Assessment of Phycoremediation Efficiency of Spirogyra Sp. Using Sugar Mill Effluent

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Abstract**—***Phycoremediation is the use of algae for the removal of pollutants from wastewater since algal species are relatively easy to grow, adapt and manipulate within a laboratory setting and appear to be ideal organisms for use in remediation studies. The present investigation was carried out to determine the phycoremediation potential of Spirogyra sp. using sugar mill effluent. The results of the present study revealed that sugar mill effluent is considerable loaded with TDS, EC, BOD, COD, TKN,* PO_4^{3-} *, Ni, Cr, Fe and Mn. The phycoremediation studies showed that the maximum removal of TDS (24.92%), EC (14.47%), pH (11.47%), BOD (47.82%), DO (21.46%), COD (15.73%), TKN (40%),* PO_4^{3-} *(44.44%), Ni (42.79%), Cr (40.74%), Fe (24.78%) and Mn (34.92%) was recorded after 60 days of phycoremediation experiments using Spirogyra sp. moreover, the removal of TDS, EC, BOD, COD, TKN,* PO_4^{3-} *, Ni, Cr, Fe and Mn of the sugar mill effluent was progressively increased at 15, 30, 45 and 60 days of phycoremediation experiments using Spirogyra sp. Therefore, the phycoremediation study clearly indicated the effectiveness of microalgae Spirogyra sp. for the removal of nutrients and heavy metals present in the sugar mill effluent.*

Keywords—Sugar mill effluent, Phycoremediation, Physico-chemical characteristics, Heavy metals, Spirogyra sp.

I. INTRODUCTION

Rapid urbanization and industrialization is placing an unprecedented pressure on water quality and demand (Kumar, 2015; Kumar and Chopra, 2016). There are numerous other constraints such as inefficient infrastructure, weak, urban and municipal regulation, inadequate financial services together set to bring deterioration in environment quality (Shah *et al.*, 2010; Padmapriya and Murugesan, 2012; Ali *et al.*, 2013; Kumar and Chopra, 2014). Industrial pollution affects the quality of pedosphere, hydrosphere, atmosphere, lithosphere and biosphere (Mohammad *et al.*, 2008; Bieby *et al.*, 2011; Kumar and Chopra, 2015). Sugar mill play a major role in polluting the water bodies and land by discharging a huge amount of wastewater as effluent. Several chemicals are used during the sugar manufacturing process mainly for coagulation of impurities and refining of the end products (Kumar, 2015; Srivastava *et al.*, 2015). Large amount of effluent generated during the manufacture of sugar contains a high amount of pollution load particularly suspended solids, organic matters, press-mud, bagasse and air pollution (Muthusamy *et al.*, 2012; Thambavani and Sabitha, 2012).

Discharge of sugar industry effluent to the land of irrigation influences the physico-chemical properties of soil (Nagaraju and Rangaswami, 2007; Kumar and Chopra, 2010). The increasing load of heavy metals has caused imbalance in aquatic ecosystems and the biota growing under such habitats accumulate high amounts of heavy metals (Cu, Zn, Cd, Cr and Ni etc.) which in turn, are being assimilated and transferred within food chains by the process of magnification (Pergent *et al.*, 1999; Kumar and Chopra, 2010). The release of industrial and municipal wastewater poses serious environmental challenges to the receiving water bodies (Yang *et al.*, 2008). Wastewater is usually rich in contaminants in the form of nutrients, heavy metals, hydrocarbons etc. The presence of nutrients especially nitrogen (N) and phosphorus (P), in the form of nitrate, nitrite, ammonia/ammonium or phosphorus in wastewater leads to eutrophication (Liu *et al.*, 2010; Yang *et al.*, 2008). Microalgae represent an integral part of the microbial diversity of wastewaters, which can also play a role in the self-purification of these wastewaters (Sen *et al.*, 2013).

Phycoremediation refers to the technology of using algae for the remediation of wastes, predominantly in the treatment of wastewaters as a part of the secondary treatment (Dresback *et al.*, 2001; Sen *et al.*, 2013). The term ‘phycoremediation’ is in vogue for more than a decade, and of late the technology have begun to taste commercial success. A number of articles have been published on phycoremediation research and many authors have successfully established the fact that treatment of wastewaters using algae, microalgae in particular, leads to remarkable reduction of an array of organic and inorganic nutrients, including some of the toxic chemicals (Beneman *et al.,* 1980; Gantar *et al.,* 1991; de-Bashan *et al.,* 2002; Queiroz *et al.,* 2007; Thomas *et al.,* 2016).

Microalgae offer a low-cost and effective approach to remove excess nutrients and other contaminants in tertiary wastewater treatment, while producing potentially valuable biomass, because of a high capacity for inorganic nutrient uptake (Bolan *et al*., 2004; Muñoz and Guieyssea, 2006; Thomas *et al.,* 2016). Using microalgae in continuous treatment processes would be of great advantage, because most industries are in dire exigency for implementing cost-effective continuous treatment processes. Algal species are relatively easy to grow, adapt and manipulate within a laboratory setting and appear to be ideal organisms for use in remediation studies (Dubey *et al.,* 2011; Sen *et al.,* 2013). In addition, phycoremediation has advantages over other conventional physico-chemical methods, such as ion-exchange, reverse osmosis, dialysis and electro-dialysis, membrane separation, activated carbon adsorption, and chemical reduction or oxidation, due to its better nutrient removal efficiency and the low cost of its implementation and maintenance (Dresback *et al*., 2001 Thomas *et al.,* 2016). Microalgae constitute a broad category of organisms encompassing photoautotrophic eukaryotic microalgae and prokaryotic cyanobacteria, which are distributed both in fresh and marine environments, with a wide range of diversity in their thallus organization and habitat (Lee, 2008). The biodiversity of microalgae is enormous and estimated to be about 200,000–800,000 species, out of which about 50,000 species are only described (Starckx, 2012). This enormous diversity and propensity to adapt to extreme and inhospitable habitats has led the scientific community to screen, identify promising strains/species/ genera and develop promising microalgae-based technologies for wastewater treatment (Fouilland, 2012; Thomas *et al.,* 2016).

Spirogyra is a member of the Algae. These are simple plants ranging from single-celled organisms (Chlamydomonas, Euglena) to complex seaweeds. They contain chlorophyll and make their food by photosynthesis (Sen *et al.,* 2013). Spirogyra is a filamentous alga. Its cells form long, thin strands that, in vast numbers, contribute to the familiar green, slimy 'blanket weed' in ponds. Thus the aim of the study was to investigate the performance of *Spirogyra sp.* in improvement of sugar mill effluent quality (Matagi *et al*., 1998; Dubey *et al.,* 2011; Sen *et al.,* 2013). The *Spirogyra sp*. 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; Dubey *et al.,* 2011; Elumalai *et al.,* 2013; Thomas *et al.,* 2016). Therefore, the present investigation was carried out to determine the phycoremediation potential of *Spirogyra sp.* using sugar mill effluent.

II. MATERIALS AND METHODS

Study sites: Rai Bahadur Narain Singh Sugar Mills Ltd. Laksar Haridwar (Uttarakhand) was selected for the collection of sugar mill effluent. The Sugar Mill is located about 24 km away from Gurukula Kangri Vishwavidyalyaya (Haridwar) in the north east. The strains of *Spirogyra sp.* were collected from the local pond situated at village Sarai, Jwalapur Haridwar (Uttarakhand).

Collection of sugar mill effluent samples: The sugar mill effluent was collected from the untreated discharge channel outlet at Rai Bahadur Narain Singh Sugar Mills Ltd. Laksar, Haridwar. The samples were collected in thoroughly cleaned plastic container of 10 Liters capacity. Some of the parameters like pH were carried out on the spot and dissolved oxygen (DO) was also fixed on the spot because time consumed during transportation could alter the results. Remaining parameters could be carried out on composite sample.

Experimental design: Five glass jars of 4 liters capacity were used for the phycoremediation study. 10 Liters sugar mill effluent were taken so as to make 25%, 50%, 75% and 100% concentration respectively and 100 gm strains of *Spirogyra sp.* were transferred in the effluent and the experiments were conducted for 60 days (Plate 1). One glass jar of control is also set up in which 5 liters of ground water is filled.

Effluent analysis: The collected effluent samples are brought to the laboratory. The effluent was analyzed before and after phycoremediation using *Spirogyra sp.* at 0, 15, 30, 45, and 60 days, respectively. The samples were analyzed for various physic-chemical parameters and heavy metals viz., total dissolved solids (TDS), electrical conductivity (EC), pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), TKN, phosphate, Ni, Cr, Fe and Mn following standard method (APHA, 2012; Chaturvedi and Sarkar, 2006).

Heavy metal analysis: The heavy metal concentration in the effluents and bore well water was determined by digesting 200 ml samples with a mixture of concentrated

HNO_3 and $HClO_4$ acid (10 ml + 2 ml). The digested samples were filtered through Whatman filter No. 42 and finally volume were made 10 ml with 0.1 N HNO_3 and analyzed for heavy metals using AAS **(Model ECIL-4129)**.

Data interpretation and statistical analysis: Mean and standard deviation were also calculated with the help of MS Excel 2007. Graphs were plotted with the help of Sigma plot, 2000. The percent removal efficiency was calculated following formula (Hurst *et al.*, 1997).

$$\text{Removal efficiency (\%)} = \frac{Ci - Ce}{Ci} \times 100$$

Where:

Ci = Concentration of the parameter before phycoremediation

Ce = Concentration of the parameter after phycoremediation using *Spirogyra sp.*

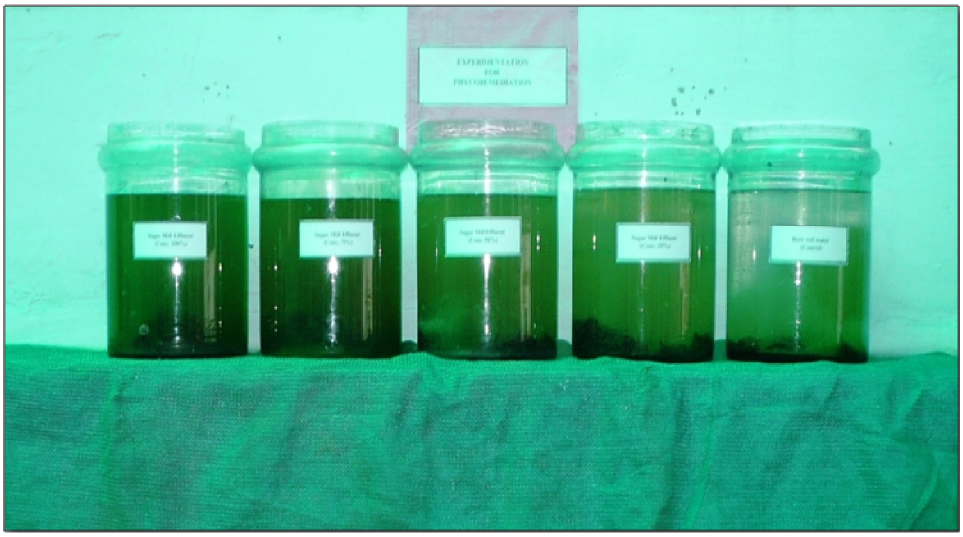

Plate 1: Phycoremediation treatment of sugar mill effluent using Spirogyra sp.

III. RESULTS AND DISCUSSION

Table 1. Phycoremediation of sugar mill effluent using Spirogyra sp. at different days.

Parameter	**Effluent characteristics**					**BIS for irrigation water**
	Before phycoremediation	**After phycoremediation**				
	Days					
	0	**15**	**30**	**45**	**60**	
TDS (mg L^{-1})	985.50 ±9.39	871.96 ±5.15	765.18 ±3.62	750.51 ±1.45	739.83 ±1.09	2100
EC (ds m^{-1})	1.52 ±0.05	1.42 ±0.02	1.37 ±0.03	1.33 ±0.04	1.30 ±0.02	_
pH	8.28 ±0.06	7.56 ±0.31	7.45 ±0.05	7.40 ±0.02	7.33 ±0.03	5.5-9.0
DO (mg L^{-1})	Nil	1.38 ±0.26	2.13 ±0.11	2.14 ±0.02	2.15 ±0.01	_
BOD (mg L^{-1})	144.24 ±1.74	124.71 ±2.81	80.65 ±0.26	78.50 ±0.24	75.26 ±0.37	100

COD (mg L^{-1})	433.76 ±4.74	410.99 ±3.74	383.82 ±3.56	370.98 ±1.45	365.51 ±0.27	250
TKN (mg L^{-1})	31.50 ±3.80	30.00 ±0.82	22.42 ±0.31	20.40 ±0.37	18.90 ±0.02	100
PO_4^{3-} (mg L^{-1})	0.81 ±0.03	0.72 ±0.02	0.54 ±0.03	0.50 ±0.02	0.45 ±0.04	_
Nickel (mg L^{-1})	2.43 ±0.05	2.34 ±0.04	1.69 ±0.04	1.41 ±0.04	1.39 ±0.03	2.0
Chromium (mg L^{-1})	2.43 ±0.04	2.25 ±0.03	1.62 ±0.08	1.51 ±0.03	1.44 ±0.03	2.0
Iron (mg L^{-1})	2.30 ±0.03	2.22 ±0.03	1.87 ±0.08	1.80 ±0.02	1.73 ±0.03	15
Manganese (mg L^{-1})	2.09 ±0.20	1.89 ±0.03	1.43 ±0.04	1.40 ±0.02	1.36 ±0.02	2.0

Mean ± SD of four replicates, - (Not Defined)

Table 2. Percent increase or decrease of different parameters of sugar mill effluent after phycoremediation using Spirogyra sp. at different days.

Parameter	**Percent increase or decrease of parameters after phycoremediation**			
	15 Days	**30 Days**	**45 Days**	**60 Days**
TDS (mg L^{-1})	-11.52	-22.35	-23.84	-24.92
EC (ds m^{-1})	-6.57	-9.86	-12.56	-14.47
pH	-8.69	-10.02	-10.62	-11.47
DO (mg L^{-1})	+13.80	+21.28	+21.40	+21.46
BOD (mg L^{-1})	-13.53	-44.08	-45.57	-47.82
COD (mg L^{-1})	-5.24	-11.51	-14.47	-15.73
TKN (mg L^{-1})	-4.76	-28.82	-35.25	-40
PO_4^{3-}	-11.11	-33.33	-38.27	-44.44
Nickel (mg L^{-1})	-3.70	-30.45	-41.97	-42.79
Chromium (mg L^{-1})	-7.40	-33.33	-37.86	-40.74
Iron (mg L^{-1})	-3.47	-18.69	-21.73	-24.78
Manganese (mg L^{-1})	-9.56	-31.57	-33.01	-34.92

-: Decrease; +: Increase

Changes in characteristics of sugar mill effluent after phycoremediation

The mean ± SD of various physico-chemical and heavy metals characteristics of sugar mill effluent (composite sample) before and after phycoremediation with *Spirogyra sp.* and percent increase and decrease in sugar mill effluent parameters are presented in Tables 1 and 2.

Total dissolved solids (TDS): During the present study, the value of total dissolved solids, TDS 985.50±9.39 mgL^{-}1 was observed in the sugar mill effluent before phycoremediation. After phycoremediation using *Spirogyra sp.* the value of TDS 871.96±5.15, 765.18±3.62, 750.51±1.45 and 739.83±1.09 mgL^{-1} were decreased after 15, 30, 45 and 60 days of phycoremediation experiments, respectively (Table 1). The TDS removal efficiency of *Spirogyra sp.* were recorded 11.52%, 22.35%, 23.84% and 24.92% after 15, 30, 45 and 60 days of the treatment (Table 2). TDS is associated with the dissolved organic matter present in the sugar mill effluent. The considerable and progressive removal of the TDS of sugar mill effluent are likely due to the uptake of various nutrients by *Spirogyra sp.* required for its luxurious growth. The findings are in line with Elumalai *et al.* (2013) who reported the highest reduction (61.71% and 61.38%) of TDS in textile dye industrial effluent treated with *Chlorella vulgaris* and *Scenedesmus obliquus*, respectively.

Electrical conductivity (EC): In the present study the value of electrical conductivity (EC) was observed 1.52±0.05 ds m^{-1} in the sugar mill effluent before phycoremediation. After phycoremediation using *Spirogyra sp.* the value of EC 1.42±0.02, 1.37±0.03, 1.33±0.04 and 1.30±0.02 dSm^{-1} were decreased after 15, 30, 45 and 60 days of phycoremediation experiments, respectively (Table 1). The EC removal efficiency of *Spirogyra sp.* was 6.57%, 9.86%, 12.56% and 14.47% after 15, 30, 45 and 60 days of the treatment (Table 2). The reduction in the EC might be due to the absorption of different ionic species present in the sugar mill effluent after phycoremediation experiments using *Spirogyra sp.* Ahmed and Nizamuddin (2012) also recorded highest value of electrical conductivity (2515µs cm-1) in untreated textile dyeing effluent which is supportive for the present study.

pH: The pH (8.28±0.06) of the sugar mill effluent was recorded to be alkaline before phycoremediation experiments (Table 1). After phycoremediation using *Spirogyra sp.* the value of pH were decreased 7.56±0.31, 7.45±0.05, 7.40±0.02 and 7.33±0.03 at 15, 30, 45 and 60 days of phycoremediation experiments, respectively (Table 2). The pH reduction efficiency of *Spirogyra sp.* was 8.69%, 10.02%, 10.62% and 11.47% after 15, 30, 45 and 60 days of the phycoremediation experiments, respectively (Table 2). Higher pH was reported by Thorat and Wagh (1999) and Sivakumar *et al.* (2011) when they analyzed tannery effluent and textile dyeing effluent respectively.

Dissolved oxygen (DO): At site observation of the value of dissolved oxygen DO was recorded (Nil) mgL^{-1} in the sugar mill effluent (Table 1). After phycoremediation using *Spirogyra sp.* the value of DO were found 1.38±0.26, 2.13±0.11, 2.14±0.02 and 2.15±0.01mgL^{-1} after 15, 30, 45 and 60 days of phycoremediation experiments, respectively (Table 2). The DO was progressively increased 13.80%, 21.28%, 21.40% and 21.46% after 15, 30, 45 and 60 days of the phycoremediation treatment, respectively (Table 2). The increase in DO of sugar mill effluent is likely due to the reduction of BOD, organic and inorganic nutrients of the sugar mill effluent after phycoremediation using *Spirogyra sp.* Similar increase in the DO was also observed in textile effluent treated using *Phormidium valderianum* which supports the present study (Shashirekha *et al.,* 2008).

Biological oxygen demand (BOD): BOD is directly associated with the contents of available organic matter present in the sugar mill effluent. The value of biological oxygen demand BOD 144.24±1.74 mgL^{-1} was observed in the sugar mill effluent before phycoremediation. After phycoremediation using *Spirogyra sp.* the values of BOD were decreased 124.71±2.81, 80.65±0.26, 78.50±0.24 and 75.26±0.37 mgL^{-1} after 15, 30, 45 and 60 days of experiments, respectively (Table 1). The BOD decrease efficiency of *Spirogyra sp.* were recorded 13.53%, 44.08%, 45.57% and 47.82% after 15, 30 45 and 60 days of the phycoremediation experiments (Table 2). The reduction in the BOD of sugar mill effluent is in the conformity of the absorption of various nutrients by *Spirogyra sp.* from the sugar mill effluent. High amount of BOD was also reported in textile dyeing effluent by Desai and Kore (2011), which support the results of the present study.

Chemical oxygen demand (COD): Chemical oxygen demand (COD) is the oxygen required to oxidize the chemical species present in the effluent. During the present study, the higher value of COD was observed 433.76±4.74 mgL^{-1} in the sugar mill effluent before phycoremediation. The values of COD of the effluent were decreased 410.99±3.74, 383.82±3.56, 370.98±1.45 and 365.51±0.27 mgL^{-1} after 15, 30, 45 and 60 days of the phycoremediation experiments, respectively (Table 1). The COD removal efficiency of *Spirogyra sp.* was 5.24%, 11.51%, 14.47% and 15.73% after 15, 30, 45 and 60 days of the phycoremediation treatment (Table 2). The reduction of COD of the sugar mill effluent is associated with the absorption of different inorganic chemical species of the sugar mill effluent by *Spirogyra sp.* during phycoremediation experiments. The decrease in COD was also reported in textile dyeing effluent treated with *Spirulina platensis* (Sivakalai and Ramanathan, 2013) which also supports the finding of the present study.

Total Kjeldahl nitrogen (TKN): Nitrogen is very important for the aquatic microalgae and is associated with different biochemical processes. The total Kjeldahl nitrogen 31.50±3.80 mgL^{-1} was observed in the sugar mill sample effluent before phycoremediation. After phycoremediation using *Spirogyra sp.* the values of TKN were decreased 30.00±0.82, 22.42±0.31, 20.40±0.37 and 18.90±0.02 mgL^{-1} after 15, 30, 45 and 60 days of experiment respectively (Table 1). The TKN removal efficiency of *Spirogyra sp.* were recorded 4.76%, 28.82%, 35.25% and 40% after 15, 30, 45 and 60 days of the treatment (Table 2). The removal of nitrogen contents of the sugar mill effluent is in the conformity of the blooming growth of *Spirogyra sp.* during phycoremediation experiments. The findings of the present study are in accordance with Oliver and Ganf (2000) who

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also noted that all forms of nitrogen are taken up as a nutrient by the microalgae, although the most common nitrogen compounds assimilated by microalgae are ammonium ($NH4^+$) and nitrate ($NH3^-$).

Phosphate: During the present study the value of phosphate (PO_4^{3-}) was observed 0.81±0.03 mgL^{-1} in the untreated effluent of sugar mill. After phycoremediation using *Spirogyra sp.* the phosphate of the effluent were decreased at 0.72±0.02, 0.54±0.03, 0.50±0.02, and 0.45±0.04 mgL^{-1} after 15, 30, 45 and 60 days of the phycoremediation experiments, respectively (Table 1). PO_4^{3-} removal efficiency of *Spirogyra sp.* were recorded 11.11%, 33.33%, 38.27% and 44.44% after 15, 30, 45 and 60 days of the treatment (Table 2). Phosphate is very essential for the growth and act as limiting factor. Plenty of phosphate in the sugar mill effluent caused the eutrophication in the aquatic environment. The removal of phosphate during the phycoremediation of sugar mill effluent using *Spirogyra sp.* is likely due to the uptake of considerable contents of phosphate by *Spirogyra sp.* The results of the present study are in agreement with Dubey *et al.* (2011) who also noted similar trend of phosphate reduction during phycotreatment of industrial effluents using blue green algae. However he recorded highest reduction in phosphate using *Nostoc*, *Oscillotoria* and *Glococapsa* as these algal species had good potential and tolerance to polluted water.

Nickel (Ni): The value of nickel was observed 2.43±0.05 mgL^{-1} in the untreated effluent of sugar mill. After phycoremediation using *Spirogyra sp.* the nickel of the effluent were decreased at 2.34±0.04, 1.69±0.04, 1.41±0.04 and 1.39±0.03 mgL^{-1} after 15, 30, 45 and 60 days of the phycoremediation experiments, respectively (Table 1). The Ni removal efficiency of *Spirogyra sp.* were 3.70%, 30.45%, 41.97% and 42.79% after 15, 30, 45 and 60 days of the phycoremediation treatment (Table 2). Chojnacka *et al*. (2005) studied biosorption of Ni equilibrium of *Spirulina* in the absence of metabolic processes.

Chromium (Cr): The value of chromium was observed 2.43±0.04 mgL^{-1} in the untreated effluent of sugar mill. After phycoremediation using *Spirogyra sp.* the chromium of the effluent were decreased at 2.25±0.03, 1.62±0.08, 1.51±0.03 and 1.44±0.03 mgL^{-1} after 15, 30, 45 and 60 days of the phycoremediation experiments, respectively (Table 1). The Cr removal efficiency of *Spirogyra sp.* were 7.40%, 33.33%, 37.86% and 40.74% after 15, 30, 45 and 60 days of the treatment (Table 2). Gupta *et al*. (2011) also studied biosorption of chromium (VI) from aqueous solutions by green algae *Spirogyra* species which supports the finding of the study.

Iron (Fe): Iron is essential for the synthesis of chlorophyll in the aquatic microphytes. In the present study the value of iron was observed 2.30±0.03 mgL^{-1} in the untreated effluent of sugar mill. After phycoremediation using *Spirogyra sp.* the iron of the effluent were decreased as 2.22±0.03, 1.87±0.08, 1.80±0.02 and 1.73±0.03 mgL^{-1} after 15, 30, 45 and 60 days of the phycoremediation experiments, respectively (Table 1). The Fe removal efficiency of *Spirogyra sp.* were 3.47%, 18.69%, 21.73% and 24.78% after 15, 30, 45 and 60 days of the phycoremediation treatment, respectively (Table 2). The reduction in the content of Fe is likely due to the significant absorption of iron by *Spirogyra sp.* during phycoremediation treatment. Kim *et al.* (2007) also studied the characterization of Iron tolerance and biosorption capacity of bacterium strain CPB4 (*Bacillus* spp.) which supports the finding of the experiment.

Manganese (Mn): In the present study the value of manganese was observed 2.09±0.20 mgL^{-1} in the untreated effluent of sugar mill. After phycoremediation using *Spirogyra sp.* the manganese of the effluent were decreased at 1.89±0.03, 1.43±0.04, 1.40±0.02 and 1.36±0.02 mgL^{-1} after 15, 30, 45 and 60 days of experiment respectively (Table 1). The Mn removal efficiency of *Spirogyra sp.* was 9.56%, 31.57%, 33.01% and 34.92% after 15, 30, 45 and 60 days of the treatment (Table 2). Manganese is associated with catalyze the synthesis of chlorophyll in the aquatic microphytes. The reduction in the manganese content is in the conformity of their absorption during the phycoremediation experiments. Dwivedi (2012) also studied the bioremediation of manganese by *Cladophora glomerata* which empowers the study. Therefore, *Spirogyra sp.* is found to be appreciable in the treatment of sugar mill effluent and have a better nutrient removal capacity.

IV. CONCLUSIONS

The present study concluded that sugar mill effluent showed maximum reduction in the effluent characteristics *viz.*, TDS (739.83±1.09 mgL^{-1}), EC (1.30±0.02 dSm^{-1}), pH (7.33±0.03), DO (2.15±0.01 mgL^{-1}), BOD (75.26±0.37 mg^{L-1}), COD (365.51±0.27 mgL^{-1}), TKN (18.90±0.02 mgL^{-1}), phosphate (0.45±0.04 mgL^{-1}), nickel (1.39±0.03 mgL^{-1}), chromium (1.44±0.03 mgL^{-1}), iron (1.73±0.03 mgL^{-1}), manganese (1.36±0.02 mgL^{-1}) of decrease sugar mill effluent after phycoremediation using *Spirogyra sp.* The decrease of sugar mill effluent parameter is likely due to that *Spirogyra sp.* absorbs the nutrient from the effluent. Moreover, TDS (24.92%), EC (14.47%), pH (11.47%), DO (21.46%), BOD (47.82%), COD (15.73%), TKN (40%),

PO_4^{3-} (44.44%), Ni (42.79%), Cr (40.74%), Fe (24.78%) and Mn (34.92%) of the sugar mill effluent were decreased after phycoremediation using *Spirogyra sp.* Therefore, the microalgae *Spirogyra sp.* have the potential for the removal of various nutrients and heavy metals of the sugar mill effluent. Further investigations are required on the characteristics sugar mill effluent concentrations using *Spirogyra sp.* for phycoremediation.

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