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Removal of Nitrogen and phosphorus from wastewater by two efficient technologies (Microalgae and trickling filter)

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Abstract

Water pollution is one of the main impediments to public health in developing countries like Pakistan, India, Bangladesh, and African regions etc. (Haider R.et al. 2017). Availability of excess nutrients is known to cause eutrophication of water bodies such as lakes and rivers, which leads to low dissolved oxygen (DO) conditions and eventually makes the water body un suitable for recreational purposes. Nitrogen and Phosphates in receiving waters originates from natural and anthropogenic sources, including agricultural runoff, atmospheric deposition, intensive farming, wetlands, and effluent from waste water treatment plants. Therefore, the waste water must receive suitable treatment before being discharged into water bodies. Microalgae and trickling filter play san effective role during waste water treatment. In this research work we selected two techniques like, mix culture of microalgae (Dunaliellasalina, Schroederiasetigera and Chlorella vulgaris), and trickling filter for compared to test the irability to remove nitrogen-nitrate(NO_3 $^-$N) and orthophosphate(PO_3^4-P)in batch cultures of wastewater treatment. The microalgae with the best cell growth configuration were selected, andintroducedasasuitablemethodfornutrientremoval.Resultsindicatethat microalgae show edahigher, total Nand $PO_3$4 – P uptakerate85% and 81% respectively, while trickling filter show edahigher removal rate of BOD, NO_3–N,as 91%, 86% respectively. So in this case we can say that both techniques are more efficient for wastewater treatment.

Keywords: Nitrogen removal; Phosphorus removal; Microalgae; Wastewater treatment; Trickling filter.

I. Introduction

The level of water pollution is increasing at a fast pace due to the mixing of sewage and industrial effluent into the residential water supply systems in big cities of the country (GU W., et al. 2017).It has been well known since decades that accelerated eutrophicationof the aquatic environment is a severe environmental problemmainly caused by human discharges of phosphorous andnitrogen in the form of agricultural fertilizer, waste and wastewater.Even though significant efforts and progress for the removal ofthese elements from wastewater have been made since the 1960s,the largest amount of these nutrients is currently not recycled.Recently, attention has been drawn to the upcoming depletion ofglobal phosphate resources within this century, endangering modernfertilizer-based agriculture and, accordingly, global foodproduction (Gilbert, 2009). Consequently, there is a demand fortechnologies to recover this lost resource. Since about 16% of the mined phosphate almost completely endsup in wastewater via human consumption (Rittmann et al. 2011), wastewater is a preferred source for sustainable P and Nmanagement. Another important fact regarding the presence of phosphate and nitrate in wastewater is of its reuse, when a nutrient rich wastewater is used for agricultural activities like irrigating the fields, plants consume these nutrients which results in lesser requirement of artificial fertilizers. The benefits of such a process will also result in the lesser depletion of ground water; surface water will be protected from discharges of wastewater effluents.

1.2 Microalgae

Microalgae are photosynthetic micro-organism whichis used in the many field such as medical, in the areas of dye and protein production etc. Vigorous studies are on-going to apply microalgae for bio-fuel production and wastewater treatment (Wang et al. 2011, Brennan et al. 2010, and Spolaore et al. 2006). A general wastewater treatment system supplies air to aerobic microbes via aeration to remove organic matter in the wastewater.In contrast, wastewater treatment technology using microalgae has a variety of benefits compared to existing wastewater treatment technology. Organic matter, nitrogen, and phosphorus can be simultaneously removed in a reactor; indeed, high removal efficiency of nutrients such as nitrogen and phosphorus is expected (Aslan et al. 2006 and Perez-Garcia et al 2011 and Sancho et al. 1999 and Shi et al. 2007). In addition, oxygen produced from photosynthesis process by microalgae is used as a source for aerobic microbes, thereby reducing aeration costs. Auto phototrophic microalgae cannot only remove nitrogen and phosphorus, but can fix CO_2 by using the CO_2 as a carbon source.

1.3 Trickling filter

Nitrates and Phosphates can be removed chemically or biologically from a water supply. Biological removal is preferable, since there is no need for the addition of extra chemicals and the volume of the regenerated sludge is appreciably smaller and hence easier to handle. Trickling filters, in contrast with activated sludge processes, provide a support medium for biofilm growth.Bacteria remain in the filter for long periods of time, thus making high hydraulic and pollutant loadings possible. The filter medium is of great importance for the function of biofilters and several experiments have been carried out both to study and compare different filter media types. The support materials used in trickling filters are either granulated or fixed media. Among the selection criteria for filter media in trickling filters are: void ratio, specific surface area, homogeneous water flow and economics. An adequate flow of air is of fundamental importance to the successful operation of a trickling filter. The principal factors responsible for air flow in an open top filter is the natural draft. The driving force for airflow is the temperature difference between the ambient air and the air inside the pores. Thus, the use of a trickling filter has the advantage of not requiring an external air supply or an aeration system. If, in addition, the mean diameter of the filter media is sufficiently small (up to 5 mm), then complete aeration and very good filtration may be affected at the same time.Trickling filter is an example of attached process in which the wastewater is passed through a filter media. A trickling filter is a three-phase system with fixed biofilm carriers. Wastewater enters the bioreactor through a distribution system, trickles downward over the biofilm surface, and air moves upward or downward in the third phase. Trickling filter components typically include a distribution system, containment structure, rock or plastic media, underdrain, and ventilation system. A slime layer gets deposited on the surface of the filter media containing aerobic bacteria which gets oxygen supply from the ambient air and food from the organicmatter present in the wastewater. Wastewater treatment using the trickling filter results in a net production of total suspended solids. Therefore, liquid-solids separation is required.In this research work we selected two techniques like, mix culture of microalgae (*Dunaliellasalina, Schroederiasetigera and Chlorella vulgaris*), and trickling filter for compared to test their ability to remove nitrogen-nitrate (NO_3^-N) and orthophosphate (PO_3^4 - P) in batch cultures of wastewater.

II. Materials and Methods

2.1 pH

The pH of samples was determined in the laboratory by using "Digital pH meter, phtester20 (Eutech Technologies)". Before measurement, the instrument was calibrated using buffer solutions of pH 4.0, 7.0 and 10.0.

2.2 Biochemical oxygen demand (BOD_5)

The BOD_5 of the water samples was determined by using 5-Day BOD test i.e. IS3025 part-44 using Iodiometric titration. It was measured by using the following formula; BOD5 (mg/l) = ($DO_1 – DO_2$)/ volume of dilution sample x 1000Where, DO_1 = DO of diluted sample immediately taken after preparation, andDO_2 = DO of the diluted sample after 5 days incubation at 20ºC.

2.3 Orthophosphates

Orthophosphates were determined using standard APHA-4500 method. A standard curve between standard solutions of known phosphate concentration and absorbance was made using 540 P react, HR TNT in HACH DR-2800 spectrophotometer at a wavelength of 610 nm. The results were measured in mg/l and by using standard curve; we have measured the phosphate concentrations by calculating the absorbance.

2.4 Nitrates

Nitrates were determined using standard APHA-4500 method using HACH Dr-2800 spectrophotometer. The program in spectrophotometer was 344 Nitrate HR TNT and performed at 610 nm. 10 ml of sample was placed in a vial a powder pillow of Nitrate HR range is then added to it, giving the sample 5 minutes to take place reaction. After 5 minutes take the reading at 610 nm.

2.5 Total Nitrogen

Total Nitrogen was determine using standard APHA-4500 method and program 394, N Total HR TNT performed at 610 nm in HACH DR-2800 spectrophotometer.

2.6 Microalgae strain and culture conditions

Mix culture of microalgae (*Dunaliellasalina, Schroederiasetigera and Chlorella vulgaris*) as shown in fig. 1. were collected from Hamirpur district of Himachal Pradesh, India and it was cultured in standard environmental condition into culture setup i.e. light period was $12^L/12^D$, temperature was 25±2, pH was 6.5 to 7.5.

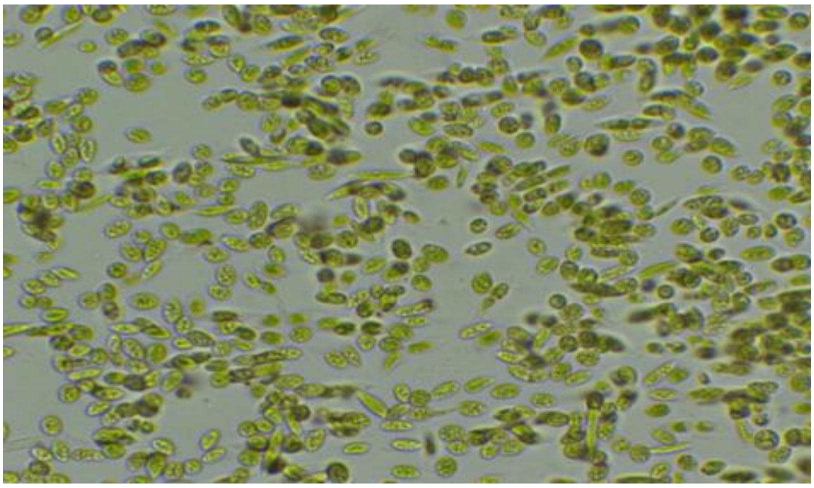

Figure1: Mix culture of microalgae (*Dunaliellasalina, Schroederiasetigera and Chlorella vulgaris*) CFL is used for light with having intensity of 6 W/m^2 and it cultures at around 21 days of incubation period in Bold's basal medium. Growth was measured by UV-spectrophotometer (Agilent cary-100) at 680 nm.

2.7 Trickling Filter

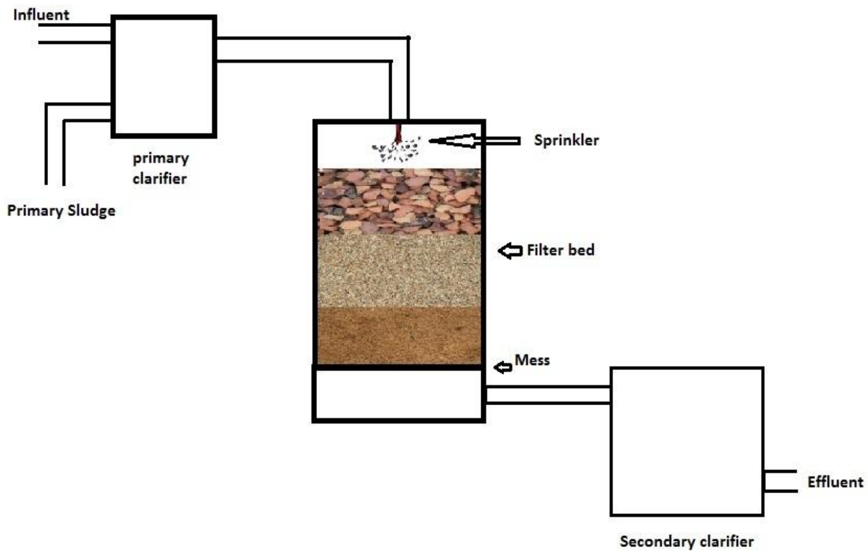

Figure: 2 Model of trickling filter

A small scale model of tickling filter as shown in fig.2was developed and the wastewater generated by the NIT Hamirpur campus was taken as the raw sewage. The design parameters taken for constructing the model as;

S. no.	Parameter	Deign Value
1	Volume of primary clarifier	15 lit.
2	Depth of media	30 cm
3	Diameter of trickling filter	20 cm
4	Hydraulic loading rate(opted)	4m^3/m^2/d
5	Per hour flow rate into the filter	2.3 lit.
6	Filter material	Sand and gravel
7	Detention time of secondary clarifier	2 hours

2.7.1 Design of filter media

The filter media used in trickling filter was analysed using sieve analysis and the results were as;

S. no.	Sieve size (mm)	Weight retained (g)	% weight retained	Cumulative % weight retained	% finer than
1	20	986	19.72	19.72	80.28
2	9.5	817	16.34	36.06	63.94
3	4.75	1907	38.14	74.20	25.8
4	2.36	736	14.72	88.92	11.08
5	1.18	554	11.08	100	0

Table 1sieve analysis results

From the above plot, the different particle sizes are calculated by the above formula are as;D_{10} = 1.579 mm; D_{30} =6.0629 mm; D_{60} = 12.7959 mm. The coefficient of uniformity is given as, Cu = D60/D10= 12.7959/1.579 = 8.103 as shown in table no.1.

2.8. Statistical analysis

Analysis of variance (ANOVA) using a General Linear Models (GLM) procedure of SPSS version 20 was conducted to determine the statistical significant difference in relationship of waste water treatment with mix microalgae culture and trickling filter. In ANOVA, seasons were treated as main plots and treatment processes were treated as subplots, considering sampling dates as replications within each treatment.

III. Results and discussion

3.1. Microalgae production rate

Mix microalgae was cultured in Bold's basal medium having 21 days incubation period in culture setup with all environment parameters as mentioned in pera 2.6 and the growth was taken by UV-spectrophotometer at 680 nm.

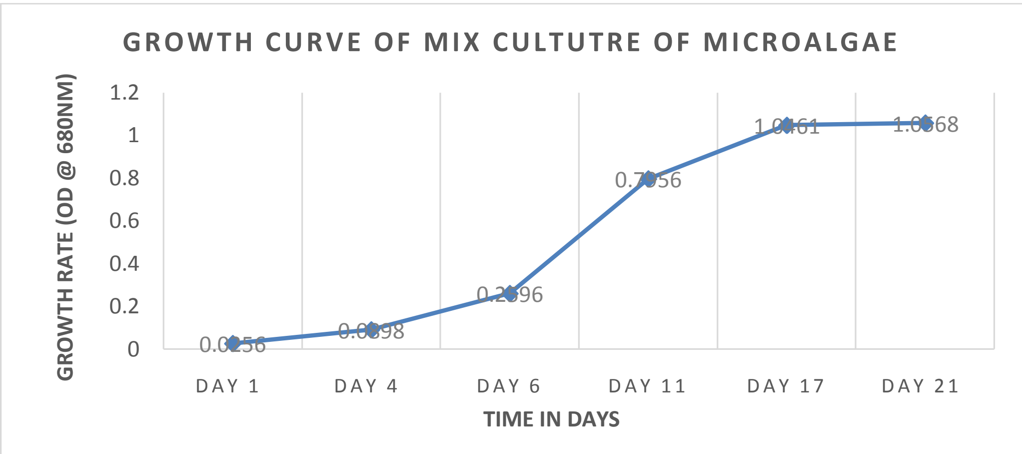

Figure no. 2 Growth curve of mix culture of microalgae

The wastewater was taken from NIT- Hamirpur treatment plant and the culture incubated at culture setup with all parameters, was allowed to incubate for a time period of 23 days with shaking by hand in a day. In our previous studies, bioflocculant was used to collect the algae cells, and a flocculation efficiency (> 98%) was achieved at both pilot-scale and in situ treatment (Ndikubwimana T et al., 2016).

Nutrients	**Day 1**	**Day 7**	**Day 17**	**Day 23**
N (Nitrate) (mg/l)	11.5	12.1	59.7	63
P (Orthophosphate) (mg/l)	133.21	125.44	74.43	24
BOD (mg/l)	180	125	66	20
Total N (mg/l)	64	-	-	9

Table no. 2 Concentration of contamination removal by microalgae

As result shown in table no.2, contamination removal that the total nitrogen (N) was removed around 85% and P was removed around 82% in 23 days from wastewater.

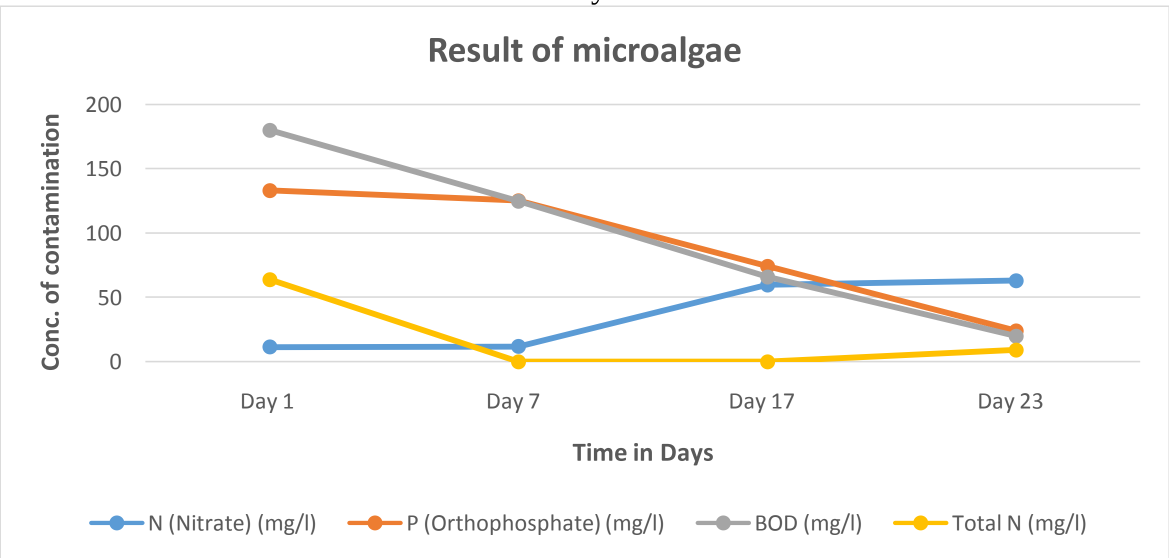

Figure no. 3 Removal of contamination by microalgae

3.2Trickling filter results

The model was allowed to run for a time period of 23 days on the running basis of 8 hours per day. Initially a seeding was done for a time period of 3 days in which the filter bed was submerged in wastewater by keeping ventilating and outlet chamber of the trickling filter closed. The advantage of seeding is that biological activities furnish on the surface of the filter bed and they start the solid-liquid separation, thereby initiating the formation of biofilm on the filter material surface. Since the influent was changed everyday as no recirculation was done, the results of trickling filter are expressed in terms of percentage removal. Analysis was done on the basis of removal efficiency of BOD, total nitrogen and phosphorus.

Parameters	**Influent**	**%removal Day 1**	**%removal Day 7**	**%removal Day 17**	**%removal Day 23**	**Effluent**
N (Nitrate) (mg/l)	7.6	……	…….	…….	……..	56.1
P (Orthophosphate) (mg/l)	133.21	2.7	21.4	56.3	76	32
Total N (mg/l)	66	3.2	11.5	48.9	80.3	13
BOD (mg/l)	196	17	40	74	91	18

Table no. 3 Concentration of contamination removal by trickling filter

As the results shown in table no. 3, that the influent on the start of the experiment was having BOD was 196 and at the end of 23 days the removal efficiency of BOD was 91%, showing a high rate of removal efficiency. Similarly the removal of orthophosphates and total nitrogen comes out to be 76% and 80%.

However, the nitrates presence, which, is an indicator of oxidation of nitrogen into stable nitrates, was 7.mg/l in the influent and rises to 56.1 mg/l in the effluent at the end of 23 days.

IV. Conclusion

This experiment confirms that mix microalgae culture (*Dunaliellasalina, Schroederiasetigera and Chlorella vulgaris*) can be considered as efficient nutrient removers from wastewater in case of total N and PO_34 – P uptake rate 85 % and 81% respectively. They are capable of completely depleting total N and P correspondingly from wastewaters containing high concentrations of Total N and phosphate while achieving high biomass productivity.

While trickling filter showed a higher removal rate of BOD, NO_3 –N,as 91%, 86% respectively. So we can say that, trickling filters, and microalgae offers an alternativemethod to conventional wastewater treatment plants.

The main conclusions of this work are:

- The high retention time of biomass in the filtersenables high hydraulic and pollutant loadings.
- The natural aeration of the filters minimizesthe operational cost while achieving at the same time high removal efficiencies.

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