International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-2, Issue-5, May 2014

Bioreclamation of Mine Waste Water through Algae: An Experimental Approach

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Abstract— **Mine water pollution is causing a major damage to flora, fauna and ecosystem by affecting its catabolic, metabolic and anabolic mechanism. Huge expenses by government is on progress to treat mine water coming from different coal mines, which includes various processes like treatment of heavy metals, and harmful chemical present in mine water. Many research works are going on in the field of waste water treatment, a newly developed waste water treatment by algae is gaining much importance. It is observed that some algal species having efficiency to remove various heavy metals which degrades the mine water. Bio purification of mine water by using algae, focus on degradation of different harmful component present in mine water. This experiment will be environmentally sustainable and economical way of treating unused waste water for different purposes.**

Index Terms— **Bioreclamation, Mine waste water and Microalgae.**

I. Introduction

The use of algae for waste water treatment is known idea and several researchers have developed techniques for exploiting the fast growth of algae and nutrient removal capacity. The nutrient removal is basically an effect of assimilation of nutrients as the algae grow, but other nutrient stripping phenomena also occur e.g. ammonia volatization and phosphorous precipitation as a result of high pH induced by the algae (Hammouda and Abdet-Raouf, 1994). Some reports revels that a large part approximately 90% of the phosphorous removal is due to this effect (Doran. and Boyle, 1979; Mesple, et.al.,1996; Proulx, et.al.,1994) .

In addition to tertiary treatment, algae may provide heterotrophs in secondary treatment with oxygen and can also be used to absorb e.g. metals from mine waste water. The increase in pH during photosynthesis also has disinfecting effect on the waste water (Noüe, et.al., 1992).

In mining operations huge quantity of water is generated and discharged on the surface or in natural water bodies without any productive use. Under B.C.C.L –Jharia coal mines releases 3,40,120 GPM (2.22 Mm3/day) of water as waste. Algal remediation technology helps in pH correction of the mine waste water, effluent and complete reduction of sludge promoter (Banerjee, et. al., 2002). Microalgae can be helpful in biodegrading of hardness of the organic pollutant. Photosynthetic microalgae have potential for utilizing excessive amount of CO^2 (Benemann and Oswald, 1996). Experts suggest that algal cultivation in waste water is advantageous and perform multiple functions such as CO^2 sequestration and nutrient recovery (Benemann, 2009). Algae of many kinds are really good indicators of water quality and many lakes are characterized based on their dominant phytoplankton groups. Many desmids are known to be present in oligotrophic water (Brook, 1965). Similarly many blue green algae occurs in nutrient –poor waters, while some grow well in organically polluted water (Braarud, 1945).

II. Materials and Methods

The experiment was conducted by taking mine waste water from five opencast coal mining projects (OCP) located at five different sites in district Dhanbad, Jharkhand, India (**Table.2.1**). The mine waste water sample was collected for the chemical analysis for the parameters i.e. pH, temperature, total hardness, Fluoride, Nitrate, Iron, Sulphate, Calcium and Manganese. The algal samples found nearby these OCP was analysed for shape, size and types (**Table.3.3**). The five samples of mine waste water were collected and 10gm algae were kept in each 100ml of mine waste water kept in beaker.

The major objective of this experiment to check the changes occurring in the some of the chemical parameters in mine water after growing algae in the same mine waste water. The treatment process were undertaken for 10 days to observe the significant changes occurring in the mine waste water in the laboratory. All the 10 chemical parameters were studied at initial stage (before putting algal biomass in mine waste water) and after 10 days of algal growth and both the data were compared.

Standard waste water sampling & chemical parameter testing methodology were adopted for the five mine waste water samples collected. Further Standard microscopic methodology was adopted for verifying them for shape, size and types of algae.

A. Site details:

All the five mine waste water were taken from the five diffferent OCP of Jharia coalfield of Bharat Coking Coal Limited (BCCL), a Government of India enterprises navaratan company from Jharkhand State, India.

Manuscript received May 20, 2014.

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Name of OCP	Mine Type	Latitude	Longitude
Dahibari-Basantimata **(MW1)**	OCP	23°42'20"&23°44'40" N	86°43'35"& 86°52'40"E
New Laikdih **(MW2)**	OCP	23°43'15"&23°44'10" N	86°43'35"& 86°51'40"E
Chaptoria **(MW3)**	OCP	23°45'28"&23°45'40" N	86°513'10"&86°57'40" E
Borira **(MW4)**	OCP	23°42'20"&23°44'40" N	86°43'35"& 86°52°40" E
Damagoria **(MW5)**	OCP	23°42'20"&23°44'40" N	86°43'35"& 86°52'40"E

Table 2.1: Geographical location details of different sites

III. Results and Observations

The experiment was conducted for the determination of the chemical changes occurs in all the five mine waste water brought through the four different algae species combindly alltogether grown in all the five different samples of mine waste water for a period of 10 days. The detail chemical analysis findings before and after 10 days of algal treatment were given betow in **Table 3.1** and **Table 3.2**.

Parameter	**Unit**	**Mw1**	**Mw2**	**Mw3**	**Mw4**	**Mw5**
Chloride	*Mg/l*	16	31	41	50	90
Fluoride	*Mg/l*	1.15	1.65	1.15	1	1.25
T.hardness	*Mg/l*	804	668	208	416	936
Nitrate	*Mg/l*	191.6	2.2	1.4	0.02	166.2
Iron	*Mg/l*	0.01	Bdl	Bdl	0.03	0.045
Sulphate	*Mg/l*	375	245	175	170	325
Calcium	*Mg/l*	321.6	267.2	83.2	166.4	374.4
Manganese	*Mg/l*	0.035	0.038	0.231	0.903	0.203
pH	-	7.7	7.5	7.6	7.9	7.5
Temp	*°C*	28	29	28	27	24

Table 3.1: Mine water before algal treatment

Parameter	**Unit**	**Mw1**	**Mw2**	**Mw3**	**Mw4**	**Mw5**
Chloride	*Mg/l*	10	20	32	27	70
Fluoride	*Mg/l*	0.61	Bdl	0.81	0.68	0.35
T.hardness	*Mg/l*	632	584	152	304	892
Nitrate	*Mg/l*	0.8	0.30	0.8	Bdl	1
Iron	*Mg/l*	Bdl	Bdl	Bdl	Bdl	Bdl
Sulphate	*Mg/l*	300	190	150	140	300
Calcium	*Mg/l*	252.8	233.6	60.8	121.60	356.8
Manganese	*Mg/l*	0.008	Bdl	0.12	0.508	0.172
pH	-	7.4	7.1	7.3	7.7	7.2
Temp	*°C*	27	26	25	25	22

Table 3.2: Mine water after algal treatment

Table 3.3 shows that the algal species isolated from the mine water or present in that area were dominant and which survive in highly polluted water of these five mine water microscopically analysed. They were spirogyra, oscillotaria, chara and diatoms. These algae were freshly isolated and collected were used as a test organisms for the treatment of mine waste water. 10gm of all four uniformly suspension of four algal species as initial inoculums of 9 days old culture in each flask containing 100ml of mine waste water samples were treated.

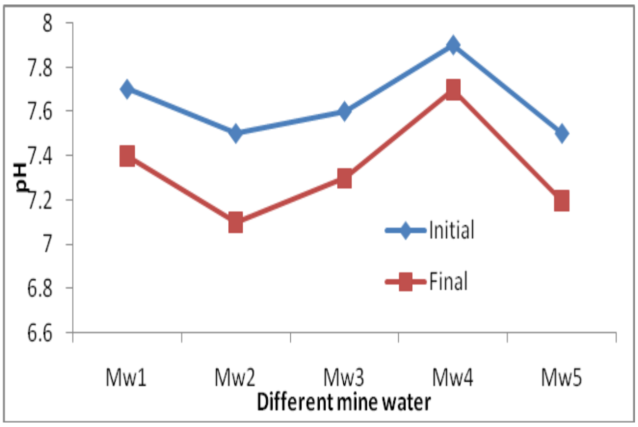
Algae sample	Place	Shape	Size(μm)	type
Spirogyra	Dahibari Basantimata	filamentous	20-40	Red algae
Diatoms	New Laikdih OCP	Round(semicircular)	20-60	Blue green algae (BGA)
Ossilaoria	Chaptoria	Filamentous (cyanobacteria)	2.54.38* 10^9	Red algae
Chara	Borira	Rod like	25-55	BGA
Diatoms	Damagoria	Round(semicircular)	20-60	BGA

Table:3.3: Details of algae used for diffferent mine waste water treatments

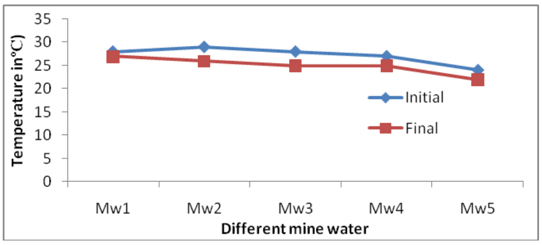
Table 3.1 shows that ten parameters were analysed before treating the five mine waste water with the algae, they are pH, Temperture, Total hardness, Chloride, Fluoride, Nitrate, Iron, Sulphate, Calcium and Manganese.

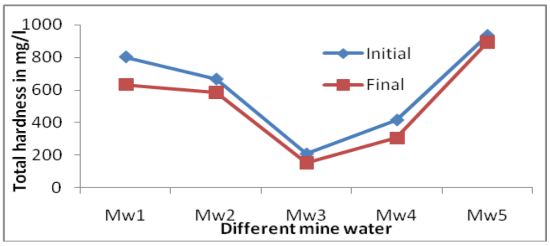
The experiment was conducted under controlled condition for the duration of 10 days and samples were analysed for the same chemical parameter such as pH, Temperture, Total hardness, Chloride, Fluoride, Nitrate, Iron, Sulphate, Calcium and Manganese (**Table.3.2**).

The pH shown by five mine water at initial stage were 7.7, 7.5, 7.6, 7.9, 7.5 in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days pH was analysed and found 7.4, 7.1, 7.3, 7.7 and 7.2 in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.

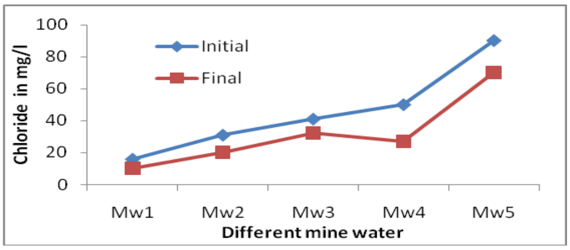


Further, the temperature shown by five mine water at initial were 28°, 29°, 28°, 27°, 24°C in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days the temperature was found 27, 26, 25, 25 and 22° C in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.
Whereas the total hardness shown by five mine water were 804, 668, 208, 416, 936 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days the total hardness was observed 632, 584, 152, 304, 892 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.

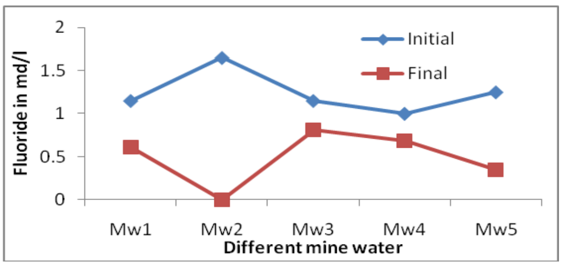




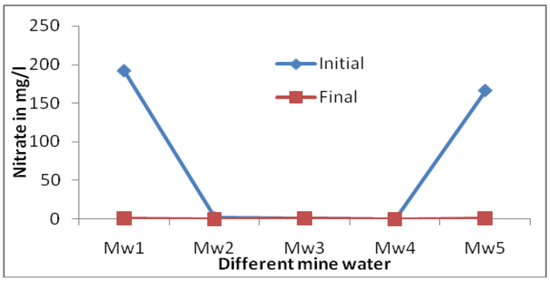
Wherein, the chlorides shown by the five mine water were 16, 31, 41, 50, 90 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days chloride was found 10, 20, 32, 27, 72 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.



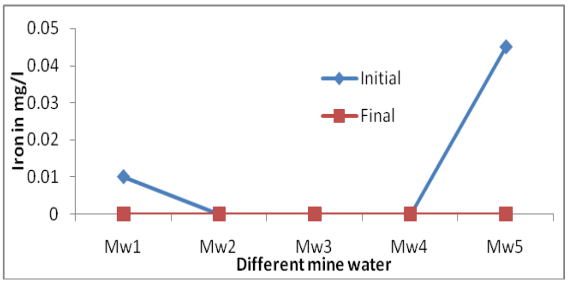
Moreover, the fluorides shown by the five mine water were 1.15, 1.65, 1.15, 1, 1.25 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days fluoride was found 0.61, below detection limit (bdl), 0.81, 0.68, 0.35 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.



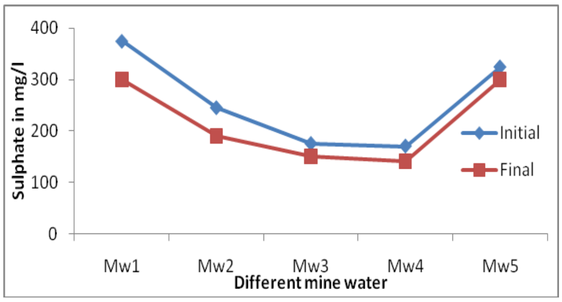
Wherein, the nitrates shown by five mine water were 191.6, 2.2, 1.4, 0.02, 166.2 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days nitrate was found 0.8, 0.30, 0.8, bdl, 1 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.



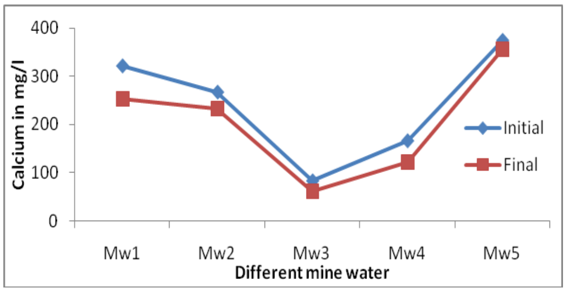
After that the iron shown by the five mine waste water were 0.01, bdl, bdl, 0.03, 0.045 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days iron was found bdl, bdl, bdl, bdl, bdl mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.



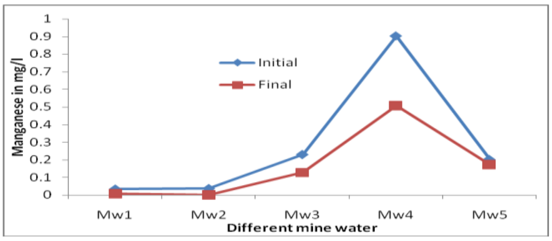
Further, the sulphates shown by five mine water were 375, 245, 175, 170, 325 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days sulphate was found 300, 190, 150, 140, 300 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.



With this calcium shown by five mine water were 321.6, 267.2, 83.2, 166.4, 374.4 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days calcium was found 252.8, 233.6, 60.8, 121.6, 356.8 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.



Along with the manganese shown by five mine water were 0.035, 0.38, 0.231, 0.903, 0.203 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. After 10 days manganese was found 0.008, bdl, 0.12, 0.508, 0.172 mg/l in Mw1, Mw2, Mw3, Mw4, Mw5 respectively.

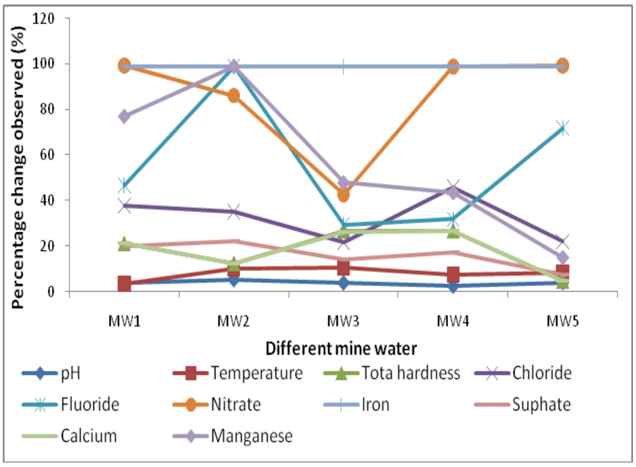


The result shown in **Table. 3.1 and 3.2** shows that algae are increasingly used in waste water treatment for their property to remove nutrients, heavy metals and organic wastes from mine waste water from different sources this is being discuss below.

IV. Finding and Discussion

In the five mine water algae has substantially decrease the pH by 3.8, 5.3, 3.9, 2.5 and 4 percent in in Mw1, Mw2, Mw3, Mw4, Mw5. Respectively. The result is with the agreement of Rajasulochana et. al., 2009. Further, Kshirsagar, 2014 reported that pH firstly decrease when algae is treated in waste water and increase from 5th day of treatment. Manoharan and Subramanyan, 1993 agreed with the findings.

Moreover, in all five mine water Total Hardness were drastically lower down through algae by 21.4, 12.6 , 26.9, 26.9 and 4.7 percent in all the five mine waste water Mw1, Mw2, Mw3, Mw4, Mw5 respectively.



Whereas, in all five mine water chloride were drastically lower down through algae by 37.9, 35.4, 21.9, 46 and 21.2 percent and fluoride reduced by 46.9, 99.0, 29.5, 32.0 and 72.0% in mine waste water in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. This finding is with the agreement of Azarpira et. al., 2014. However Elumalai et. al., 2013 observed very high reduction in chloride of effluent from the textile industry using lorria syndium chonsordium; Ahmad et al 2013, also reported very high reduction in chloride by using chlorella and mixed culture during phycoremediation of sewage water. Similar trend noted by Zaffri & Alvi 2010 reported significant reduction in chloride with oscillotoria, nostoc & spirogyra.

Wherein, all the five mine water nitrate reduction was noticed by 99.5, 86.3, 42.8, 99.0 and 99.3% in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. The reduction in Nitrate is due to utilisation of NO^{3+} while algal species for their growth may be removed in reduction in treated mine waste water. This is an agreement of Azarpira et. al., 2014. The Kshirsagar, 2013 reported best reduction capacity in nitrate from waste water algae. Further Tam Wong 1990 also reported high level of nitrate reduction in waste water through algae.

Further, in all five mine water iron were drastically lower down through algae by 99.0% each and manganese reduced by 71.1, 99.0, 48.0, 43.7 and 15.2% in mine waste water in Mw1, Mw2, Mw3, Mw4, Mw5 respectively. The drastic change in metal concentration in waste water, firstly observed by Oswald and Gootas, 1957. Further heavy metal ions bioaccumulation gained attention only recently by Oswald 1988, and Dhoshi et. al., 2007. Morever Priyadharshani et. al., 2011 elaborated this bio remediation through micro algae in waste water. There have also been reports of accumulation of Cu^{2+}, Pb^{2+} and Cr^{3+} as well as Ni^{2+}, Cd^{2+}, Co^{2+}, Fe^{2+} and Mn^{2+} by algae (Chen et al., 2008, Gupta and Rastogi, 2008, Sari and Tuzen, 2008, Pahlavanzadeh et al., 2010, Gupta et al., 2010, Chakraborty et al., 2011, Lourie and Gjengedal, 2011, Kumar et al., 2012, Tastan et al., 2012 and Piotrowska-Niczyporuk et al., 2012).

In addition to these, in all five mine water sulphate were drastically lower down through algae by 20.0, 22.4 , 14.2, 17.6 and 7.6 percent in all the five mine waste water Mw1, Mw2, Mw3, Mw4, Mw5 respectively. Azarpira, et. al., 2014 reported significant reduction in sulphate by algal species treated waste water. These results are agreement with Chandra et. al., 2004 who reported 99% reduction in sulphate of tannery effluent. Further Ahmad et al 2013 reported considerable reduction in sulphate using mixed algal culture in waste water treatment. Elumalai et. al., 2013, Kumar & Chopara 2012 have same agreement with the finding of this experiment.

While in all five mine water calcium were drastically lower down through algae by 21.4, 12.6 , 27.6, 26.9 and 4.7 percent in all the five mine waste water Mw1, Mw2, Mw3, Mw4, Mw5 respectively.

Beside this, optimal temperature is always maintained by algae for its proper growth in any condition reported by Grobberlar 1982, Sodar 1981, Fontas et. al., 1987, Borowitzka 1988 and Ehivalri et. al., 2000. In **Table 3.1 and 3.2** after the algal treatments in mine waste water the temperature came down from 22°C to 27°C i.e., reduction by 3.5, 10.3, 10.7, 7.4 and 8.3% in all five mine water. Noue et. al., 1992 & Borowitzka 1998 reported that temperature around 15°C to 25°C suits most algal species for optimal growth and for waste water treatment.

VI. Conclusion

From the study it is clear that algal species can improve the quality of mine water by reduction in pH, Temperature, Nitrate, Iron, Chloride, Fluoride, Total Hardness, Sulphate, Calcium and Manganese. The reduction of different parameter of different order found in all fine mine water treated with combine algal culture. The highest potential for phyco remediation for all the above parameter was reported in lowering down concentration in mine waste water. Consequently, different species of algae can be used for sustainable waste water treatment in coal mining areas.

Therefore, It was found that remediation using algal species in mine waste water and effective in environmental issues for mine waste water remediation which not recycle nutrient but also improves mine waste water for other purposes.

ACKNOWLEDGMENT

The author are thankfull to the Director, CSIR- CIMFR, Barwa Road, Dhanbad-826015, Jharkhand, India for providing the facility to complete and permission to publish this article.

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