential in increasing DO among all the three treatments, as observed in Fig. 7.

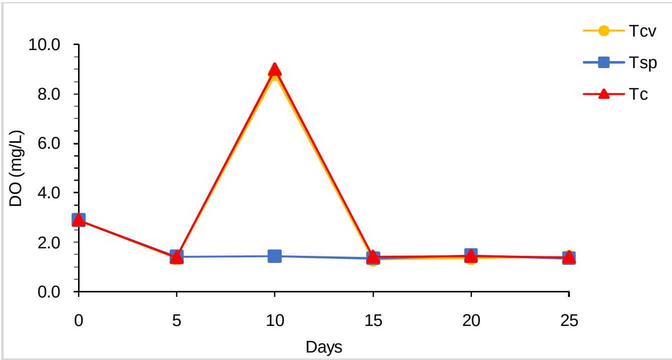

Fig. 7. Trend of change in dissolved O_2 level in different treatments

3.2.5. Changes on the level of biochemical oxygen demand

T_{SP} brought the effluent COD level down to 295 mg/L, T_{CV} brought it down to 301 mg/L and the T_C brought it down to 269 mg/L. The combined treatment of S. platensis and C. vulgaris showed relatively better reduction in COD level among all the three treatments, as observed in Fig. 8.

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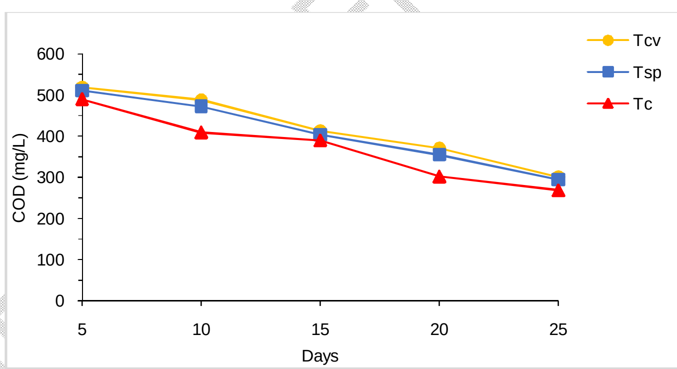

Fig. 8. Trend of change in chemical O_2 demand in different treatments

3.3. Heavy metal conc. profile of the samples after treatment

Heavy metals were analyzed in both treated and untreated effluent by acid-digesting all the samples. Collected textile wastewater carries Cr, Cd, Pb, Zn, and Fe. Changes is heavy metal quantities after treatments are summarized in Table 6.

Table 6. Analysis of changes in heavy metal conc. of the samples throughout the treatments

Heavy metals (ppm)	Treatments	Days				
		5	10	15	20	25
Cr	T_{CV}	0.783	0.702	0.651	0.581	0.462
	T_{SP}	0.774	0.701	0.677	0.602	0.584
	T_{C}	0.874	0.705	0.633	0.596	0.501
Cd	T_{CV}	0.721	0.688	0.601	0.552	0.473
	T_{SP}	0.722	0.702	0.652	0.549	0.533
	T_{C}	0.779	0.701	0.654	0.593	0.506
Pb	T_{CV}	0.891	0.782	0.721	0.674	0.553
	T_{SP}	0.904	0.851	0.750	0.679	0.605
	T_{C}	1.010	0.901	0.854	0.755	0.673
Zn	T_{CV}	0.552	0.501	0.441	0.391	0.301
	T_{SP}	0.691	0.632	0.602	0.599	0.532
	T_{C}	0.681	0.605	0.567	0.501	0.473
Fe	T_{CV}	0.788	0.701	0.681	0.601	0.501
	T_{SP}	0.879	0.805	0.776	0.707	0.632
	T_{C}	0.867	0.779	0.703	0.679	0.603

3.3.1. Impact overCr conc. in the sample

There have been seen that chromium in textile wastewater in primary level was less than 0.9ppm. After 5 to 25 days treatments Cr removed by *Chlorella* sp. is 0.783ppm to 0.462ppm. After 5 to 25 days treatments Cr removed by *Spirulina* sp. is 0.774ppm to 0.584ppm. After 5 to 25 days treatments Cr removed by consortium of *Chlorella* sp. and *Spirulina* sp. are 0.874ppm to 0.501ppm.

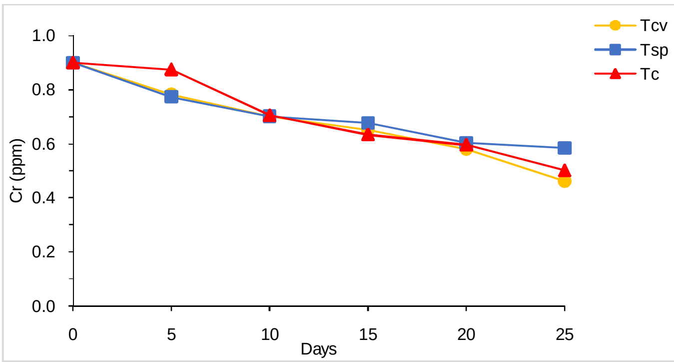

Fig. 9. Differences in the Cr conc. pre and post treatments

3.3.2. <u>Impact over Cd conc. in the sample</u>

There have been seen that cadmium in textile wastewater in primary level was less than 0.8ppm. After 5 to 25 days treatments Cd removed by *Chlorella* sp. is 0.721ppm to 0.473ppm. After 5 to 25 days treatments Cd removed by *Spirulina* sp. is 0.722ppm to 0.533ppm. After 5 to 25 days treatments Cadmium removed by consortium of *Chlorella* sp. and *Spirulina* sp. are 0.779ppm to 0.506ppm.

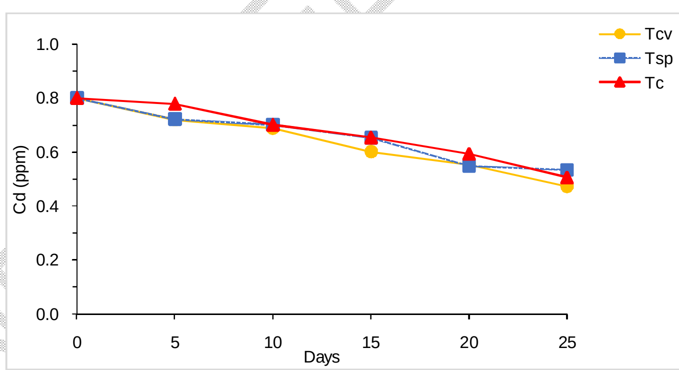

Fig. 10. Differences in the Cd conc. pre and post treatments

3.3.3. <u>Impact over Pb conc. in the sample</u>

There have been seen that lead in textile wastewater in primary level was less than 1.06ppm. After 5 to 25 days treatments Pb removed by *Chlorella* sp. is 0.891ppm to 0.553ppm. After 5 to 25 days treatments Pb removed by

Spirulina sp. is 0.904ppm to 0.605ppm. After 5 to 25 days treatments Pb removed by consortium of *Chlorella* sp. and *Spirulina* sp. are 1.01ppm to 0.673ppm.

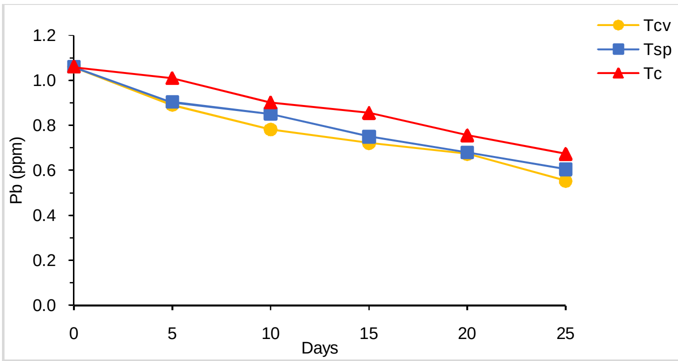

Fig. 11. Differences in the Pb conc. pre and post treatments

3.3.4. <u>Impact over Zn conc. in the sample</u>

There have been seen that Zinc in textile wastewater in primary level was less than 0.7 ppm. After 5 to 25 days treatments Zn removed by *Chlorella* sp. is 0.552ppm to 0.301ppm. After 5 to 25 days treatments Zn removed by *Spirulina* sp. is 0.691ppm to 0.532ppm. After 5 to 25 days treatments Zn removed by consortium of *Chlorella* sp. and *Spirulina* sp. are 0.681ppm to 0.473ppm.

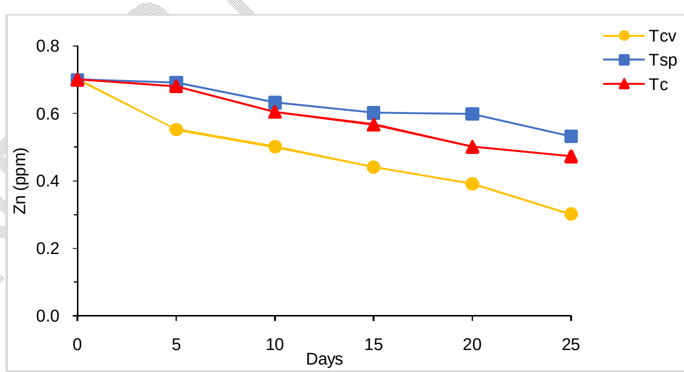

Fig. 12. Differences in the Zn conc. pre and post treatments

3.3.5. Impact over Fe conc. in the sample

There have been seen that Iron in textile wastewater in primary level was less than 0.9145ppm. After 5 to 25 days treatments Fe removed by *Chlorella* sp. is 0.788ppm to 0.501ppm. After 5 to 25 days treatments Fe removed by *Spirulina* sp. is 0.879ppm to 0.632ppm. After 5 to 25 days treatments Fe removed by consortium of *Chlorella* sp. and *Spirulina* sp. are 0.867ppm to 0.603ppm.

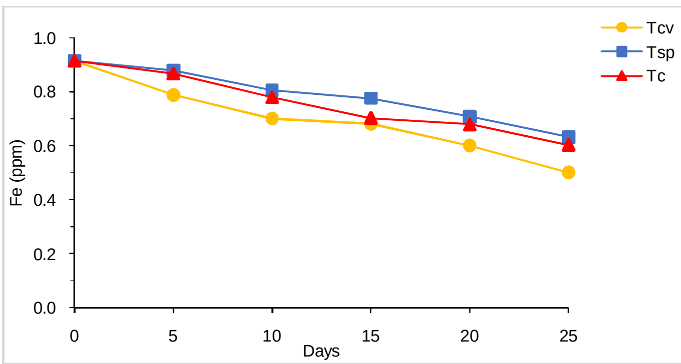

Fig. 13. Differences in the Fe conc. pre and post treatments

Comment [DG5]: Is when the discussion?

4. Conclusion

Biological remediation of tannery effluent is a cost-effective, environment-friendly, and easily accessible method that significantly removes heavy metals from the environment. The study suggests that treating textile wastewater with cyanobacteria *(Spirulina platensis* and *Chlorella vulgaris*) can effectively remove pollutants, reduce COD, TDS, and EC and increase DO.*C. vulgaris*: Zn > Cr > Pb > Cd >Fe and S. *platensis*: Cd > Zn >Pb> Fe > Cr, and the combination treatment: Pb > Cd > Zn > Fe >Cr. The observation showed high efficiency of *S. platensis* in TDS reduction and Zn absorption and *C. vulgaris* in COD reduction and Pb absorption. Based on the current research, it can be concluded that after the treatments with microalgae most of the physicochemical parameters decreased below the permissible limit. The observation suggested an overall improvement of textile effluent quality can be improved. Further investigation is needed to optimize conditions for the bioremediation of Cr and Pb from contaminated sites. Therefore, further investigation is undergoing to study their combined potential in larger-scale textile wastewater treatment more precisely.

Comment [DG6]: It is necessary to comment on the highest and lowest concentration of the metal and not all metals

Comment [DG7]: It is necessary to comment on the highest and lowest concentration of the metal and not all metals

Comment [DG8]: It is necessary to comment on the highest and lowest concentration of the metal and not all metals

Data Availability

All data created for this research are provided within the article/supplementary material; further enquiries can be directed to the corresponding author(s).

References

1. Alvarez, E.A., Mochon, M.C., Sánchez, J.J. and Rodrı́guez, M.T., (2002). Heavy metal extractable forms in sludge from wastewater treatment plants. Chemosphere, 47(7), pp.765-775.
2. Noor, R., Ahmed, T. and Munshi, S.K., (2017). State of bioremediation in Bangladesh: current concept and implementation compared to global approaches. CLEAN–Soil, Air, Water, 45(1).
3. Roy, C., Jahan, M. and Rahman, S., (2018). Characterization and treatment of textile wastewater by aquatic plants (macrophytes) and algae. Eur J Sustain Dev Res, 2(3), p.29.
4. Jiries, A.G., Al Nasir, F.M. and Beese, F., (2002). Pesticide and heavy metals residue in wastewater, soil and plants in wastewater disposal site near Al-Lajoun Valley, Karak/Jordan. Water, air, and soil pollution, 133(1), pp.97-107.
5. Ramachandran, P., Sundharam, R., Palaniyappan, J. and Munusamy, A.P., (2013). Potential process implicated in bioremediation of textile effluents: a review. Adv Appl Sci Res, 4(1), pp.131-145.
6. Dhote, J., Ingole, S. and Chavhan, A., (2012). Review of wastewater treatment technologies. International journal of engineering research & technology, 1(5), pp.1-10.
7. Dixit, R., Malaviya, D., Pandiyan, K., Singh, U.B., Sahu, A., Shukla, R., Singh, B.P., Rai, J.P., Sharma, P.K., Lade, H. and Paul, D., (2015). Bioremediation of heavy metals from soil and aquatic environment: an overview of principles and criteria of fundamental processes. Sustainability, 7(2), pp.2189-2212.
8. Bayoumi, M.N., Al-Wasify, R.S. and Hamed, S.R., (2014). Bioremediation of textile wastewater dyes using local bacterial isolates. International Journal of Current Microbiology and Applied Sciences, 3(12), pp.962-970.
9. da Silva Oliveira, A., Bocio, A., Beltramini Trevilato, T.M., MagossoTakayanagui, A.M., Domingo, J.L. and Segura-Muñoz, S.I., (2007). Heavy metals in untreated/treated urban effluent and sludge from a biological wastewater treatment plant. Environmental Science and Pollution Research-International, 14(7), pp.483-489.

10. Wang, L., Min, M., Li, Y., Chen, P., Chen, Y., Liu, Y., Wang, Y. and Ruan, R., (2010). Cultivation of green algae Chlorella sp. in different wastewaters from municipal wastewater treatment plant. Applied biochemistry and biotechnology, 162(4), pp.1174-1186.
11. Darwesh, O.M., Moawad, H., El-Rahim, W.M.A., Barakat, O.S. and Sedik, M.Z., (2014). Bioremediation of textile reactive blue (RB) azo dye residues in wastewater using experimental prototype bioreactor. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 5(4), pp.1203-1219.
12. Dwivedi, P. and Tomar, R.S., (2018). Bioremediation of textile effluent for degradation and decolorization of synthetic dyes: a review. International Journal of Current Research in Life Sciences, 7(4), pp.1948-1951.
13. Ali, S., Rizwan, M., Ibrahim, M., Nafees, M. and Waseem, M., (2017). Role of bioremediation agents (bacteria, fungi, and algae) in alleviating heavy metal toxicity. In Probiotics in agroecosystem (pp. 517-537). Springer, Singapore.
14. Salgueiro, J.L., Perez, L., Maceiras, R., Sanchez, A. and Cancela, A., (2016). Bioremediation of wastewater using Chlorella vulgaris microalgae: Phosphorus and organic matter. International Journal of Environmental Research, 10(3), pp.465-470.
15. Jahan, M. A. A., Akhtar, N., Khan, N. M. S., Roy, C. K., Islam, R., & Nurunnabi, M. (2014). Characterization of tannery wastewater and its treatment by aquatic macrophytes and algae. Bangladesh Journal of Scientific and Industrial Research, 49(4), 233-242.
16. Lim, S.L., Chu, W.L. and Phang, S.M., (2010). Use of Chlorella vulgaris for bioremediation of textile wastewater. Bioresource technology, 101(19), pp.7314-7322.
17. Chen, H. and Pan, S.S., (2005). Bioremediation potential of spirulina: toxicity and biosorption studies of lead. Journal of Zhejiang University. Science. B, 6(3), p.171.
18. A Study on the TDS Level of Drinking Mineral Water in Bangladesh, Mohammad Rafiqul Islam, Mohammad Khairul Islam Sarkar, Tanzina Afrin, Shafkat Shamim Rahman, Rabiul Islam Talukder, Barun Kanthi Howlader, Md. Abdul Khaleque. American Journal of Applied Chemistry 2016; 4(5): 164-169
19. Effect of Nanotechnology on Cancer Disease, Mohammad Khairul Islam Sarkar, Hafij Ali, Mahmudullah Bhuiya, Lutfa Akther, Chapol Kumar Roy, Mohammad Rafiqul Islam, and Md. Rasel Bhuiyan; Journal of Bionanoscience, Volume 12, Number 3, June 2018, pp. 297-315(19); American Scientific Publishers DOI: https://doi.org/10.1166/jbns.2018.1532.

20. Kulkarni, S.D., Auti, T. and Saraf, S., (2016). Bioremediation study of dairy effluent by using Spirulina platensis. Res. J. Life Sci. Bioinform. Pharm. Chem. Sci, 1(6), p.325.

21. Abdel-Razek, M.A., Abozeid, A.M., Eltholth, M.M., Abouelenien, F.A., El-Midany, S.A., Moustafa, N.Y. and Mohamed, R.A., (2019). Bioremediation of a pesticide and selected heavy metals in wastewater from various sources using a consortium of microalgae and cyanobacteria. Slov Vet, 56(Suppl 22), pp.61-73.

22. Moradi, Z., Haghjou, M.M., Zarei, M., Colville, L. and Raza, A., (2021). Synergy of production of value-added bioplastic, astaxanthin and phycobilin co-products and Direct Green 6 textile dye remediation in Spirulina platensis. Chemosphere, 280, p.130920.

23. Andrade, C.J. and Andrade, L.M., (2018). Microalgae for bioremediation of textile wastewater. An overview. MOJ Food Process Technol, 6(5), pp.432-433.

24. Salam, O.E.A., Reiad, N.A. and ElShafei, M.M., (2011). A study of the removal characteristics of heavy metals from wastewater by low-cost adsorbents. Journal of Advanced Research, 2(4), pp.297-303.

25. Sarayu, K. and Sandhya, S., (2012). Current technologies for biological treatment of textile wastewater–a review. Applied biochemistry and biotechnology, 167(3), pp.645-661.

26. April L. Ulery, Robert Flynn & Ramona Parra (2004) Appropriate Preservation of Dairy Wastewater Samples for Environmental Analysis, Environmental Monitoring and Assessment volume 95, pages117–124.