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Industrial Wastewater Treatment by Microalgae

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Abstract

Today, the most important problem of every industry is how to tackle the wastewater? There are many researchers work on it; several methods are introduced to reduce the pollution due to wastewater, which is caused by many industrial processes. Recently, algae have become significant organisms for biological purification of wastewater since they are able to accumulate plant nutrients, heavy metals, pesticides, organic and inorganic toxic substances and radioactive matters in their cells/bodies.

In this research work, microalgae samples were collected from local river and cultivated in different media solutions. Fully-grown algae was used to treat the wastewater collected from local industries. Microalgae treatment of wastewater reduces the BOD, COD, TDS, TSS, and TS. The percentage reduction of BOD, COD, TSS, TDS, and TS was 86-92%, 82-88%, 60-66%, 47-53%, 45-53% respectively. Ammonium nitrogen reduced to 78-82% and total nitrogen content reduced to 77-83% by the algal treatment on wastewater. The pH is also changes from acidic nature to neutrality.

Key words: wastewater, microalgae, nutrients.

Introduction

The released of organic and inorganic substances into the environment of domestic, agricultural and industrial water activities leads to pollution [1, 2]. Therefore, the most important problem of every industry is how to tackle the wastewater? Several methods are introduced to reduce the water pollution of wastewater which is caused by many industrial processes. The composition of wastewater reflects the life styles and technologies practiced in the producing society. It is a complex mixture of natural organic and inorganic materials as well as man-made compounds. Three quarters of organic carbon in sewage are present as carbohydrates, fats, proteins, Amino acids, and volatile acids. The inorganic constituents include large concentrations of sodium, calcium, potassium, magnesium, chlorine, sulphur, phosphate, bicarbonate, ammonium salts and heavy metals [3, 4].

There are five types of treatment on wastewater: Preliminary treatment, Primary treatment, Secondary treatment, Tertiary treatment, Quaternary treatment. The preliminary treatment is just a physical sedimentation; primary treatment is to remove that settable solids; secondary treatment is to reduce BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand); tertiary treatment is used to remove all organic ions and inorganic ions; while quaternary treatment is to reduce the heavy metals from the wastewater. Tertiary treatment is four to eight times costly than primary treatment, and the quaternary treatment is sixteen times costly than the primary treatment [4, 5].

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The algae are prokaryotic as well as eukaryotic cellular organism. It is defined as ubiquitous group of aerobic photosynthetic organism characterised by presence of photosynthetic pigment and their ability to carry out a plant like photosynthesis [4]. The algae are autotrophic, heterotrophic and mixotrophic in nature depending on the light availability. The most common element in an average algal cell is $C_{106}H_{181}O_{45}N_{16}P$ for optimal growth. There are six phyla of algae and 80000 species of algae currently present on the earth. The detailed classification of algae including phylum, pigments, their cell wall composition and reserved food is shown in table 1. The 50% of total photosynthesis is carried out by algae over the terrestrial plants. These algae are rapidly multiplying cells and their life cycle is very simple. The eukaryotic algae have oxygen evolving photosynthesis and they use inorganic nutrients and carbon as their source of nutrient [6].

The algal treatment is the tertiary treatment but it acts as a secondary as well as quaternary as it reduces BOD, COD and reduce heavy metals also [7]. In addition to tertiary treatment, microalgae may provide heterotrophs in secondary treatment with oxygen, and can also be used to absorb metals from wastewater. The increase in pH during photosynthesis also has disinfecting effect on the wastewater. The waste water exposed with algae shows rapid decreased in the level of metals and the total nitrogen content that is ammonium, nitrate and nitrite [3, 7, 8].

The cost of the tertiary and quaternary treatment is minimised by the treatment on wastewater by using algae. In this research work cultivation of algae is carried out and it is used for the treatment of wastewater form local industries.

Table1: The classification of algae including Phylum, Pigments, their Cell wall composition and reserved food

Phylum	Pigments	Cell wall Composition	Reserve Food
Chlorophycae	Chlorophyll-a,b Carotene, Xanthophylls	Cellulose	Starch
Euglnophyta	Chlrophyll-a,b	No wall	Fats and paramylum
Chrysophyta	Chlorophyll-a,c Caroteneoids	Pectin impregnated with silica	Oil and lecucosin
Pyrrophyta	Caratoneoids, Xanthophylls	Cellulose and pectin	Starch and oil
Phaeophyta (Brown algae)	Chlorophyll-a,c Xanthophylls	Cellulose and alginic acid	Laminarin, Fats
Rhodophyta (Red algae)	Chlorophyll-a, Phycocyanin Phycoerythrin	Cellulose	Starch

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Experimental Methodology

Materials

All the chemical required for the experimental work were procured from reputed firms. Chemical required are: Calcium chloride, Magnesium sulphate, Ferric chloride, Di potassium hydrogen sulphate, Potassium Di hydrogen sulphate, Ammonium chloride, Manganous sulphate, Potassium hydroxide, Potassium iodide, Sodium azide, Concentrated sulphuric acid, Starch indicator, Sodium thiosulphate, Potassium Dichromate, Ferrous ammonium sulphate, Silver sulphate, Mercury Sulphate, Ferroin indicator, Boric acid, Methyl orange pH indicator, Potassium Sulphate. Double distilled water was used throughout the experimental work.

Selection of wastewater

The wastewater is collected from local industries and coded as OPWW-sample-1, OCWW-sample-2 and DSWW-sample-3. All the basic parameters of waste water samples were investigated and listed in table 2.

Table 2: Basic parameters of Wastewater sample collected from local industries.

Parameters	Unit	OPWW-sample-1	OCWW-sample-2	DSWW-sample-3
pH		4.5	4	3
BOD	mg/l	1.25	3.00	1.58
COD	mg/l	425	9000	7500
TSS	mg/l	1500	6000	1250
TDS	mg/l	814000	817000	128000
TS	mg/l	815500	823000	129250
Total Nitrogen	mg/l	64.44	89.6	85.56
Ammonia-N	mg/l	18.94	23.52	20.57

Collection of microalgae

For the wastewater treatment, the mixed culture microalgae are chosen. The algae culture is taken from the Girana River, Jalgaon district. The algae occur in the Girana River is generally blue green algae. The chlorophycae phylum is generally occurs in the Girana river [9].

Media preparation for cultivation of microalgae

Algae sample collected is cultivated in the different types of medium and also cultured in fresh water separately. Different medium was prepared as prescribed, such as CFTRI Medium, BG-11 Medium, BBM Medium and CHU 13 Medium. All the media ingredients were added to double distilled water and final volume was made up to 1 litre. The different medium for algae cultivation is given in the table 3. The pH of all the media were adjusted with the help of 1N HCl and 1N NaOH.

Table 3: Different types of medium for algae Cultivation

Stock Solution	CFTRI Medium,	BG-11 Medium,	BBM Medium.	CHU 13 Medium
$NaNO_3$	1.5g	1.5g	0.25g	-
KNO_3	-	-	-	0.4g
KH_2PO_4	-	-	0.175g	-
K_2HPO_4	0.5g	0.04g	0.075g	0.08g
$MgSO_4.7H_2O$	0.2g	0.075g	0.075g	0.2g
NaCl	1.0g	-	0.025g	-
$CaCl_2.2H_2O$	0.04g	0.036g	0.025g	0.107g
Citric Acid	-	0.006g	-	0.1g
Ferric Ammonium Citrate	-	0.006g	-	0.02g
EDTA (Disodium salt)	-	0.001g	0.05g	-
$FeSO_4.7H_2O$	0.01g	-	0.00498g	-
K_2SO_4	1.0g	-	-	-
KOH	-	-	0.31g	-
Water	-	1 lit	1 lit	1 lit
Trace Metal	-	1 ml	1 ml	1 ml

Source: (www.cap.ac.uk/media/recipes.htm)

The trace element solution used in the media was prepared separately as per the media requirement (table 4) and specified quantity was added culture media. Finally, the culture media was autoclaved at 121ºC for 20 minutes before inoculation with micro algal samples.

Table 4: Different types of Trace metal solutions

Chemicals	**Trace metal 1** (BG-11 Medium)	**Trace Metal 2** (BBM Medium)	**Trace Metal 3** (CHU 13 Medium)
H_3BO_3	2.86 g	0.01142 g	5.72 g
$MnCl_2 \cdot 4H_2O$	1.81 g	1.44 g	3.62 g
$ZnSO_4 \cdot 7H_2O$	0.222 g	8.82 g	0.44 g
$NaMoO_4 \cdot 2H_2O$	0.39 g	-	0.084 g
$CuSO_4 \cdot 5H_2O$	0.079 g	1.57 g	0.16 g
$Co(NO_3)_2 \cdot 6H_2O$	49.4Mg	49.5mg	-
$CoCl_2$	-	-	0.02 g
MoO_3	-	0.71g	-
pH	7.4	6.6	7.5

Source: www.cap.ac.uk/media/recipes.htm

Cultivation of algae

About 20 ml of collected algae was immersed in four media solutions as prepared earlier in a conical flask and plugged with non-absorbent cotton. These flasks were placed in incubator and the growth of microalgae in all four media was observed for 10 – 30 days. An incubator temperature was programmed at 25ºC. light intensity at 2000-2500 lux. Algae culture was exposed alternately to light and dark for 16 and 8 hrs respectively. pH of solution was maintained in the range of 7-8. Among all four medium, BG-11 media was

found suitable for the growth of microalgae. Media solution was filtered and algae was used for wastewater treatment [4, 6, 10, 11].

Microalgal treatment of wastewater

Wastewater treatment by microalgae was conducted in batch operation. Algae developed in media solution was filtered and mixed with about 1000 ml wastewater in 2 lit beaker. Air is circulated through the solution by using air pump. Regularly temperature, colour and pH of the solution was observed for about 10-12 days. After twelve days BOD, COD, TSS, TDS, and TS of treated solution was estimated.

Results and Discussion

Effect of algae growth on pH of wastewater

On the regular interval pH of the samples were observed. Figure 1 represents the variation in pH of all three samples. It has been observed that pH of the all sample approached to neutral value in about 8 to 12 days. This implies that components responsible for acidic nature of the wastewater get reduces. Which are specifically phosphate, nitrates and nitrites.

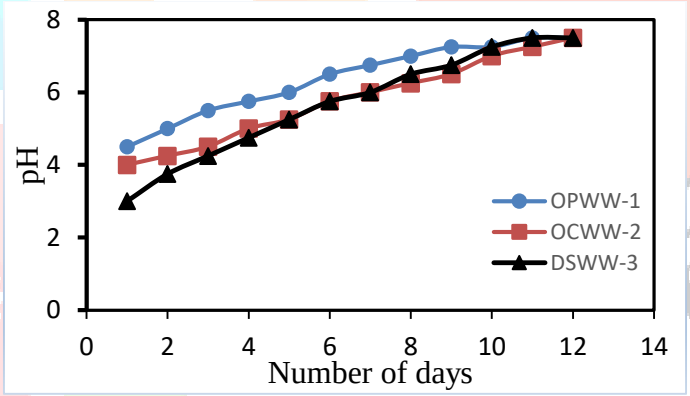

Figure 1. Effect of algae growth on pH of sample

Effect of algae growth on various parameter of wastewater

As the pH of the wastewater sample under treatment increases to 7-8 in 8-12 days, which depends on the initial pH and composition of wastewater. All the samples were treated for twelve days. After twelve days wastewater samples were filtered and different parameters such as BOD, COD, TSS, TS, TDS, total nitrogen (TN), ammonia-nitrogen (AN). Figure 2. represents the percentage reduction of different parameters of wastewater sample after microalgal treatment. After treatment BOD reduced to 86-92%, COD reduced to 82-88%, TSS reduced to 60-66%, TDS reduced to 47-53%, TS reduced to 45-53%, total nitrogen content reduced to 77-83% and ammonium nitrogen reduced to 78-82%. These results support the increase in pH of the sample due to reduction of phosphate, nitrates and nitrites present in wastewater. Reduction in various parameters of wastewater is due to utilization of phosphate, nitrates and nitrites by algae as nutrients. Also, the colour of the wastewater before and after treatment was observed (Figure 3).

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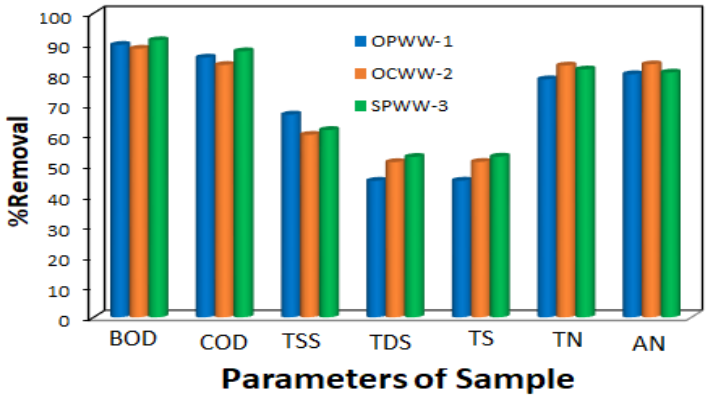

Figure 2: % Removal of different parameters for wastewater sample.

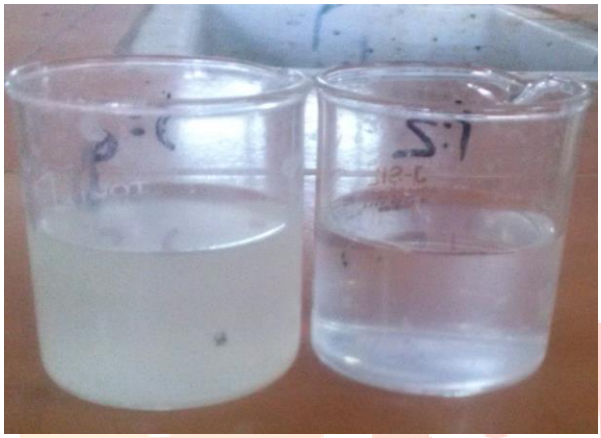

Figure 3: Wastewater sample (OPWW-sample-1) before and after algal treatment

Conclusion

Microalgae (*Chlorophycae)* sample was collected from local river and it was cultivated in BG-11 medium. Cultivated algae was then used to treat the wastewater collected from local industries. Within twelve days, pH changes from acidic nature to slightly neutrality. Reduction of different parameters (BOD, COD, TDS, TSS, TS, TN and AN) of wastewater by microalgae infers that the Microalgae treatment of industrial wastewater can be a substitute to other complex chemical processes. The biomass of the algae after treatment can be used for bio-fuel production, fertilizer production, hydrogen gas production and pharmaceutical. Enormous volume of wastewater can be treated economically and environment friendly by this method.

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