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Open Pond Biological Treatment of Wastewater using Microalgae

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Abstract- **The increased interest in micro-algae as a feedstock for petro-chemicals driven by the anticipated global crude-petroleum shortage and environmental security has brought them into forefront. Known for their nutrient uptake potential, these microalgae could be employed to treat wastewater biologically which will be much cheaper than the conventional chemical method. With this vision, this study has dealt with the biological treatment of wastewater in open pond system in terms of treatment depth, efficiency and duration. Municipal wastewater after overnight settling has been treated in open pond using wastewater-borne natural community of algae. Standard methods were used for analysis of influent, effluent, and population ecology of the treatment systems. Optimum water depth for maximum treatment efficiency was found to be 20 cm and that of optimum duration of treatment was found to be 1–2 weeks. Whereas, effluent quality improved by end of 1st week for some parameters (phosphate and nitrate), they were better for some other parameters by end of 2nd week. By 3rd week the effluent quality and algal density in the system degraded indicating consumption by grazers and release of nutrients back to the system. The study concluded that wastewater treatment could be achieved using microalgae but need further study on effect of consumer removal on treatment efficiency.**

Keywords: Raceway, phycoremediation, biomass, physico-chemical

I. INTRODUCTION

Untreated or partially treated wastewaters from varieties of anthropogenic activities are adding nutrient to aquatic ecosystems resulting in eutrophication and deterioration of ecological health of the ecosystems [1]. The major and direct sources of these nutrients are industrial and municipal wastewater. The principal reason behind such negligent practice is the high financial demand by conventional wastewater treatment methods without any direct economic return. The conventional treatment method is also associated with secondary pollution. As a savior of this situation, micro-algae can be employed for treatment of wastewater. This in turn can provide economic benefits from downstream processing of biomass along with its other benefits. The other motivation in such production of algal biomass is the increased interest [2] in micro-algae as a feedstock for petro-chemicals driven by the anticipated global crude-petroleum shortage and environmental security. Such multipurpose technology can ensure the management of wastewater to keep the water resources clean and save the globe from an artificial water shortage.

Micro-algae are generally very efficient in nutrient scavenging [3] and biomass production (e.g. 2 g/l/day dry biomass) [4] compared to terrestrial as well as other aquatic plants. Algae are up to several hundred times more productive per unit of land than other crops depending on the species and growth conditions. Lardon et al. (2009) [3] reported that photosynthetic efficiencies of algae range from 3 to 8%, compared with 0.5% for many terrestrial crops. Unlike other oil crops, they can double their biomass within 24 hr; as short as 3-4 hours during the exponential growth [5]. Micro-algae (e.g. *Chlorella* sp., *Scenedesmus* sp., *Cosmarium* sp. etc.) can be cultivated on otherwise non-productive lands or in brackish, saline, and wastewater that has little competing demand. These advantageous characteristics of micro-algae have brought them into treatment of wastewater otherwise called as phycoremediation [6].

The use of microalgae in wastewater treatment (phycoremediation) has long been promoted [7]. The interest in phycoremediation is prompted from the fact that conventional treatment processes are limited with several characteristics: (1) variable efficiency depending upon the nutrient to be removed; (2) costly to operate; (3) the chemical processes often lead to secondary pollution (of sludge byproducts and treated water); (4) loss of valuable potential nutrients (N, P). The conventional treatment processes also are affected with incomplete utilization of natural resources [8]. Compared to physical and chemical treatment processes, algae based treatment can potentially achieve nutrient removal in a less expensive and ecologically safer way with the added benefits of resource recovery and recycling [9]. This Phycoremediation is one of the most effective methods of wastewater treatment available [10] which removes nutrients and heavy metals, discourages growth of pathogens (due to aeration and increased pH by photosynthesis), furnish O_2 to heterotrophic aerobic bacteria to mineralize organic pollutants, and sequestration of CO_2 in turn [11]. Microalgae can indeed support the aerobic degradation of various hazardous contaminants [11] and concentration, transformation and degradation of xenobiotics [11]. Nutrient removal with the aid of microalgae is comparable to other conventional technologies and offers an elegant solution to tertiary and quinary treatments [12].

There are several ways in which microalgae can be grown [13] and employed for wastewater treatment. They can be open (oxidation ponds, raceway ponds etc.) or closed-controlled (Controlled raceway ponds, photobioreactors etc.) systems. The higher inputs (technical, energy and cost) in photobioreactors increases the unit cost of wastewater treatment and biomass production [14] but lowers the 'net energy yield' (for fuel purpose) of the produced biomass. Therefore, the only practicable methods of large-scale and cost effective method of wastewater treatment and production of microalgae are open raceway ponds [15]. An advance open pond system is 'high rate algal pond (HRAP)'. HRAP raceway ponds in general are 0.2–1.0 m deep where mixing is normally provided by a paddle wheel to give a mean horizontal water velocity of approximately 0.15–0.3 m/s [16]. A maximum pond depth of 60 cm [17] can be maintained but usually are not more than 30 cm deep to allow efficient penetration of light [2]. Grobbelaar (2010) [18], emphasized along with other factors on optimization of culture depth (or optical cross section) and mixing and resultant turbulence for attaining average long-term rates close to 50 g(dw) m^{-2} day^{-1} at a photosynthetic efficiency >2%. Unfortunately, no current approach has been demonstrated to be simple and inexpensive enough for economical large-scale use with algae. However there are still scope of improvement in terms of efficiency of treatment, biomass production and harvesting. With this background, the study has dealt with the biological treatment of wastewater in open pond system in terms of treatment depth, efficiency and duration.

II. MATERIALS AND METHODS

A. *Technical Approach*

The technical approach followed for the study is as given in the flow diagram (figure 1). Since it is an open system a native algal community occurring in the region has been taken for this purpose. The second major reason for choosing a natural community is that the inherent diversity can ensure stability and sustainability to the cultivation system. This consideration is supported by Smith and crew (2014) [19] according to whom algal cultures can be defined (one or more selected strains), or are made up of an undefined mixture of strains; carefully maintained monocultures are not found in wastewater treatment systems; when wastewater resources are used, naturally occurring mixed cultures of algae dominate.

B. *Wastewater and experimental algae*

The wastewater treatment was carried out in open tanks in natural outdoor condition (Figure 2). The wastewater was drawn from the open sewerage flowing in IIT Delhi campus using a pump to store in a tank before starting the experiments. After 24 hour settling, the wastewater was released into 3 open tanks of equal length (1m) and breadth (1m). Water height was maintained at 20 cm, 40 cm and 60 cm. Submersible pumps were installed in the tanks for providing mixing of the wastewater. Similarly, wastewater treatment in a raceway was also tested. The raceway is an elliptical structure with a 60 cm wide path around a 10cm X 332 cm long central wall. The tanks and raceway are covered with polypropylene non-woven breathable membrane. This membrane helped in avoiding the entry of aerial materials such as leaves, litters etc. The membrane ensured a diffused light condition for the systems. Unlike poly house there is no green house effect of the membrane. This also helped in restricting mosquito breeding in the tanks. Water height was maintained at 20 cm. At this water height, the amount of wastewater subjected to treatment is 1020 L. Water in the raceway also was mixed using submersible pump. The tanks were not inoculated with any external inoculums. A natural community of wastewater borne algae developed spontaneously in the tanks and raceway within 2-3 days of (mixing) starting the experiment.

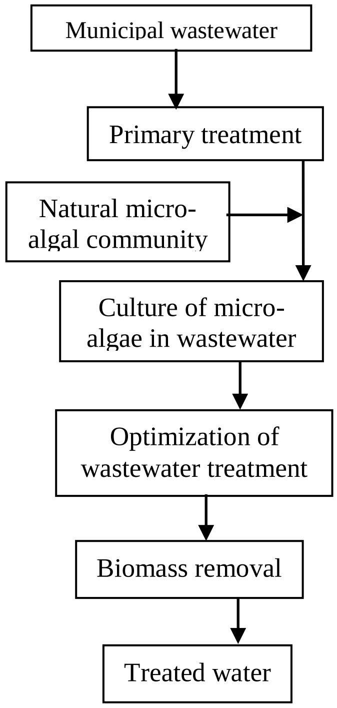

Fig 1. Flow diagram for treatment of wastewater using micro-algae

The experiments were run under direct sunlight and ambient temperature conditions with natural day–night cycle. The temperature fluctuated from 25–30 °C during the study period. After 21 days, algal biomass was harvested.

C. *Microalgal culturing and community composition*

As mentioned earlier, no external inoculate was used for inoculating the wastewater treatment systems. A natural community of wastewater borne algae developed spontaneously in the tanks and raceway within 2-3 days of (mixing) starting the experiment. The composition of algal community was analyzed using light microscope (Dewinter binocular polarizing microscope).

D. *Bio-physico-chemical analysis of waste water*

Since most of the parameters change with time, the physical and chemical parameters such as water temperature (Temp), pH, dissolved oxygen (DO), Oxidation Reduction Potential(ORP), Electrical Conductivity(EC), Total Dissolved Solid(TDS), Salt and Turbidity were analyzed using in situ GPS attached multi-parameter water analysis meter (Aqua-meter, Aquaread, UK) at the sampling site .

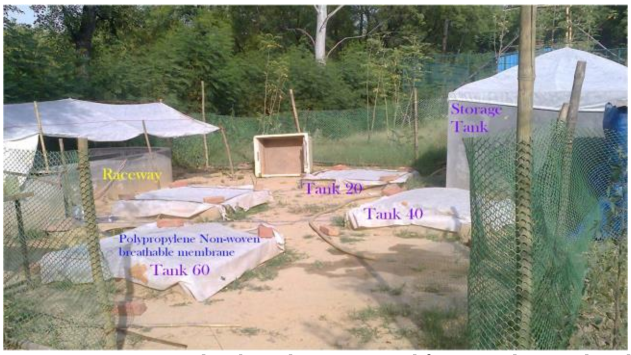

Fig 2. Experimental tanks and raceway pond for microalgae mediated wastewater treatment

Parameters like alkalinity, carbonate, bicarbonate, chloride, nitrate, ammonia, inorganic phosphorus, calcium, magnesium and total hardness were determined using various standard methods [20, 21]. Biochemical oxygen demand (BOD5 at 20°C) and chemical oxygen demand COD was analysed using the standard method [21]. The analysis of algal growth was done in terms of optical density (OD) dry weight (DW) and total chlorophyll.

III. RESULTS AND DISCUSSION

The biological treatment of domestic waste water with algal system to remove nutrients such as nitrogen and phosphorous and to provide oxygen for aerobic bacteria was proposed over 5 decades ago by Oswald and Gotaas (1957)[7]. Waste water mainly treated by aerobic or anaerobic biological degradation; however the treated water still contains inorganic compounds such as nitrate, ammonium and phosphate ions which lead eutrophication in lakes which lead to formation of harmful algal blooms. Microalgal culture offers a cost-effective approach to utilize waste nutrients as microalgae are very efficient in nutrient uptake [3]. Moreover, the algal consortia rather than a monoculture can perform well in wastewaters as the loss of one alga from the consortia may be compensated by the other algae.

A. *Physico-chemical characteristics of raw sewage water*

The physic-chemical characteristic of the municipal wastewater is listed in table I. It shows that the wastewater is alkaline (pH 7.69±0.63) very low dissolved oxygen (0.1±.03) supported by the –ve redox potential (-286.7±7.2). This reduced condition has helped in bearing high ammonia (6.96±0.13), and low nitrate (0.41±.07) value. The inorganic phosphate content is also low compared to discharge standards (CPCB). The main source of phosphate may house hold detergents. Although the nutrient element values are within CPCB discharge limits for discharge into surface waters, the COD (259±12.1 ppm) and BOD values (101 ±4.9 ppm) are little bit high. The hardness is 348±15 ppm. The alkalinity of 342.86±21ppm is mainly contributed by bicarbonates. The water has high EC (973±22 µS/cm), TDS (633±17 ppm) and salt content (0.48±.08 ppm). The available P:N ratio is around 1:4 which is potential of supporting a good growth of microalgal population.

TABLE I: PHYSICO-CHEMICAL CHARACTERISTICS OF RAW SEWAGE WATER

Parameter	Mean value
Colour	Black+Yellow
Odour	Septic
Temperature	25.6±0.8
ORP (mV)	-286.7±7.2
pH	7.69±0.63
DO (mg/L)	0.1±.03
EC (µS/cm)	973±22
TDS (mg/l)	633±17
Salt (ppt)	0.48±.08
Turbidity (NTU)	72.7±8.3
BOD (mg/l)	101 ±4.9
Filterable BOD (mg/l)	43±3.7
COD (mg/l)	259±12.1
Filterable COD (mg/l)	110±7.3
Nitrate (mg/l)	0.41±.07
Ammonia-N	6.96±0.13
Phosphorous (mg/l)	0.515±.08
Chloride (mg/l)	132±11
Alkalinity (mg/l)	342.86±21
Acidity (mg/l)	20±1.2
Total Hardness (mg/l)	348±15

B. *Optimization of water depth for wastewater treatment*

For this purpose, three depths as 20 cm, 40 cm and 60 cm were tested. Mixing of wastewater in the tanks was provided using submersible pumps. According to water depth the tanks with 20 cm, 40 cm and 60 cm water are coded as T-20, T-40 and T-60 respectively. T-20 was provided with 1 pump, T-40 with 2 pumps and T-60 with 3 pumps to ensure similar HRT.

i. *Influence of treatment water depth on physical characteristics of wastewater*

The depth dependent changes in wastewater with respect to time during the treatment period are shown in table II. Since sampling was done at the surface of all tanks, there is hardly any change in the temperature of water column. The pH in all tanks is in alkaline range and has varied between 7.7 and 9.0. It is reported that the pH can shoot beyond 10 during day time if photosynthetic activity is high. These values thus show that there was not much photosynthetic activity indicating low algal growth (following section). There are drastic differences in the DO and ORP values among the different treatment systems. The ORP on day-0 for all systems was -286.7. The values become +ve first in T-20 (29.1; day-6); followed by T-60 (84.1; day-8) and T-40 (76.6; day-8). The starting DO of 0.1 ppm improved fast in T-20 followed by T-40 to reach above 10 by day 8. In T-60, similar condition reached by day 10. The starting EC (973 µS/cm) and TDS (633 ppm) and salt (0.48 ppt) of the wastewater declined (787 µS/cm, 511 ppm, 0.39ppt) till day-14 only in case of T-20. In contrary, in case of the other two treatments, these parameters declined slightly initially and increased later. The turbidity under all treatments initially decreased, increased and then decreased. The initial decline corresponds to settling of particulates and removal of colours. The next increment in turbidity corresponds to algal growth. The final decline corresponds to removal of algal cells by grazing, settling and film formation.

TABLE II: CHANGES IN PHYSICAL CHARACTERISTICS OF WASTEWATER DURING TREATMENT (Temp. °C, ORP (mV), DO (mg/l), EC (µS/cm), TDS (mg/L), Salt (ppt), Turbidity (NTU))

Time (days)	0	2	4	6	8	10	12	14	16	18	20	22	24	
Temp.	25.6	28.3	28.2	27.6	26.3	26.6	26.5	26.8	31.1	28.1	28.6	26.9	33.4	T-20
ORP	-286.7	-237	-129.3	29.1	63.7	57.6	29.6	38.2	17.7	54.9	35.4	59.5	14.7	
pH	7.69	7.61	7.46	7.57	8.17	8.14	8.84	8.68	8.69	8.51	8.71	8.32	9.06	
DO	0.1	0.11	0.98	2.06	12.56	13.22	11.96	10	10.43	9.45	10.28	11.24	13.33	
EC	973	936	949	946	849	820	799	787	874	890	896	884	904	
TDS	633	608	631	614	551	533	518	511	568	577	574	574	587	
Salt	0.48	0.46	0.47	0.47	0.42	0.41	0.39	0.39	0.43	0.44	0.44	0.44	0.44	
Turb.	72.7	56.3	41.9	28.2	39.6	66.2	88.9	98.2	84.9	69.4	21.2	51.6	17.5	
Temp.	25.6	28.5	27.9	27.8	26.5	26.9	26.5	27.3	31.9	28.5	29.4	27.2	33.8	T-40
ORP	-286.7	-237.9	-201.3	-46.2	76.6	67.8	49.1	53.1	39.6	61.4	45	70.3	26.6	
pH	7.69	7.59	7.69	7.66	8.02	8.09	8.6	8.57	8.55	8.35	8.55	8.11	8.93	
DO	0.1	0.08	0.39	0.61	10.86	10.83	8.81	10.77	10.29	11.22	10.88	9.76	10.82	
EC	973	983	989	996	963	955	975	897	1035	1062	1048	1060	1056	
TDS	633	638	639	647	625	620	633	583	672	690	681	689	686	
Salt	0.48	0.49	0.51	0.49	0.47	0.47	0.48	0.45	0.52	0.52	0.52	0.53	0.52	
Turb.	72.7	37.7	43.2	45.6	22.7	26.7	43.2	82.6	32.1	48.6	53.1	55.4	20.1	
Temp.	25.6	27.9	28.6	27.9	26.4	27.2	27.3	28.1	32	28.9	29.8	27.9	34.4	T-60
ORP	-286.7	-279.1	-228	-48.1	84.1	80	62.4	69.8	56	73.7	52.1	69.1	38.8	
pH	7.69	7.56	7.39	7.76	7.82	7.72	8.31	8.38	8.38	8.14	8.49	8.16	8.82	
DO	0.1	0.05	0.08	0.52	0.49	2.29	6.53	10.85	9.1	10.26	9.54	9.3	13.02	
EC	973	966	998	977	943	968	983	927	1002	1011	997	1048	1002	
TDS	633	629	647	0.641	607	629	638	602	651	656	648	674	651	
Salt	0.48	0.48	0.49	0.48	0.46	0.48	0.49	0.46	0.5	0.5	0.5	0.52	0.5	
Turb.	72.7	50.5	51.5	55.5	25	60.5	53.9	30.1	13.4	52.2	52.9	45.2	9.5	

The change in the physical parameters shows that T-20 is the best treatment among the three. So, 20 cm water depth was chosen for maintaining the water level while running the raceway pond. For a concluding remark, other chemical and biological parameters are also considered.

ii. Chemical and biological changes in wastewater during depth optimization study

Table III is showing the changes in chemical and biological parameters of wastewater during depth optimization study. The optical density of water at 678 nm shows an increase upto day 14 which declined drastically by day 21 in all tanks. Among the tanks The OD678 was highest for T-20 in all the sampling events. Similar trend could be found for total chlorophyll content. However, the OD values and chlorophyll values are not high as expected in such nutrient rich systems. This may have happened due to grazing by zooplanktons, film formation due to presence of filamentous algae and settling due to poor mixing.

As expected, the NH_4-N was highest (6.69 ppm) at day zero in the untreated wastewater. This ammoniacal nitrogen gradually was converted to nitrate when the dissolved oxygen increased in the systems due to mixing as well as algal photosynthetic activity. This could be seen from the increased NO_3-N within the first two weeks. By second week the algal growth was there but the nitrate-nitrogen was surplus and could be consumed by 3rd week. By third week, there was still high amount of NO_3-N in T-60 may be due to low algal density and high water volume. The inorganic phosphorus decreased from 0.52 to around 0.2 in all treatments. Although the residual P was almost similar in all tanks, the highest and fastest removal was in T-20. By third week, there was again release of phosphorus into the system due to grazing and decay. There is almost no change in alkalinity level in all treatments, although it was slightly low in case of T-20 by second week. Chloride values decreased initially up to second week (highest decrease again being in T-20) and increased slightly by third week. Total hardness has gradually decreased till 3rd week. Overall, T-20 has performed better among all treatments. Hence, the water depth was decided to keep at 20cm for studying the treatment in the raceway.

TABLE III: CHANGES IN CHEMICAL AND BIOLOGICAL PARAMETERS OF WASTEWATER DURING TREATMENT

Time(days)	0	7			14			21		
Treatments		T-20	T-40	T-60	T-20	T-40	T-60	T-20	T-40	T-60
OD 678	0.134	0.239	0.223	0.213	0.349	0.298	0.249	0.048	0.042	0.041
Chlorophyll (mg/l)	0.00	0.49	0.27	0.14	0.82	0.61	0.46	0.33	0.16	0.13
NO_3-N (mg/l)	0.41	4.21	2.40	1.33	12.58	16.27	17.65	0.27	0.53	17.08
NH_4-N (mg/l)	6.96	1.83	2.71	5.89	0.02	0.01	0.02	0.03	0.02	0.02
P (mg/l)	0.52	0.26	0.50	0.56	0.19	0.22	0.28	0.23	0.19	0.22
Chloride (mg/l)	132.1	115.0	117.9	117.9	99.4	103.7	102.2	107.9	103.7	109.3
Alkalinity (mg/l)	343	357	414	471	343	414	343	329	400	343
Hardness (mg/l)	320	168	138	168	132	128	124	124	120	128

C. Wastewater treatment in Raceway

From the above depth optimization study, 20 cm water height was selected for running the raceway. Period of wastewater treatment was optimized through this study. Physical parameters were studied every alternate day. Chemical and biological parameters were analyzed every week until getting a conclusive trend in the results.

i. Optimization of treatment period: changes in physical characteristics of wastewater

Changes in physical parameters during treatment are given in table IV. It shows that from a negative value of -286.7 mV the ORP become +ve within 2 days. The value increased (50.1 mV) till day-16 and then started declining. The decline would have occurred due to decline in photosynthetic activity and increase in respiratory activity resulting in consumption of DO. The DO value has improved gradually from 0.1 mg/l to above 15 by day-8, slightly increased up to day-18 (16.13 mg/l) and then started declining. There was occurrence of a lot of consumers (zooplanktons and worms) in the system by this time resulting in increased respiratory activity. After second week, a bad odour also started prevailing in the system. Turbidity, which indirectly measures presence of particulate matter, started declining (from 72.2 to 10.3) till day-6 and started increasing suddenly due to algal growth. The initial turbidity must be due to colour and particulate matter. The initial decline in turbidity may have occurred due to prevalence of oxic condition which decolourized the water. Due to occurrence and growth of algal population then the turbidity must have increased which finally declined due to increase in the consumer population. pH is in alkaline range (7.69-9.85) which has increased with time may be due to photosynthetic activity, highest value was recorded on 12th day. The algal growth parameters are discussed in the following section. EC, TDS and Salt values have declined till day-10 and again started increasing. The initial decline may be associated with consumption of nutrients by the developing algal community. Towards later part, the increase may be associated with evaporative concentration and release of nutrients to the medium by consumers.

From the analysis of the physical parameters, two week treatment period seems to be an optimum time, as the important values have occurred during this end of second week and conditions degraded by end of 3rd week. Study of the chemical and biological parameters would help in drawing a conclusive remark regarding this.

TABLE IV: CHANGES IN PHYSICAL CHARACTERISTICS OF WASTEWATER DURING TREATMENT

Time (days)	0	2	4	6	8	10	12	14	16	18	20	22	24
Temp.	25.6	28.1	27.1	25	24.1	24.0	23.9	24.4	24.3	26.7	26.9	28.8	31
ORP	-286.7	7.0	9.2	21.9	41.9	43.7	49.2	47.7	**50.1**	25.3	8.8	8.8	3
pH	7.69	7.62	7.61	7.64	8.26	8.22	**8.95**	8.68	8.35	8.75	8.87	8.76	8.29
DO	0.1	0.35	1.23	4.55	15.14	15.66	15.27	15.2	15.26	**16.13**	15.32	14.48	7.53
EC	973	969	969	1033	910	**820**	861	852	908	977	986	1034	1199
TDS	633	629	645	663	590	**531**	559	553	625	638	651	673	777
Salt	0.48	0.48	0.46	0.51	0.45	**0.41**	0.43	42	0.48	0.48	0.5	0.5	0.57
Turb.	72.7	69.7	30.1	10.3	93	133	129	126	138	**215**	206	168	54.9

ii. Optimization of treatment period: weekly changes in biological, chemical and some physical parameter in wastewater

Weekly changes in biological, chemical and some physical parameter in wastewater during treatment is given in table V. The optical density at 678 nm (OD678) for measurement of algal density in wastewater on day zero was 0.134. This value was contributed by non-algal colour and dead particulate matter. This value increased to 0.636 by second week contributed mainly by algal growth. By third week the value decreased to 0.094 may be due to grazing by consumers [22] and film formation/ clumping with filamentous algae. The total chlorophyll and dry biomass (in terms of total suspended solid) followed the same trend as optical density. The highest biomass was only 0.214 g/l which is a very low value compared to reported literatures [18]. The biomass value needs to be increased by reducing the grazing pressure and removal of filamentous algae.

Among chemical paremeters, ammoniacal nitrogen was initially very high 6.96 mg/l which decreased to 0.02 mg/l by 2nd week and slightly increased (0.81mg/l) by 3rd week. The decline in value may have occurred due to partial consumption and conversion in to nitrate-N under aerobic condition facilitated by mixing and algal growth. Nitrate-N value was 0.41 mg/l on day-0, which has increased gradually and reached 0.83 by end of 3rd week. The increased value at end of 3rd week may have happened due to heavy grazing (low OD, chlorophyll and biomass) and release of the nutrients into the medium [10]. Similarly, phosphate values declined from 0.515 ppm to 0.14 ppm in the 1st week and again started increasing to reach 2 ppm by end of 3rd week. The decline in the first week may be associated with algal uptake and precipitation due to oxic condition. During the following weeks the simultaneous algal uptake, and release from dead particles and grazing activity may have resulted in net phosphate gain in the media. Moreover, secondary nutrient limitation [23] may have resulted in non-uptake of available nutrients. Chloride content and total hardness have shown similar trend of a decline upto 2nd week and increase by end of 3rd week. This may again be attributed to initial uptake for algal growth followed by a release in the later phase due to consumptive activity, also may be due to evaporative concentration. Alkalinity, mainly contributed by bicarbonate has declined in the 1st week followed gradual increase to reach even beyond starting levels. Acidity has remained almost at same level with a slight decrease from the starting value. A starting crude BOD of 101 ppm had a filterable BOD value of 43 ppm. The filterable BOD at the end of 3rd week is 35.4. Similarly, a crude COD of 259 ppm had a filterable COD value of 110 ppm resulting in lesser value (97.6 ppm) at the end of 3rd week.

The initial colour of wastewater was blackish yellow which became clear and remained clear till 2nd week. By 3rd week the yellowish colour again reappeared. Similarly, initial septic odour disappeared as soon as oxic condition prevailed in the system but reappeared by end of 3rd week associated with low DO, low photosynthetic activity and increased consumptive activity.

TABLE V: WEEKLY CHANGES IN DIFFERENT PARAMETERS OF WASTEWATER DURING TREATMENT

Parameter	Day 0	Week 1	Week 2	Week 3
OD 678	0.134	0.419	0.636	0.094
Chlorophyll (mg/l)	0	0.67	1.59	0.78
Biomass (mg/l)	0.096	0.136	0.214	0.031
NH_4-N(mg/l)	6.96	0.05	0.02	0.81
NO_3-N (mg/l)	0.41	0.15	0.34	0.83
P (mg/l)	0.515	0.14	0.39	2.00
Cl (mg/l)	132	129.22	119.28	130.64
Hardness (mg/l)	348	246	120	132
Alkalinity (mg/l)	342	280	320	400
Acidity (mg/l)	20	15	15	15
BOD (mg/l)	101	--	--	--
Filterable BOD (mg/l)	43	--	--	35.4
COD (mg/l)	259	--	--	--
Filterable COD (mg/l)	110	--	--	97.6
Colour	Black+yellow	Clear	Clear	Yellowish
Odour	Septic	Odourless	Odourless	Fishy smell

The above analysis of the physical, biological and chemical parameters suggests that a treatment period of 1–2 weeks is the optimum time period for getting best results in term of the effluent quality and as well as algal biomass production. A continuous cultivation and harvesting system may provide further improvements by reducing the grazing pressure [19].

D. Population Ecology of the treatment system

Wastewater environment is an ideal media for a wide range of microorganisms specially bacteria, viruses and protozoa, planktons etc. In our study we are trying to develop an ideal condition in waste water natural environment for growing native microalgae. The present study was carried out to screen and evaluate the potential strain of microalgal consortia from waste water environment (filamentous and unicellular) in terms of nutrient removal, improvement of water quality and biomass production in wastewater under outdoor natural conditions. Earlier report revealed that microalgae employed for nutrient removal, are *Chlorella*, *Scenedesmus*, and *Spirulina* which are most commonly observed algae in wastewaters [24]. In this present investigation the most tolerant genera were found to be, *Merismopedia*, *chroococcus*, *Scenedesmus*, *selenastrum*. *Chlorella*, *Oocystis*, *Sphearocystis*, *Cosmarium*, *Navicula*, *Oscillatoria*, *Phormidium*, *Ulothrix*. Some species of algal grazer such as rotifer, daphnia were found in the algal-waste water treatment system. The development of algal defence theory in freshwater systems predicts that increased grazing should cause a decrease in the abundance of desirable algae, which should be replaced by slower growing, more resistant algae [25]. Figure V below shows the microscopic images of some important genera of microalgae in waste water. This diversity is the fate and strength of open pond treatment systems [19]

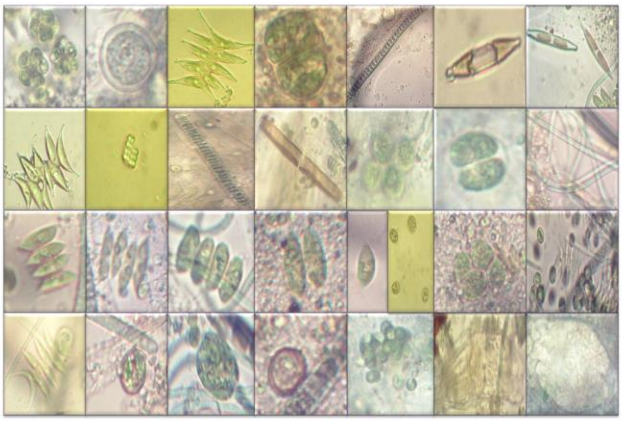

Fig. 3. Microphotograph of some important genera of wastewater microalgae and *miscoscopic anima)*

IV. CONCLUSION

The above study has employed microalgae as agent in treatment of domestic wastewater in open pond system. It was found from the study that a consortium of microalgae thrives in the open pond treatment system. The optimum water depth for getting maximum treatment efficiency was found to be 20 cm. Similarly, the optimum time period of treatment is found to fall between 1 to 2 weeks in term of the effluent quality and as well as algal biomass production. The population ecology of the system indicates that reduction of grazing pressure may help in improving the performance of the system further.

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VI. REFERENCES

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