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INVESTIGATION ON ALGAL BIOMASS PROGRESSION IN POLLUTED POND WATER - THE WAY FORWARD

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Abstract

Municipal wastewater treatment is a global issue and an expensive process. Treatment of the wastewater using algal growth is a cost-effective approach, because of easy propagation of algae in wastewaters through utilization of most of the nutrients and in turn reduces the pollution load. As a preliminary research work, laboratory scale studies were done using native algal species collected from particular sources. They were grown in different pond waters to observe the biomass development in comparison to their growth in their original source pond water. Results showed that algal biomass was highest in the pond water, from which the algal sample was obtained followed by other pond water samples, artificial media and control. Biomass showed positive correlations with improvement in water quality parameters and a stationary phase was observed in the later stages of growth. The study also supports the use of native algal species for treatment of wastewaters. Excessive algal growth in water bodies is a serious environmental issue, however in a long-term perspective this biomass can also be harnessed for various other end uses along with wastewater treatment.

Keywords: biomass, pollutant removal, waste reduction, wastewater, water quality

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1. Introduction

Wastewaters generated from municipal and industrial activities are hazardous due to the presence of various pollutants which effect aquatic life when discharged into water bodies. Contamination of these water bodies restricts further use of the water. Therefore, wastewater should be treated prior to its disposal. Sometimes, even after treatment, the treated domestic and agro-industrial wastewater contains considerable amounts of phosphorus and nitrogen. Which when discharged into the water bodies, lead to their eutrophication and subsequent augmentation of algal bloom (Lau et al., 1997; Strungaru et al., 2019). Eutrophication is a serious environmental problem and has become more pervasive since the 20th century (Craggs et al., 2011). Globally, according to a survey conducted by the International Lake Environment Committee, 54% of Asian, 53% of European, and 48% North American lakes are eutrophic (ILEC and LBRI, 1988). According to Woertz et al. (2009), the economic losses due to eutrophication of freshwaters are estimated to be $2.2 billion per year (Woertz et al., 2009).

In view of the above facts, several studies have successfully utilized algae for the treatment of wastewater. The pollutants present in the wastewater are a good source of nitrogen,

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phosphorous, and potassium for algal growth. These algae, while using the N and P for its growth reduces the nutrient load in a few hours to a few days (Abdel-Raouf et al., 2012). Green algae like *Chlamydomonas*, *Euglena*, *Diatoms* have been reported to tolerate organic pollution from wastewaters. In commercial practice, the diluted wastewater is inoculated with particular species of algae obtained from different sources (Delgadillo-Mirqueza et al., 2016; Fatemeh et al., 2014).

However, a dearth of studies exists on comparison of pond wastewater treatment using their native algal species. Native species have greater potential to grow and flourish in their original environment and thus incurring dual benefits of treatment as well as biomass production. The significant amount of wastewater generated from cities can be channelized to increase the amount of produced algal biomass for various beneficial purposes (Craggs et al., 2011; Saleh et al., 2019; Woertz et al., 2009). As a preliminary study, the main objective of the present work was to observe the improvement in water quality due to algal growth followed by the development in algal biomass and productivity in different pond waters.

2. Material and methods

2.1. Study area

Dhanbad district in Jharkhand state of India is one of the biggest coal belts in the country and has been engaged in mining activities for more than a century. There are about 200 coal mines in Jharia coalfields of the district which produce prime coking coal (Singh, 2012). Along with the mining activities, large scale coal-based industries, like coal washeries pollute inland ponds with their discharged wastewater. Despite the predominant mining activities in the district, the selected ponds in this study are not receiving wastewater discharges from the coal based industries and are situated near the municipal residential areas.

The ponds were constructed with an aim to meet the water requirement of the human settlements in the area. Rainfall is the main source of water for these ponds. However, railway discharges and drain water have been found to be released into these pond systems. The annual temperature of the study area varies from 11°C to 38°C. The average annual precipitation is around 1203 mm and the climate is tropical (Climate Dhanbad, 2018).

2.2. Sampling

A field sampling was done in April 2017, followed by analysis in the laboratory. In field sampling, pond water was collected from four designated ponds P1, P2, P3 and P4 situated in Dhanbad district of Jharkhand state in India as shown in Fig. 1. The local names of the ponds are "Bekarbandh", "Ranibandh", "Kusunda" and "Polytechnic" respectively. All the ponds are situated near national highway 32 crossing through the district.

The ponds P1 and P2 are located 2 km from our host institute CSIR-CIMFR, while P3 and P4 is located 7.5 km and 3 km away from the institute respectively. Recreational activities were also found in bigger ponds like P1. During, the summer months (March-June), the ponds start to dry and incur an elevation in algal growth due to the increased concentration of nutrients (Fig. 2). Water samples in replicates were collected in prewashed and sterile 5L bottles. Before sample collection, the bottles were rinsed with the sample itself. The algal samples were collected from P1 wherein the growth was densest. The algal biomass was collected with the help of mesh net (Stevenson and Bahls, 1999). The samples were immediately transported to our laboratory for analysis.

Fig. 2. Algal growth on P1 pond situated near national highway and surrounded by residential complexes

2.3. Water analysis

The collected pond water samples were analyzed for pH using a pH meter (Eutech pHTest10, Oakton, Thermo Fisher) after calibration with standard buffers (of pH 4.0, 7.0, 9.2) and total dissolved solids (TDS) by using the gravimetric technique. Total hardness (TH), calcium (Ca), chloride (Cl), total alkalinity and total acidity were analyzed by volumetric titration methods using ethylene diaminotetraacetic acid, silver nitrate, sulphuric acid and sodium hydroxide solutions, respectively. Magnesium (Mg) was calculated by multiplying the difference of TH and Ca both as $CaCO_3$ with a factor 0.243.

Sulphate (SO_4) was analyzed by gravimetric technique after precipitation with barium chloride. Analysis for BOD (biological oxygen demand) was done by collecting water samples in two BOD bottles. One BOD bottle was incubated in a BOD incubator for 5 days at 20°C, while DO (dissolved oxygen) of the sample in the other BOD bottle was determined on the 1st day. After 5 days of incubation, DO of the water from the incubated bottle was again determined to calculate the difference from the previous DO and obtain BOD. The COD (chemical oxygen demand) of the water samples was determined by titration with ferrous ammonium sulphate after digestion with potassium chromate and sulphuric acid.

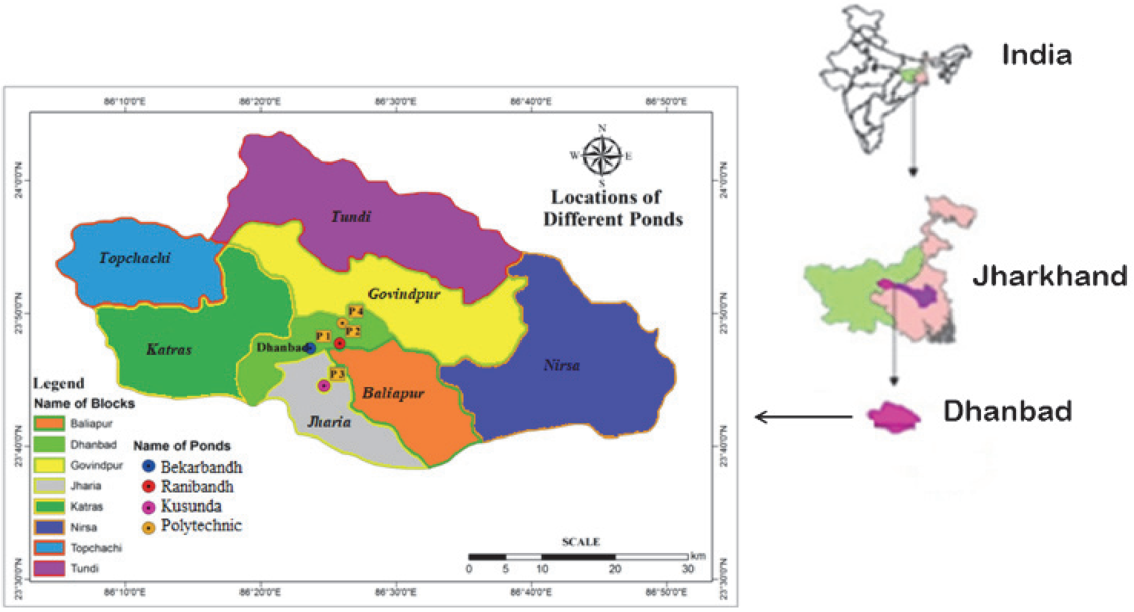


Fig. 1. Location of different ponds in Dhanbad district of Jharkhand State in India

All the analyses were done in triplicates and according to the methods described in American Public Health Association (Greenberg et al., 1992). The calculated data was compared to desirable and permissible limits of Indian drinking water specifications (BIS 10500, 2012) to ensure their suitability for human consumption.

2.4. Algae cultivation experiment

The experiments were carried out in 2000 ml Erlenmeyer flasks. Working volume for the experiment was 1000 ml while the remaining space in the flask was left for promoting gaseous exchange. The ratio of growth medium and inoculum amount was same for all the water samples. First the algal samples collected from P1 were analyzed for shape, size and type through LEICA 10446321, S6D Trinocular stereo Zoom Microscope. The algae were then separated from the field samples by filtering through Whatman 42 filter paper (Chuntapa et al., 2003).

The samples were washed thoroughly with fresh Zarrouk medium (Chuntapa et al., 2003). Thereafter 30 g of the freshly isolated algae were weighed and transferred into four separate flasks containing 1000 mL of pond waters from the four ponds respectively and also in tap water (control). Another flask was also prepared with tap water with added salts like 0.04 g/L calcium chloride, 0.2 g/L magnesium sulphate, 0.5 g/L potassium dihydrogen phosphate, 1 g/L sodium chloride, and 0.01 g/L ferrous sulphate as per Chuntapa et al. (2003). The cultures were mixed and kept on a shaker water bath with temperature control system during the whole study and the temperature was maintained to 25 ± 2°C. The flasks were plugged with non-absorbent cotton wool to allow gaseous exchange for algal growth. Each run was carried out in triplicates to ensure consistency of the results. To validate the performance of algal culture from P1 on water quality improvement, the algal cultures from ponds P2 were also obtained and grown in pond waters P1, P2, P3, P4 and tap water separately while following the similar methodology.

The data obtained from both experiments has been shown in Table 1 and Table 2 respectively. However, a sufficient amount of algal biomass could not be collected from P3 and P4. The study was continued for a month and the change in the water quality as well the algal biomass was recorded after every 5 days. The algal biomass from each flask was filtered out, dried at 80°C in oven for 36 hours, followed by weighing, and subtraction of the weight of the filter paper (Riaz et al., 2018). Growth measurement of algal biomass was done by the formula of productivity (g/L/day) as given below in Eq. (1) (Danesi et al., 2011).

$$Productivity = \frac{Maximum\ \ biomass\ \ concentration\ (g/L) - Initial\ \ biomass\ \ concentration(g/L)}{Cultivation\ \ time\ \ for\ maximum\ \ biomass\ \ concentration\ (days)} \tag{1}$$

For quality control analytical grade (Merck) reagents were used. Reagents were prepared in double distilled water. Glassware used for analyses were washed, rinsed with distilled water, and sterilized before use. All the instruments used in the study were properly calibrated. Further calculation was done using the observed values from laboratory experiments in standard formulas to obtain the actual results (Greenberg et al., 1992) Calculations were performed through Microsoft Excel–2007. Microsoft Excel–2007 was also used to obtain scatter plots between biomass and water quality parameters along with the coefficient of determination between the variables.

3. Result and discussion

The values of all the analyzed parameters in the pond water and tap water samples have been shown in Table 1 and compared to the prescribed desirable and permissible limits (BIS 10500, 2012; EPR, 1986). Tap water parameters were within the desired standard values and had the quality of a safe drinking water. However, pond water had higher ionic content when compared to the standard values (BIS 10500, 2012), which could be beneficial for algal growth. For example, the pH in all the samples ranged from 6.9 - 8.2, which is within the desired range and showed neutral to alkaline nature. The alkaline pH is mainly due to presence of Ca and Mg salts (Shyamala et al., 2008). Tap water had TDS below the desirable limit (500 mg/L) i.e. 117 mg/L unlike other pond water samples which had TDS above desirable limit. This may be due to contamination through the discharges released from nearby household activities. Hardness and Ca also showed a similar trend. Mg was <30 mg/L (desirable limit) in all samples except sample P1 (33 mg/L). Like Mg, alkalinity also showed the lowest value in tap water (68 mg/L) and highest in P1 (202 mg/L). Alkalinity of water provides an idea about the natural salts present in the water (Shyamala et al., 2008). Cl in all the samples was below desirable limit (250 mg/L). Zhou et al. (2012) has reported that waste water containing abundant nutrients like Nitrogen, phosphorus, magnesium, sodium, potassium, iron, calcium, copper, zinc are beneficial for promoting algal growth as found in our study.

Table 1. Change in water quality after algal growth. All the parameters are in mg L^{-1} except pH

Parameters*	***Days***	***Sample***				
		P1	***P2***	***P3***	***P4***	***Tap water***
pH	0	6.9	7.3	8.2	7.2	7.9
	5	7.0	7.3	8.3	7.1	8.0
	10	7.1	7.3	8.3	7.3	8.1
	15	7.1	7.4	8.4	7.3	8.2
	20	7.1	7.4	8.3	7.4	8.2
	25	7.1	7.5	8.4	7.4	8.3
	30	7.1	7.5	8.4	7.4	8.3
Total dissolved solids	0	1141	912	886	644	117
	5	1052	856	820	565	117
	10	987	830	787	516	117
	15	940	817	770	490	115
	20	919	812	760	483	111
	25	908	809	756	477	111
	30	900	807	754	474	107
Total hardness	0	516	416	346	270	64
	5	378	298	240	151	64
	10	314	241	196	107	62
	15	282	217	174	95	61
	20	277	205	162	88	60
	25	269	197	156	81	58
	30	267	195	154	79	58
Calcium	0	152	131	99	86	22
	5	99	82	76	80	22
	10	81	65	63	71	21
	15	74	60	59	69	20
	20	68	56	58	66	20
	25	66	52	58	56	18
	30	60	49	57	51	18
Magnesium	0	33	22	23	13	2
	5	25	22	23	13	2
	10	25	20	23	12	2
	15	21	18	19	12	2
	20	20	17	17	12	2
	25	20	17	16	10	-
	30	19	16	16	8	-
Alkalinity	0	202	110	90	120	68
	5	153	84	79	94	67
	10	145	72	67	88	59
	15	139	70	65	80	56
	20	134	66	61	75	53
	25	132	63	58	74	53
	30	132	62	58	72	52
Chloride	0	82	46	32	66	50
	5	73	39	32	58	50

	10	68	33	26	53	49
	15	66	27	23	51	45
	20	66	27	23	50	41
	25	61	26	19	46	41
	30	60	26	18	39	39
Chemical oxygen demand	0	62	36	56	38	-
	5	58	32	53	33	-
	10	53	28	49	28	-
	15	50	24	47	25	-
	20	49	24	47	25	-
	25	49	23	46	24	-
	30	46	22	45	21	-
Ammonium nitrogen	0	2.13	1.12	0.96	0.77	0.1
	5	1.65	0.83	0.89	0.59	-
	10	1.43	0.71	0.84	0.48	-
	15	1.35	0.68	0.81	0.42	-
	20	1.24	0.64	0.81	0.39	-
	25	1.19	0.62	0.79	0.39	-
	30	1.14	0.58	0.76	0.34	-
Nitrate nitrogen	0	0.42	0.34	0.08	0.05	0.01
	5	0.31	0.30	0.08	0.04	0.01
	10	0.25	0.28	0.07	0.01	-
	15	0.20	0.27	0.03	-	-
	20	0.19	0.25	-	-	-
	25	0.18	0.23	-	-	-
	30	0.17	0.22	-	-	-
Phosphate	0	0.96	0.67	0.12	0.09	-
	5	0.77	0.51	0.11	0.06	-
	10	0.62	0.49	0.11	0.04	-
	15	0.59	0.48	0.08	0.01	-
	20	0.56	0.36	0.04	-	-
	25	0.53	0.33	0.01	-	-
	30	0.51	0.32	0.01	-	-

The values represent mean values of the replicates; The values have been compared to BIS 10500 2012 and EPR 1986; NR: no relaxation
All the values of each parameter were below permissible limit.

In our study, BOD in P1 was higher than the standard permissible limit. The algal species which were isolated from the pond wastewater were mainly *Spirogyra*, *Oscillotaria,* and *Chara*. The microscopic view of algae has been shown in Fig. 3.

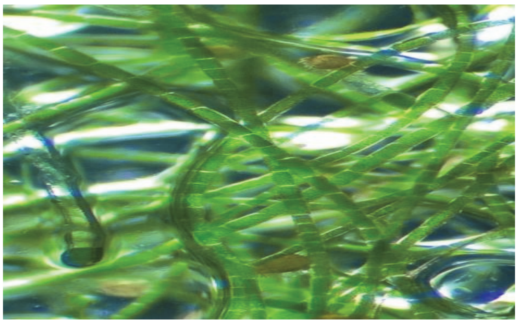


Fig. 3. Microscopic view of algae collected from pond water P1 under 40x resolution

Decrease in the values of above water quality parameters due to algal growth can be observed vividly in Table 1. Potential of native algae for pollutant removal from its source water can be observed by comparing Table 1 and Table 2. The growth of algal biomass and their differences among various media has been shown in Fig. 4. A similar trend was seen even after 30 days with the tap water control showing the least biomass growth. As the ponds were receiving wastewater from municipal settlements, they were enriched with nutrients required for algal growth (indicated by the BOD and COD content) and hence showed higher biomass as compared to the control.

This amount of biomass corresponded to an algal productivity of 0.1 – 0.2 g/L/day after 15 days and 0.1 – 0.4 g/L/day after 30 days (shown in Fig. 5). Researchers have reported a productivity of 0.06 - 3 g/L/day (McGinn et al., 2012; Naqqiuddin et al., 2014). However, the productivity of the algal biomass was less after 30 days compared to 15 days due to attainment of stationary phase (Fig. 4). The growth curves of algae in the media also showed a stationary phase after 30 days (Fig. 4).

In the stationary phase, the cells in the media remain metabolically active and the reproductive rate is balanced by the death rate. Theoretically, in the absence of nutrients, the maximum algal growth rate is attained as per Michaelis Menten kinetics. Balser et al. (2015) reported that stationary phase occurs due to a limiting factor, for example the lack of nitrogen source which results in a reduction in protein content, ultimately leading to death phase. Higher mineral content in P1 depicted the expected highest biomass of algae after 30 days (Fig. 4). This is also supported by the positive correlations and R^2 values (coefficient of determination) obtained from the scatter plots derived between algal biomass and water quality parameters (Figs. 6a, 6b, 6c, 6d, 6e).

The linear regression equations and the R^2 value derived through the plots gave us the relation between the two variables and depicted how close the data were to the fitted regression line. Li et al. (2014) reported a stronger positive correlation between algal biomass and total phosphorus present within a concentration range between 0.09 - 0.16 mg/L. Highest algal growth was found in the P1 flask, pond from which the algae was harvested.

Yanyan et al. (2011) used a treated wastewater sample with an initial COD of 133 mg/L to grow algal bacterial biomass and observed an average biomass productivity of 10.9 ± 1.1 g/m^2 d along with a removal percentage of 98% after 8 days. The growth of algal biomass simultaneously reduces the nutrient content in the wastewater as reported by various authors and listed in Table 3.

Table 2. Change in water quality after algal growth. All the parameters are in mg L^{-1} except pH

Parameters*	***Days***	***Sample***				
		P1	***P2***	***P3***	***P4***	***Tap water***
pH	0	6.9	7.3	8.2	7.2	7.9
	5	6.9	7.3	8.2	7.2	7.9
	10	7.0	7.4	8.2	7.3	8.0
	15	7.1	7.4	8.4	7.4	8.1
	20	7.1	7.5	8.3	7.4	8.2
	25	7.1	7.5	8.4	7.4	8.3
	30	7.2	7.6	8.4	7.5	8.4
Total dissolved solids	0	1141	912	886	644	117
	5	1073	837	851	591	114
	10	1009	811	819	543	111
	15	964	800	803	518	105
	20	944	796	794	512	103
	25	934	793	791	507	100
	30	927	789	785	505	100
Total hardness	0	516	416	346	270	64
	5	389	289	253	163	62
	10	326	233	210	120	61
	15	295	210	189	109	61
	20	291	199	178	103	58
	25	284	191	173	97	54
	30	283	188	172	96	51
Calcium	0	152	131	99	86	22
	5	105	78	85	84	20
	10	88	62	73	80	20
	15	82	58	70	79	18
	20	77	55	70	77	18
	25	76	52	71	68	18
	30	71	50	71	64	17
Magnesium	0	33	22	23	13	2
	5	30	19	30	12	2
	10	31	18	31	11	2
	15	28	17	28	11	-
	20	28	17	27	10	-
	25	29	16	27	10	-
	30	29	14	28	9	-
Alkalinity	0	202	110	90	120	68
	5	164	75	86	106	66
	10	157	64	81	101	57
	15	152	63	80	94	53
	20	148	60	77	90	49
	25	147	58	75	90	48
	30	142	58	76	89	46
Chloride	0	82	46	32	66	50
	5	79	35	30	65	49
	10	75	30	25	61	47
	15	74	26	23	60	42
	20	71	25	19	60	37
	25	69	23	11	57	36
	30	64	20	11	51	33

Chemical oxygen demand	0	62	36	56	38	-
	5	61	28	51	40	-
	10	60	25	48	36	-
	15	58	23	47	34	-
	20	58	23	38	35	-
	25	49	22	38	35	-
	30	47	20	38	33	-
Ammonium nitrogen	0	2.13	1.12	0.96	0.77	0.1
	5	1.71	0.82	0.96	0.66	-
	10	1.5	0.69	0.93	0.56	-
	15	1.43	0.65	0.91	0.51	-
	20	1.33	0.6	0.90	0.49	-
	25	1.29	0.57	0.90	0.5	-
	30	1.25	0.52	0.89	0.46	-
Nitrate nitrogen	0	0.42	0.34	0.08	0.05	0.01
	5	0.36	0.28	0.08	0.01	-
	10	0.31	0.27	0.08	-	-
	15	0.27	0.27	0.01	-	-
	20	0.27	0.26	-	-	-
	25	0.27	0.25	-	-	-
	30	0.27	0.25	-	-	-
Phosphate	0	0.96	0.67	0.12	0.09	-
	5	0.83	0.49	0.11	0.04	-
	10	0.69	0.48	0.11	0.01	-
	15	0.67	0.48	0.1	-	-
	20	0.65	0.37	0.1	-	-
	25	0.63	0.35	0.08	-	-
	30	0.62	0.35	0.09	-	-

The values represent mean values of the replicates; The values have been compared to BIS 10500 2012 and EPR 1986; NR: no relaxation

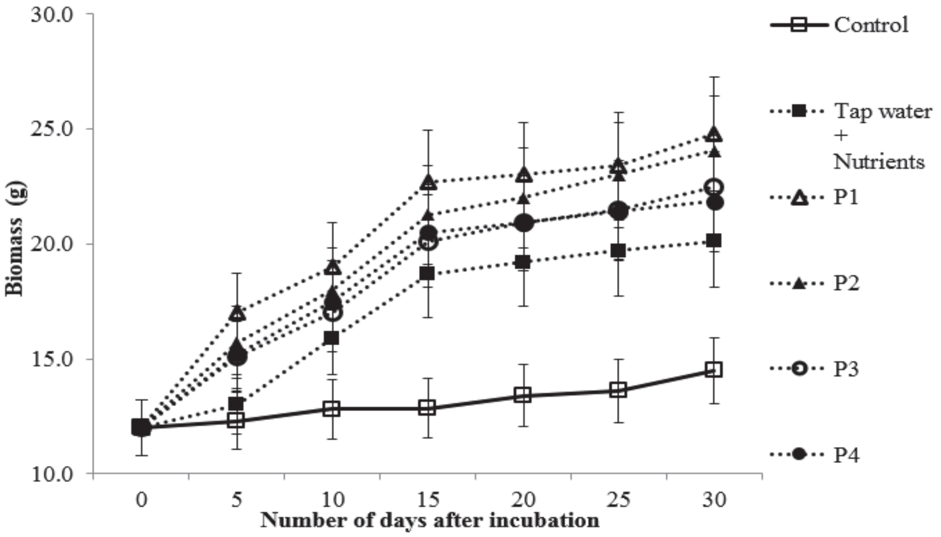


Fig. 4. Growth of algal biomass (g) in different medium with respect to the control

They have reported the reduction of various pollutants from municipal wastewaters by the growth of both eukaryotic algae and cyanobacteria. Overall, nitrogen is the primary nutrient requirement for algal growth (Ferdowshi, 2013; Wang et al., 2011, 2013). For example, 1 g of ammonia nitrogen or nitrate nitrogen produces 16 g of algal biomass while consuming 18 – 24 g of CO_2 in the process (Qiang and Richmond, 1996). This incurs a dual benefit by reducing the pollutant content along with sequestering carbon from the atmosphere.

In this aspect, Yanqun et al. (2008) reported that microalgae can be used for the production of biodiesel, bio-oil, bio-syngas, and bio-hydrogen, during which it can also be coupled with flue gas for CO_2 mitigation.

Sydney et al. (2011) showed 145 mg CO_2 uptake per gram of biomass in a day in their study with the algae *Botryococcus braunii* which also accumulated 36% oil according to dry weight. *Spirulina platensis* showed 85% CO_2 removal efficiency in a bench scale study with hollow fiber membrane photobioreactor. It was proposed that it is a promising method for CO_2 sequestration along with wastewater treatment and biofuel production (Kumar et al., 2010).

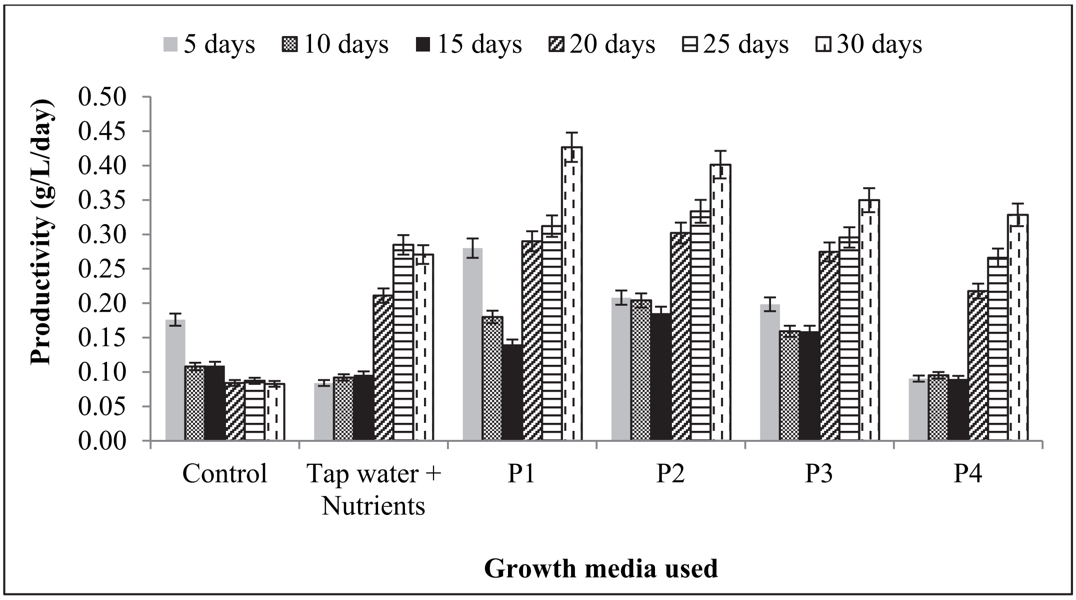
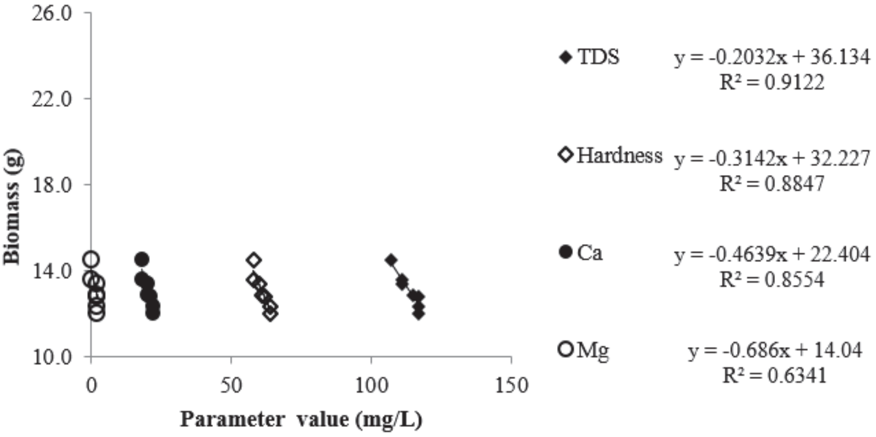
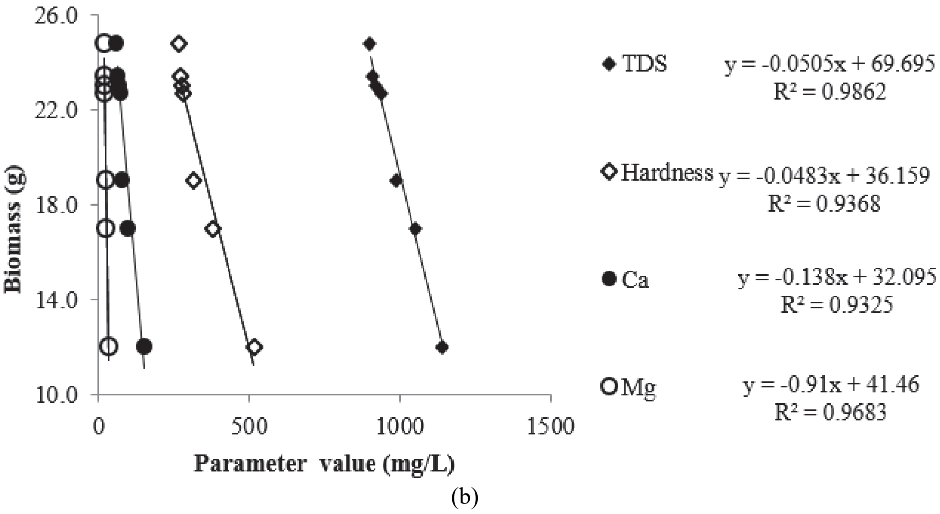


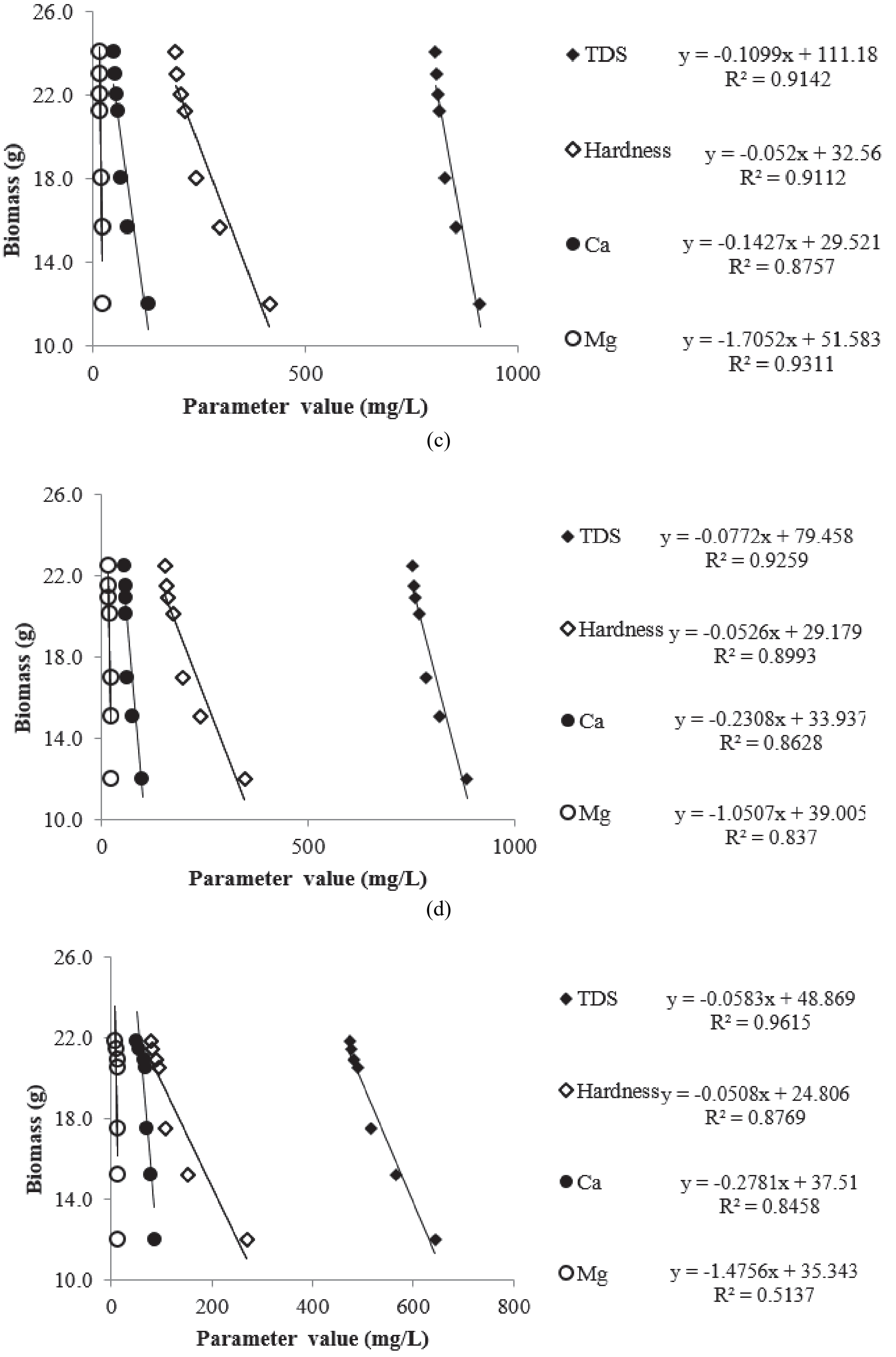
Fig. 5. Productivity of algal biomass (g/L/day) in different growth media (labeled across each group of bars) with respect to the control



(a)



(b)



(c)

(d)

(e)

Fig. 6. Scatter plots of water quality parameter vs algal biomass in each growth flask: (a) control, (b) P1, (c) P2, (d) P3, (e) P4. The regression equation for each plot vs biomass in each flask is shown beside the plots

Table 3. Removal of water pollutant by different algae species

Species used	*Pollutants removed*	*Type of wastewater*	*References*
Chlorella vulgaris	Nitrogen, Phosphorus	Domestic wastewater	Lau et al. (1997)
Chara sp., *Nitella* sp., *Mougeotia* sp., *Ulothrix* sp.	Uranium	Alkaline medium, Acid mine drainage (diluted)	Kalin et al. (2005)
Chlorella vulgaris, *Scenedesmus rubescens*	Nitrogen, Phosphorus	Municipal wastewater	Shi et al. (2006)
Chlorella vulgaris	NH_4-Nitrogen	Wastewater effluent	Kim et al. (2010)

Chlorella vulgaris, Botryococcus braunii	Nitrogen, Phosphorus	Domestic wastewater	Sydney et al. (2011)
Neochloris oleoabundans	Nitrogen, Phosphorus	Municipal wastewater	Wang and Lan (2011)
Filamentous blue-green algae	Chemical oxygen demand, Phosphorus, Total nitrogen	Municipal wastewater	Yanyan et al. (2011)
Auxenochlorella protothecoides	Nitrogen, Phosphorus, Carbon	Municipal wastewater	Zhou et al. (2012)
Chlorella sp.	Nitrogen, Phosphorus	Municipal wastewater	Wang et al. (2013)
Chlamydomona sp., Reinhardtii sp., Scenedesmus obliquus, Dictyosphaerium pulchellum	Nitrogen, Phosphorus	Municipal wastewater	Ferdowshi (2013)
Chlorella vulgaris	NH_4-Nitrogen, Chemical oxygen demand	Municipal wastewater	Delgadillo-Mirqueza et al. (2016); Fatemeh et al. (2014)
Chlorella salina	Phosphate, NH_4-Nitrogen	Tannery effluent	Jaysudha and Sampath (2014)
Chlorella sp.	Chemical oxygen demand, Biological oxygen demand, Total nitrogen, Total phosphorus, total petroleum hydrocarbons	Petrochemical wastewater	Madadi et al. (2016)

Most of these studies showed that algae growth can be a cost-effective solution for treatment of wastewater, as it could remove pollutants like nitrogen, phosphorus and other ions which if not removed can cause plankton blooms in water bodies. The removal percentage is often 80 – 100 in 10 – 15 days. Alternatively, it can be used to produce biomass for some useful purposes, while also reducing the cost of waste removal from water sources.

4. Conclusion

Algae can flourish efficiently in wastewater streams which contain the required nutrients for algal growth. Although various studies have reported algal growth and their simultaneous effects on wastewater treatment yet, more studies are necessary to support the idea that native algal species provide the most effective solution for wastewater treatment.

Harvested native algal species can show improved pollutant removal from the source water, due to their adaptability to the habitat as shown in the study. This is a better cost-effective alternative in this aspect and could be a feasible technology for long-term treatment of municipal wastewater.

Further work can also demarcate the potential use of that wastewater. The harvested algal biomass can also be useful for other end uses apart from removal of pollutants which would have otherwise caused eutrophication in water bodies.

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