Journal of Advances in Biology & Biotechnology
11(2): 1-5, 2017; Article no.JABB.29979
ISSN: 2394-1081

SCIENCEDOMAIN *international*
www.sciencedomain.org

Algae to Remove Phosphorous in a Trickling Filter

K. Dölle[1*] and C. Watkins[1]

[1]Department of Paper and Bioprocess Engineering (PBE), College of Environmental Science and Forestry (ESF), State University of New York (SUNY), Syracuse, New York 13210, USA.

Authors' contributions

This work was carried out in collaboration between both authors. Author CW designed the study and performed the statistical analysis. Author KD wrote the final draft and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2017/29979
Editor(s):
(1) Ibrahim Farah, Department of Biology, Jackson State University, USA.
Reviewers:
(1) Mahmoud Nasr, Alexandria University, Egypt.
(2) Kasem Chunkao, Kasetsart University, Thailand.
(3) Stig Morling, Royal Institute of Technology (KTH), Sweden.
Complete Peer review History: http://www.sciencedomain.org/review-history/17341

Original Research Article

Received 8th October 2016
Accepted 19th December 2016
Published 24th December 2016

ABSTRACT

At a waste water treatment facility, secondary treatment process algae species *Cladophora glomerata* and *Vaucheria* is growing in a trickling filter. This study investigates the role of the algae and its potential for phosphor removal. Phosphorus removed by algae in the trickling filter reached 52% or 902.5 g per day at a flow rate of 9000,000 l/d.

Keywords: Algae; phosphorus removal; trickling filter; waste water treatment.

1. INTRODUCTION

Algae of the species Cladophra is growing on a trickling filter in the secondary treatment process at the village of Minoa Waste Water Treatment Facility (WWTF) in Central New York State [1]. In addition, common earth worm species *Eiseniella tetraedra* and *Dedrodrilus rubidus* can be found living in the algae growing on the trickling filter [1].

Cladophra is a filamentous green algae that grows attached to solid substrates [2,3]. Cladophra specie can be found since the 1950's, in the northeastern portion of the United States including Lake Michigan and some of the other Great Lakes [4,5,6]. Algae growth in lakes can be linked to high nutrition levels, light, pH, and temperature [6,7]. WWTF were identified as main source of phosphorous for algae growth. In addition urban sources such as increased use of

*Corresponding author: E-mail: kdoelle@esf.edu;

fertilizers in agricultural operations, improper sewage systems, and heavy rain events contribute to the amount of phosphorus entering large water bodies by rivers [8,9,10].

A Trickling filter is a fixed bed waste water treatment system that uses a fixed bed material such as rock, slag, wood or random placed plastic packing as growth media for microorganisms under aerobic conditions [11,12]. At the investigated trickling filter Brentwood structured-sheet media is used as growth media for a biological film that contains a population of microorganisms such as anaerobic, aerobic and facultative bacteria. An aerobic oxidation occurs as the waste water passes the biofilm reducing the carbonaceous biological oxygen demand (CBOD) in the waste water stream followed by nitrification through nitrification bacteria that grow on the media in the lower part of the trickling filter not exposed to sunlight [13,14].

Cladophra will grow when phosphorus levels in the receiving waste water are high [15]. Cladophra growth on the trickling filter at the WWTF is observed if phosphorous levels of the influent waste water are in the range of 3.00 mg/l to 35 mg/l depending on influent flow and time of year.

At the WWTF typical influent waste water quality parameters, measured at a certified laboratory, are for total phosphorous (TP) 3.8 mg/l, ammonium (NH_3) of 18 mg/l, total Kjeldal nitrogen (TKN) 31 mg/l, chemical oxygen demand (CBOD) 119 mg/l, total suspended solids (TSS) of 150 mg/l and biological oxygen demand (BOD_5) of 125 mg/l at an average temperature of 15℃. Influent levels to the waste water treatment facility vary daily and during the year based on seasonal variations.

The influent box of a secondary treatment trickling filter system receives a total flow of 950,000 l/d of pretreated municipal wastewater. 571,500 l/d are received from a primary clarifier and 378,500 l/d from constructed wetlands. From the influent box the waste water travels through to filter out organic solids and some nutrients.

The trickling filter effluent is treated in a secondary clarifier followed by disinfection and then discharged into a stream below the permit level with a TP of 0.8 mg/l, NH_3 of 0.5 mg/l, TKN 1.3 mg/l, CBOD <4 mg/l, TSS of <4 mg/l and BOD_5 of <4 mg/l which were measured at a certified laboratory.

The following study explores the phosphorous remediation potential of algae growing on a trickling filter in the secondary treatment system.

At the investigated trickling filter algae grows directly on top of the Brentwood plastic media. Influent waste water contacts first the algae layer before it reaches the Brentwood growth media were an aerobic oxidation occurs that reduces the biological waste in the waste water by over 90% on average.

The focus of this study is to investigate the role of algae in a wastewater treatment facility to remediate phosphor from the receiving waste water stream. The study was conducted in March were worm species are not at their peak and both winter and summer algae are present [1].

2. METHODOLOGY

The methodology section describes the different methods used to determine, fulfill and understand the research project objectives for the phosphorous removal with *Cladophora glomerata* and *Vaucheria* at a trickling filter.

2.1 Sample Collection and Preparation

To gain an understanding of how much phosphorus is being taken up by the algae species growing on the trickling filter (Picture 1), samples were collected in March when worm presence was at a minimum, and any worms collected could be easily separated from the algae sample before analyses of the dry weight [1].

Picture 1. Winter and summer algae on trickling filter [16]

At the surface of the trickling filter eight algae samples from a square area of 150 mm (6 in) were collected in one gallon zip lock bags. The samples were brought back to the laboratory. At the laboratory worms contained in the algae samples were removed prior to algae processing.

Sample collection for the WW was carried out by collection of 200-800 ml of trickling filter water in 1l Nalgene bottles.

2.2 Sample Processing

To gain an understanding of how much phosphorus is being taken up by the algae species growing on the trickling filter the total algae mass amount was calculated and the phosphorous content in the trickling filter waste water feed flow and discharge was measured. The samples were collected in March when worm presence was at a minimum and any worms collected could be easily separated from the algae sample before analyses of the dry weight [1].

2.3 Sampling Points

The trickling filter has a radius of 6.08 m (20 ft.). As observed, an alga is growing only on the surface of the Brentwood trickling filter media. The trickling filter has a surface area for algae growth of 116.13 m^2 (1,256.6 ft^2).

Eight algae samples of 150 mm x 150 mm (6 in. by 6 in.) were collected at the trickling filter surface. Four samples were collected at a radius of 5.47 m (18 ft.), and four samples at a radius of 1.22 m (4 ft.) 90 degrees apart as shown in Fig. 1.

Waste water samples were taken to compare phosphorus amounts before and after passing through the trickling filter. The trickling filter feed waste water samples were taken from the trickling filter arm at the same radius as the algae samples. The trickling filter discharge samples were taken from the trickling filters discharge channel before the waste water enters the secondary clarifier.

2.4 Sample Analyses

The water samples were analyzed using a Bran+Luebbe Autoanalyzer 3 spectrometer (United States) following manufacture methods and procedures to measure total phosphorous content as required by the waste water treatment plants permit.

Specimens for the Scanning Electron Microscope (SEM) analysis were soaked in 2.5% glutaraldehyde solution for 1 hour, followed by dehydrating them in ethanol. The samples were then sputter coated with gold palladium and analyzed with a JEOL 5800LV scanning electron microscope.

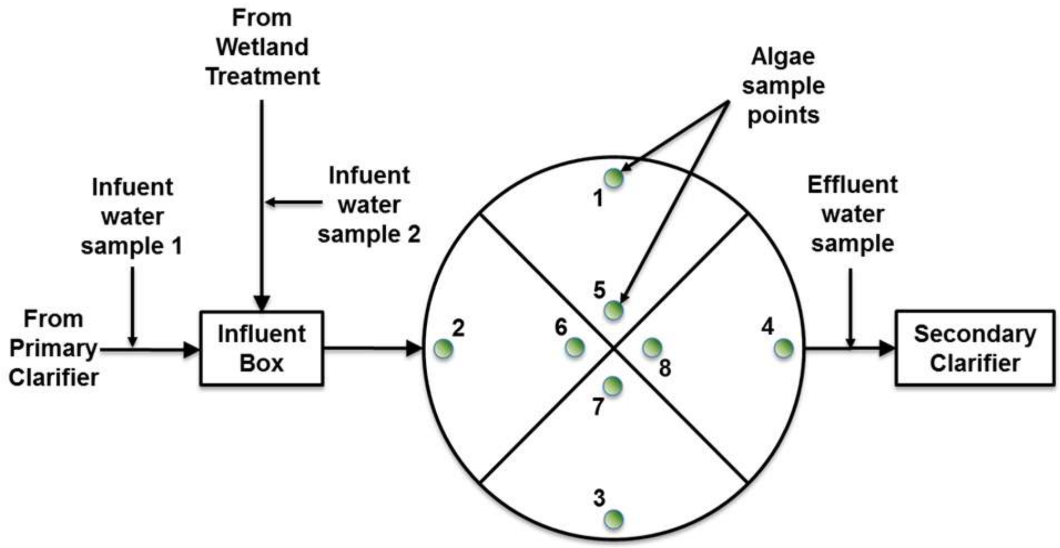


Fig. 1. Algae and water sampling points

3. RESULTS AND DISCUSSION

During sampling, it was noted that algae growth on the trickling filter surface is not constant. The chosen sampling points reflect a good distribution of the trickling filters algae layer of winter and summer algae.

3.1 Phosphorus Uptake

For the phosphorus uptake measurements, the results of the estimation of total algae on the trickling filter are shown in Table 1.

Table 1. Total algae estimation on trickling filter

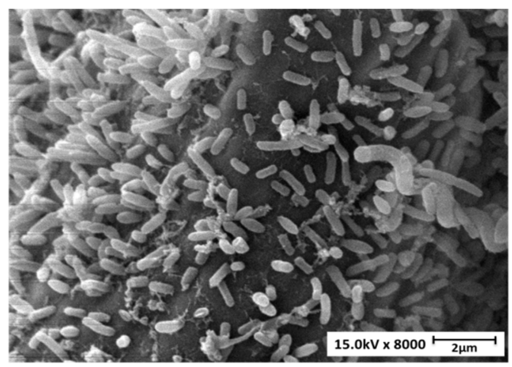
Algae sample	Wet Wt. (g)	Dry Wt. (g) (95.45% moisture content)
1	213.56	9.72
2	154.33	7.02
3	432.05	19.66
4	261.40	11.89
5	221.40	10.07
6	210.33	9.57
7	412.70	18.78
8	408.98	18.61

The average wet weight at a 95.45% moisture content of the eight algae samples was 289.34 g/225 cm^2 (36 in^2). The average dry weight was 13.17 g/225 cm^2 (36 in^2). The average dry weight per cm^2/in^2 was 0.06 g and 0.37 g respectively.

The analyses of the phosphorous content for the trickling head box influent from the primary clarifier were measured at 2.136 mg/l. The phosphorous content in the wetland effluent was measured at 1.671 mg/l. The calculated total phosphorous at the above flow rates from the primary clarifier and the wetland to the head box results in a total phosphorous content of 1.951 mg/l for the trickling filter influent waste water stream.

The measured phosphorous content in the pre-treated waste water correlates with the waste water treatment plants analyses by a certified laboratory were total phosphorous level of 2.000 mg/l for the feed waste water and 1.900 mg/l for the wetland feed waste water to the trickling filter were reported. However, the certified laboratory samples were not taken at the same time as the actual trickling filter samples.

The phosphorous content of the pre-treated waste water after it has passed the trickling filter was measured at 1.016 mg/l. Therefore, 0.950 mg/l of phosphorous or 52% of the influent phosphorous is removed by the algae layer growing on the trickling filter. The total phosphorous uptake by 69.68 kg of dry algae biomass growing on a total trickling filter surface area of 116.13 m^2 (1,256.6 ft^2) in March was calculated at 902.50 g/d. The capacity per gram of algae to take up phosphorous can be calculated at 0.013 g/d. However, it is important to keep in mind that phosphor influent levels to the waste water treatment facility vary during the year. Phosphorus levels could also vary from year to year depending on seasonal variation**.** Based on the results it can be suggested that algae cannot take up all phosphorus from the waste water on the trickling filter alone. Microorganisms as shown in Picture 2 look similar to microorganisms found by Levin such as *Aerobacter aerogenes*, strain A3, that are capable and proven to take up phosphorus in wastewater [12].



Picture 2. Bacteria on algae [17]

The phosphorus uptake analysis was performed for total phosphorus, further tests should be performed to discover and analyze orthophosphate uptake.

Further studies should be conducted estimating seasonal phosphorus uptake.

4. CONCLUSION

Algae biomass can be used to remove phosphorus from waste water streams. This study showed that 902.5 g/d (1.989 lbs./d) can be achieved. This amount might vary based on algae growth rate and algae mass retained on a trickling filter media surface and the phosphorus content in the waste water influent stream during a yearly operation. Utilizing algae on a trickling filter to remove phosphor could be an inexpensive alternative for cost strapped US municipalities operating a water treatment facility, due to a short fall in waste water infrastructure funding [18].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Doelle K, Peluso C. Earthworm and algae species in a trickling filter. Journal of Advances in Biology & Biotechnology. 2015;3(3):132-138.
2. Jackson MB, Vandermeer EM, Heintsch LS. Attached filamentous algae of northern lake superior: Field ecology and biomonitoring potential during 1983. J Great Lakes Res. 1990;16(1):158–168.
3. UW-Extension. Wisconsin costal management program. Cladophra in Lake Michigan; 2016. Available:http://dnr.wi.gov/topic/greatlakes/documents/CladophoraFactsheet.pdf (Accessed 10 October 2016)
4. Canale RP, Auer MT. Ecological studies and mathematical modeling of *Cladophora* in Lake Huron: 5. Model development and calibration. J. Great Lakes Res. 1982;8: 112-125.
5. Auer MT, Kuczynski, Gawede R. Phosphorous provenance and *Cladophora* growth in Lake Ontario, Michigan Technology University Report 24; 2014.
6. Harris VA. Nuisance algae on Lake Michigan Shores. University of Wisconsin Sea grant Institute. 2005;02. Available:http://aqua.wisc.edu/publications/PDFs/NuisanceAlgae.pdf (Accessed 10 October 2016)
7. Kreis R. Lake erie phosphorus loading and *Cladophora* updates. Lake Erie EPA Science Advisory Board (SAB) Review Panel, Chicago, IL, June 21 – 22; 2016.
8. Bootsma H, Young EB, Berges JA. Cladophra abudance and physical/ chemical conditions in the Milwaukee Region of Lake Michigan, Milwaukee Metropololitan Sewage District; 2006. Available:http://www.mmsd.com/-/media/MMSD/Documents/Water%20Quality/Reports/*cladophora*_report.pdf (Accessed 10 October 2016)
9. Cost estimate of Phosphorous removal at waste Water treatment plants, Ohio Environmental Protection Agency; 2013. Available:http://epa.ohio.gov/Portals/35/wqs/nutrient_tag/OhioTSDNutrientRemovalCostEstimate_05_06_13.pdf (Accessed 10 October 2016)
10. Environmental Defense Canada. Clean not green. Freshwater Future. 2014;8.
11. Joint Department of the Army and Air Force USA. Domestic wastewater treatment. Technical Manual TM 5-814-3/AFM 88-11. 1988;3.
12. Tchobanoglous G, Burton FL, Stensel HD, editors. Waste water engineering: Treatment and reuse / Metcalf & Eddy, Inc. 4th ed. McGraw-Hill Higher Education; 2003.
13. Solomon C, Casey P, Lake A. Trickling filter achieving nitrification. Environmental Technology Initiative. 1998:1-4. Available:http://www.nesc.wvu.edu/pdf/WW/publications/eti/TF_tech.pdf (Accessed 10 October 2016)
14. Levin GV, Shapiro J. Metabolic uptake of phosphorus by wastewater organisms. J. Water Pollution Control Federation. 1965;37(6):800-821.
15. Doelle K, Watkins C. Application of algae as a biomass feedstock source at a waste water treatment facility. Journal of Advances in Biology & Biotechnology. 2015;4(3):1-9.
16. Photo by Klaus Dölle, Summer and Winter Algae on Trickling filter, Jpg-File.
17. Photo by Klaus Dölle, Bacteria growing on algae, Jpg-File.
18. US Environmental Protection Agency (EPA), EPA Survey Shows $271 Billion Needed for Nations Wastewater Infrastructure; 2016. Available:https://www.epa.gov/newsreleases/epa-survey-shows-271-billion-needed-nations-wastewater-infrastructure (Accessed 10 October 2016)

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/17341