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Nutrient recycling by *Scytonoma multiramosum* and *Pithophora polymorpha* from match factory effluent

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ABSTRACT

The quality of life on earth is linked inextricably to the overall quality of the environment. Environmental pollution and contamination with metals has become a key area of concern. Contamination by toxic metals in the aquatic environment is a widespread phenomenon, especially in the developing countries where high-cost remediation technology is not affordable. Changes in technology and manufacturing practices are providing relief to these problems. However, some of the present methods for environmental cleaning results in the production of harmful by-products. Hence, there is a growing need to develop environment friendly processes to clean the environment without generating harmful byproducts. Microalgae may perform tertiary treatment due to their ability to incorporate inorganic nitrogen and phosphorous for growth and also have the capacity to remove heavy metals as well as some toxic organic compounds. This study examines the possibility of using microalgae to remove metals from match factory wastewater.

Key words: Match factory effluent, Nutrient recycling, micro algae.

INTRODUCTION

Water pollution and the waste disposal is one of the most difficult tasks for the scientist's world over. Industrial wastes and discharges have been recognized as one of the major sources of toxic chemicals polluting the environment. Water pollution is one of the most serious problems faced by man today. Since, water is the universal solvent, which is capable of dissolving or carrying in suspension a variety of toxic materials. Several rivers and other aquatic systems are utilized for the disposing of industrial effluents and sewage.

Most techniques today are based on physical displacement or chemical replacement, generating yet another problem in the form of toxic sludge, the disposal of which adds further burden on the techno-economic feasibility of the treatment process. In view of this, the development of a new technique is necessary to meet the environmental standards at affordable costs. In this regard an innovative technology that is gaining momentum in the field of environmental studies is phycoremediation. This technology is a silent with an answer for all environmental threats. The use of bioprocess to remediate pollutants is described as bioremediation (Mason, 1997). This type of strategy can offer a more suitable alternative to the conventional physical and chemical methods.

The present study aims to analyse physico-chemical properties of untreated and treated wastewater and to evolve effective and economic biological treatment method of match factory effluent using selected microalgae namely *Scytonema multiramosum* and *Pithophora polymorpha*.

MATERIAL AND METHODS

Match factory effluent was collected from

Gudiyattam, Vellore District of Tamilnadu state, India. In order to select organism for the treatment process, microalgal populations were collected at different places from where the effluent was collected, isolated and identified by using the standard manual (Anand, 1998) and were maintained in CFTRI medium (Singh, Dhar, Pabbi, Prasanna and Arora, 2002) and Bold Basal medium following Nicholas and Bold (1965).

To study the role of microalgae in match factory effluent, the following protocols were employed. i) Effluent without *Scytonema multiramosum* and *Pithophora polymorpha* (control) and ii) Effluent treated with *Scytonema multiramosum* and *Pithophora polymorpha.* Experiments were conducted in duplicates and repeated three times. Samples were periodically (every 5th day) analyzed for various physico-chemical parameters by using standard methods (APHA, 2000). The experiment was carried out for 20 days.

RESULTS AND DISCUSSION

In the present study when the match factory effluent was treated with *Scytonema multiramosum* and *Pithophora polymorpha,* the colour changed from slightly blackish to blackish green from the 5th day onwards. The development of effective and low cost technology for the decolorisation of wastewater is important (Inthron *et al.*, 2002). Pure and mixed algal cultures removed 50–70% of colour within three months of incubation and colour reduction pattern showed a rapid removal rate followed by declining removal rate phase. The impact of colour in aquatic system studied by Owne (1990) and reported that altered colour and turbidity reduce net productivity through the alteration of photosynthesis of aquatic plants.

Turbidity in the effluent was found to be reduced by 60.31 percent when the effluent was treated with *Scytonema multiramosum* and 48.68 percent by *Pithophora polymorpha* (Fig.1a). The action of algae is primarily responsible for purification of wastewater rapid purification depends on the unrestricted activities and production of this organism. Bioflocculants are extra cellular macromolecules that are known for their activity to clarify turbid water. The production of these molecules has been observed in green algae (Kaplan *et al.*, 2001) and cyanobacteria (Fattam and Shilo, 1984). Organic suspended solids are found responsible for the turbidity, reduced light penetration and impairment of photosynthetic activity of aquatic life.

Total solids in the present study reduced by 5.45 percent when the effluent was treated with *Scytonema multiramosum* and 23.59 percent by *Pithophora polymorpha* (Fig.1b).

Total dissolved solids in the effluent were found to be reduced by 67.88 percent when the effluent was treated with *Scytonema multiramosum* and 25.11 percent by *Pithophora polymorpha* (Fig.1c). Similar kind of work was reported by (Kannan *et al.*, 2004). The TDS in the effluent renders it unsuitable for irrigation, hence further treatment or dilution is necessary before the effluent is discharged.

Total suspended solids in the effluent were found to be reduced by 14.70 percent by *Scytonema multiramosum* and 33.87 percent by *Pithophora polymorpha* (Fig.1d). In the present study large amount of suspended solids was observed which has been discharged by industries. Similar observations have been made by Govindan and Sundaralingam (1977) in textile mill effluents. The high amount of suspended solids caused stable temperature in the effluent and could affect the productivity by interfering with the light penetration on the receiving wetlands.

The pH of the effluent which was 6.4 was reduced by 5.96 with *Scytonema multiramosum* and 6.12 with *Pithophora polymorpha* (Fig.1e). The pH of the effluent was reduced by *Scytonema multiramosum* and *Pithophora polymorpha*. in the medium (Subramanian, 1982; Subramanian and Shanmugasundaram, 1986). Similar kind of acidic nature of sugar effluent was reported by many workers (Jesudass and Akila, 1996; Senthil kumar *et al.*, 2001 and Kannan *et al.*, 2004). Most of the strains were found to tolerate increasing concentrations of effluent up to 100% though there was a different response. *Scytonema multiramosum* showed better growth in the effluent.

Hardness of water is due to carbonate of calcium, magnesium, silicate and phosphate. Hardness in effluent would make it unsuitable for industrial purpose as it may cause scaling of equipments (Goel *et al.*,1994). In the present study calcium was reduced to 70 percent by *Scytonema multiramosum* and 35 percent by *Pithophora polymorpha* (Fig.1f). Similarly magnesium was reduced to 80 percent by *Scytonema multiramosum* and 8.88 percent by *Pithophora polymorpha* (Fig.1g) proving efficient uptake of the algae. Even though, calcium is undoubtedly required for cyanobacterial growth (Fogg *et al.*, 1973), substantial reduction in calcium level cannot be explained by uptake. Divalent cations such as calcium and magnesium are known to be essential for flocculation and would co-flocculate (Richmonad and Becker, 1986).

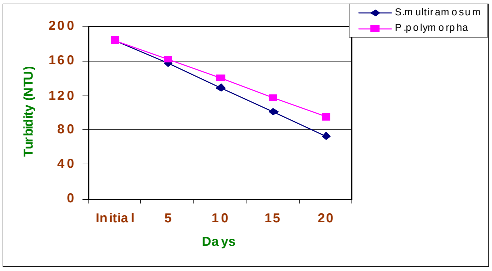
In the present study, 73.72 percent of sodium was reduced when the effluent was treated with *Scytonema multiramosum* and 28.18 percent by *Pithophora polymorpha* (Fig.1h)*;* similarly, 73.33 percent of potassium was reduced by *Scytonema multiramosum* and 30.00 percent of potassium reduced when the effluent was treated with *Pithophora polymorpha* (Fig.1i). Kelly (1951) pointed out the importance of sodium in assessing the suitability of water for irrigation. He has also stressed that the excess of sodium ion in irrigation water causes clogging of particles. Increased sodium content in effluent responsible for the high salinity (Ramasubramanian *et al.*, 2006).

In the present study, 11.14 percent of iron was increased when the effluent was treated with *Scytonema multiramosum* and 11.14 percent iron was reduced by *Pithophora polymorpha* (Fig.1j). Similar observations were reported by Senthil Kumar (2001) and Kannan *et al.* (2004). In the rapid stage, the metal ions are adsorbed on to the surface of microorganism. In the slow stage, the metal ions transport across the cell membrane into the cytoplasm. Most of the algal forms occurring in the polluted fields have well defined sheath. Only the ensheathed forms of blue-green algae were found tolerating high concentrations of industrial effluents in laboratory culture (Adhikary, 1985; Adhikary & Sahu, 1988). Thus it is fairly convincing that these outermost surface structures play an important role in making ensheathed forms of blue green algae thrive in adverse conditions.

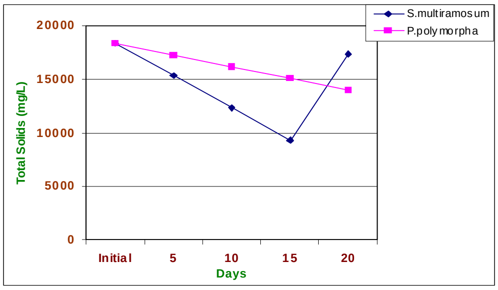
In the present study, nitrate was reduced to 7.27 percent, when the match factory effluent was treated with *Scytonema multiramosum* and 24.24 percent by *Pithophora polymorpha* (Fig.1k)*.* Vilchez and Vega (1994) reported that alginate-entrapped *Chlamydomonas reinhardtii* cells provide a stable and functional system for removing nitrogenous contaminants from wastewater. As light intensity increased, a proportional increase in nitrate uptake was observed. These results indicate that cellular nitrate uptake is a growth-dependent process: the higher the algal growth rate the higher the cellular nitrate uptake rate. Therefore, any efforts in improving algal growth rates will likely lead to the enhancement of nitrate removal. The nitrate removal was mainly a result of assimilation by the algae.

Chlorides are generally considered as one of the major pollutants in the effluents which are difficult to be removed by conventional biological treatment methods. In the present study, 74.13 percent of chloride was reduced when the effluent was treated with *Scytonema multiramosum* and 18.65 percent by *Pithophora polymorpha* (Fig.1l)*.* Uma and Subramanian (1990) observed a 30 percent chloride reduction under laboratory conditions by Halo bacterium and only additional 12-17 percent with cyanobacteria in ossein effluent. In the present study sulphate content in the effluent was found to be reduced to 69.30 percent when the effluent was treated with *Scytonema multiramosum* and 55.03 with *Pithophora polymorpha* (Fig.1m)*.* The high sulphate content in wastewater is harmful to the aerobic and anaerobic wastewater treatment.

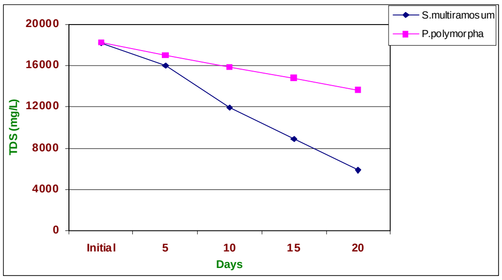
In the present study phosphate content in the effluent was found to be reduced to 46.29 percent when the effluent was treated with *Scytonema multiramosum* and 25.39 percent with *Pithophora polymorpha* (Fig.1n). The increase of phosphate with all carbon sources was appreciably low at higher NH_4^+-N concentrations in the waste, but it was quite high at lower concentrations. The reason attributed for such behavior was the limited biological uptake of phosphorus. Further, the cyanobacteria are known to absorb and store large amounts of phosphorus as polyphosphate granules (Fogg *et al.*, 1973). Megharaj *et al.,* (1992) reported


S.multiramosum
P.polymorpha
Turbidity (NTU)
200
160
120
80
40
0
Initial
5
10
15
20
Days

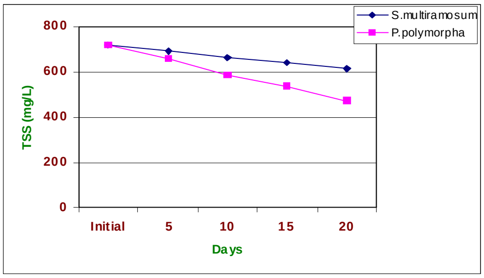
(a)


S.multiramosum
P.polymorpha
Total Solids (mg/L)
20000
15000
10000
5000
0
Initial
5
10
15
20
Days

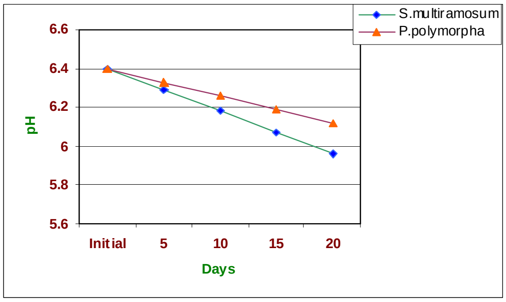
(b)


S.multiramosum
P.polymorpha
TDS (mg/L)
20000
16000
12000
8000
4000
0
Initial
5
10
15
20
Days

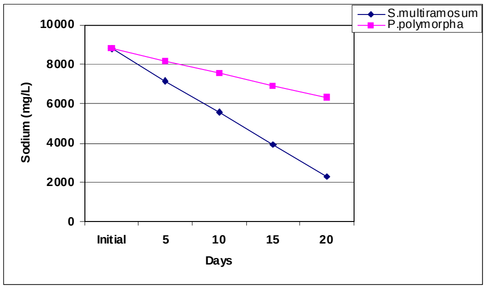
(c)


S.multiramosum
P.polymorpha
TSS (mg/L)
800
600
400
200
0
Initial
5
10
15
20
Days

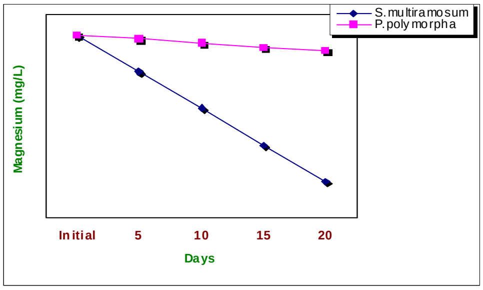
(d)


S.multiramosum
P.polymorpha
pH
6.6
6.4
6.2
6
5.8
5.6
Initial
5
10
15
20
Days

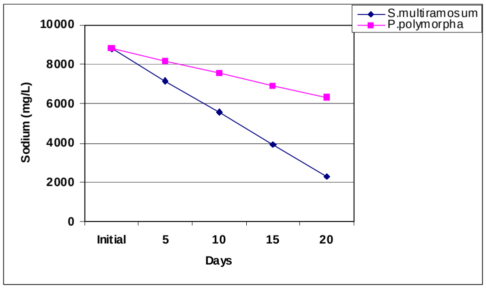
(e)


S.multiramosum
P.polymorpha
Sodium (mg/L)
10000
8000
6000
4000
2000
0
Initial
5
10
15
20
Days

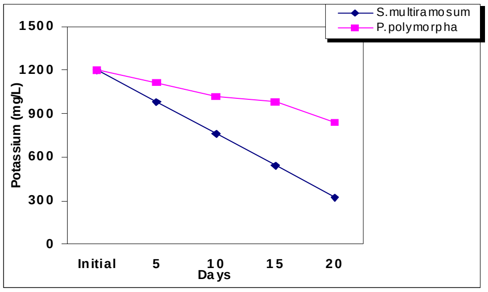
(f)


S.multiramosum
P.polymorpha
Magnesium (mg/L)
Initial
5
10
15
20
Days

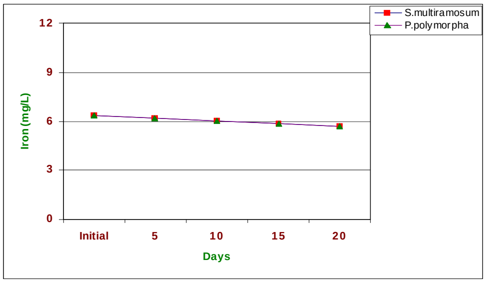
(g)


S.multiramosum
P.polymorpha
Sodium (mg/L)
10000
8000
6000
4000
2000
0
Initial
5
10
15
20
Days

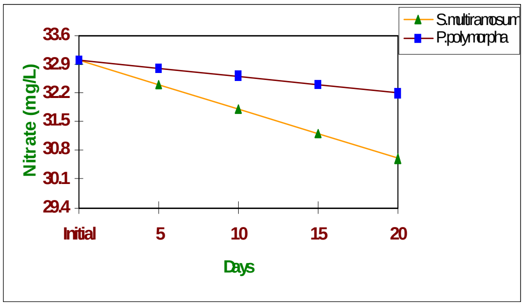
(h)


S.multiramosum
P.polymorpha
Potassium (mg/L)
1500
1200
900
600
300
0
Initial
5
10
15
20
Days

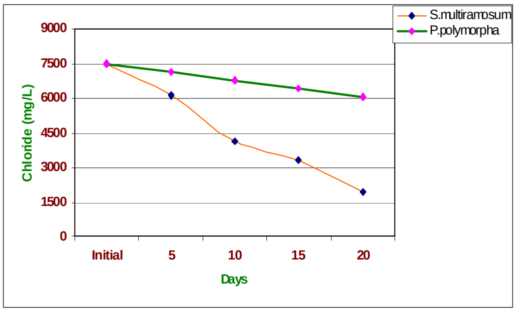
(i)


S.multiramosum
P.polymorpha
Iron (mg/L)
12
9
6
3
0
Initial
5
10
15
20
Days

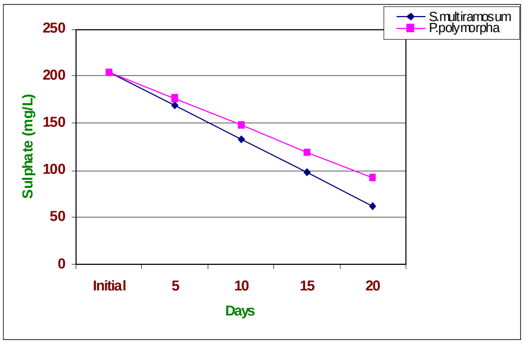
(j)



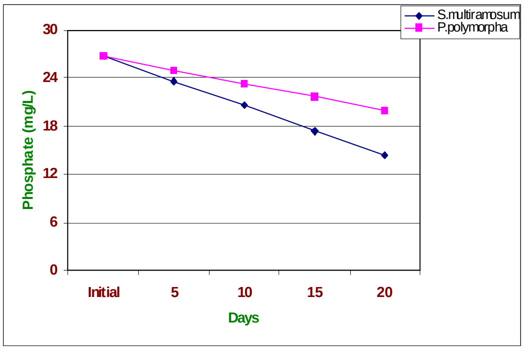
(k)



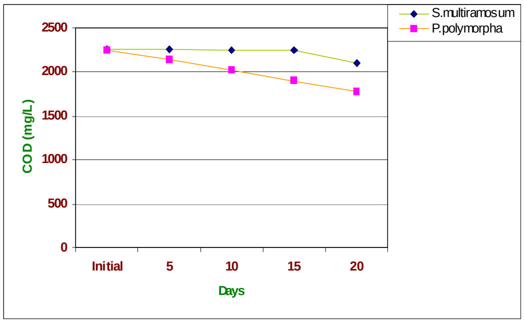
(l)



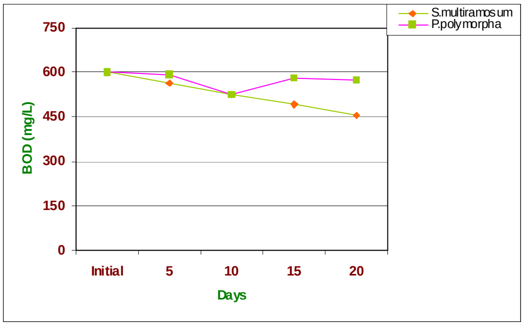
(m)



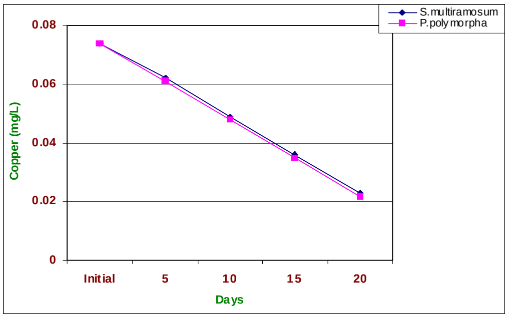
(n)



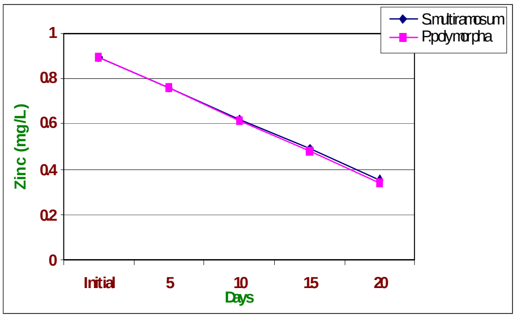
(o)



(p)



(q)



(r)

Fig.1. Changes in the concentrations of a) Turbidity b) Total solids c) TSS d) TDS e) pH f) Calcium g) Magnesium h) Sodium i) Potassium j) Iron k) Nitrate l) Chloride m) Sulphate n) Phosphate o) BOD and o) COD p) Copper and q) Zinc

that alginate-immobilized *Chlorella vulgaris* was more efficient in removing both the nutrients (N and P) from wastewater than *Scenedesmus bijugatus*. Exponentially growing cells of both the algae effected a greater uptake of phosphorus, whereas the age of the cultures was found to have no direct impact on the removal of nitrogen. Kaya and Picard (1996) conducted an experiment with immobilized *Scenedesmus bicellularis* using high and low viscosity chitosan and konjac flour to enhance the stability of hardened gels during tertiary treatment of wastewaters containing high concentration of phosphate (1M).

Higher values of BOD and COD may be due to presence of organic and inorganic load in wastewater which was decamping and increasing temperature. Singh and Shrivastava (1988) found that the higher values of BOD and COD may be due to high organic pollution, which reduces flow of water. Mishra and Saksena (1989) have reported that BOD and COD are widely recognized as important parameters for measurement of organic load or wastewater. The values of BOD and COD measured through experiments for the wastewater sample showed that the values of the BOD and COD do not follow a linear relationship. The BOD values in the effluent were found to be reduced by 24.00 percent when treated with *Scytonema multiramosum* and 4.00 percent by *Pithophora polymorpha* (Fig.1o).

The COD values in the effluent were found to be reduced by 7.12 percent when treated with *Scytonema multiramosum* and 21.01 percent by *Pithophora polymorpha* (Fig.1p). The match factory waste contains lot of complex organic compounds. Depending on their ratios the waste stream at various outlets, the amount of BOD's have varied widely compared to the COD values. That could be the reason that in some of the values the BOD's have not increased to the extent as compared to the increase in the CODs observed. This was due to the presence of the compounds which are mostly non biodegradable. Since the ratio of the BOD and COD values have changed depending on the type of compounds present it is quite impossible to determine the exact nature and amount of the compound. In this study an attempt was made to find out the best probable relation between the BOD and COD. This observation was in conformity with the studies of Baruah *et al* (1996); Amudha and Mahalingam (1999) and Kumar *et al.,* (2001) in different industrial effluents.

Copper exposure in the environment is inevitable. The effectiveness of copper uptake by microalgae grown in the match factory effluent was studied. The results showed that a high percentage of copper removal (69.10%) was achieved by *Scytonema multiramosum* and 70.46 present by *Pithophora polymorpha* reared in the match factory industry effluent (Fig.1q). Similar results were also obtained by Chan *et al.*, (1981) in mixture of electroplating and sewage effluent. Wundram *et al.*, (1996) in his study concluded that 72% of the variability in species richness could be attributed to increases in copper.

In the present study the zinc reduction occurs up to 60.40 percent when the effluent was treated with *Scytonema multiramosum* and 62.08 percent was reduced by *Pithophora polymorpha* (Fig.1r). Zinc is an essential element for many enzymatic activities (Cheblowski and Coleman, 1986) in plants. However, zinc at toxic concentration affects the growth and metabolism of green plants (Shrotri *et al.*, 1981). Since heavy metals often form the major constituents of complex industrial and energy process wastes, they may cause cellular abnormalities that affect the ability of cells to adjust to polluted conditions.

CONCLUSION

The timely and cost-effective remediation of metal and organic contaminated sites mandate an understanding towards the extent and mechanisms by which toxic metals inhibit organic biodegradation. Past attempts to quantify the impact of metals on biodegradation are difficult to interpret because they have generally been used on total metal rather than solution-phase or bioavailable metal concentrations. The mechanisms by which metals inhibit biodegradation vary with the composition and complexity of the system under study and include both physiological and ecological components. A thorough understanding of these systems, taking into account various levels of complexity is needed to develop new approaches to remediation of contaminated sites. A number of approaches, including addition of metal resistant micro algae, pH adjustment and additives that reduce metal bioavailabity were existing. However, field trials are needed to validate these approaches. Based on the results, it can be concluded that both *Scytonema multiramosum* and *Pithophora polymorpha* have the potential to be used in match factory effluent treatment. Further research is needed to evaluate the potential of micro algal biotreatment on the large scale basis with efficient harvesting methods.

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