ISSN: 2523-5664 (Print)
ISSN: 2523-5672 (Online)
CODEN: WCMABD

Water Conservation and Management (WCM)

DOI: <http://doi.org/10.26480/wcm.02.2021.66.70>

RESEARCH ARTICLE

ROLE OF PHYCOREMEDIATION IN DOMESTIC WASTEWATER TREATMENT

Nandini Moondra*, Namrata D Jariwala, Robin A Christian

Civil Engineering Department, S.V. National Institute of Technology (SVNIT), Surat, Gujarat, India-395007.

*Corresponding Author Email: nandini7808@yahoo.in

This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ARTICLE DETAILS

Article History:

Received 20 July 2021
Accepted 24 August 2021
Available online 02 September 2021

ABSTRACT

Conventional domestic wastewater treatment in most developing countries is confined to secondary treatments, mainly focusing on solids and organics removal, which results in eutrophication when the effluents are discharged into receiving bodies. Thus, to resolve the issues associated with the conventional treatment system, in the present study, microalgae was introduced in the primary treated effluent collected from a sewage treatment plant to study the efficiency of the system in reducing eutrophication and other challenges of secondary treatment. Phycoremediation is an effective and eco-friendly treatment alternative that reduced the primary-treated effluent's $\text{PO}_4\text{-P}$, $\text{NH}_3\text{-N}$ and COD concentration to 97.89%, 98.81%, and 88.24%, respectively at the identical HRT practiced for secondary treatment. One-way ANOVA was also conducted to determine the effectiveness of the system statistically. The experimental and statistical analysis proved that microalgal treatment could resolve the challenges of conventional secondary treatments if adopted for domestic wastewater.

KEYWORDS

Chlorella vulgaris, HRT, nutrients, organic matter, photosynthetic- aeration.

1. INTRODUCTION

Wastewater generation is an inevitable process as it is approximately 80% of the water consumption in society. However, the wastewater characteristics generated result from the life comforts and technologies practiced daily (Abdel-Raouf et al., 2012). Developing countries such as India (middle and low-income countries) are looking for infrastructures for effective wastewater treatment systems. Most of the population resides in rural areas, facing challenges like an ever-increasing population and enhanced lifestyles. The issue is severe because of the fast pace of urban development, and effective effluent measures are mandatory to control and treat wastewater (Brenner et al., 2008).

In developing countries, conventional municipal wastewater treatment is confined to secondary treatments, mainly focusing on solids and organics removal (Neveux et al., 2016). In conventional biological wastewater treatment processes, oxygen demand by aerobic bacteria accounts for the most significant portion, roughly half of electricity demand for a typical secondary wastewater treatment facility utilizing the activated sludge process (Samori et al., 2014). Hence, secondary effluents released to nearby receiving bodies are rich in nutrients (nitrogen and phosphorus), resulting in eutrophication and dead zones in water bodies, ultimately polluting the freshwater sources. Tertiary treatments that enhance nutrient removal are less in practice due to their high energy and cost requirements and additional concerns of safe sludge disposal (Kube et al., 2018).

The ultimate goal of wastewater management is to protect the environment commensurate with public health and socio-economic concerns. The development of clean, sustainable and renewable energy technologies is the key to overcome greenhouse gas emissions and energy crises. Hence, the current scenario needs to practice such a treatment

process that can overcome the limitations of present wastewater treatment systems in an energy-saving, cost-effective and eco-friendly way. Microalgal processes are nowadays regarded as sustainable platforms for wastewater treatment. They exhibit a lower energy demand for oxygen supply due to the photosynthetic oxygen production by microalgae while supporting efficient nutrient removal and resource recovery (Quijano et al., 2017).

Wastewater acts as an excellent low-cost growth medium for microalgae (Delrue et al., 2016). Various researches have reported the effectiveness of *Chlorella vulgaris* in nutrient removal from domestic wastewater with an efficiency >95% at 9 days HRT, 99% and 72% efficiency for phosphorus and nitrogen removal at 10 days HRT, 79% efficiency at 14 days HRT (Sydney et al., 2011; Caporgno et al., 2015; Shaker et al., 2015). However, HRT mentioned in literature for the microalgal system is a couple of days, which influences energy consumption, cost and the installation's footprint, making this system inappropriate for domestic wastewater treatment in STPs (sewage treatment plant). Thus in this study, an attempt was made to analyze the effectiveness of *Chlorella vulgaris*, a microalgal species, for treating primary treated domestic wastewater collected from the STP of a smart city of India. The present study was conducted in a natural environmental condition at 7 hours HRT (same as a secondary treatment system in the STP).

2. MATERIALS AND METHODS

In this study, *Chlorella vulgaris*, a microalgal species, used was provided by Ahmedabad-based consultancy. The microalgal culture was kept in a natural environment. The efficiency of microalgal species in removing nutrients and other physico-chemical parameters was analyzed through a batch mode lab-scale study. The site for the experimental setup was the

Quick Response Code

Access this article online

Website:
www.watconman.org

DOI:
[10.26480/wcm.02.2021.66.70](http://doi.org/10.26480/wcm.02.2021.66.70)

open space inside the Old Classroom Complex building (21.16°N, 72.78°E) in the SVNIT campus, Surat. The experimental site received significant sunlight for 5-6 hours, with the temperature variation from 27°C to 30 °C. The study was conducted in a 20 L Bisleri plastic container kept upside down with a working volume of 15 L.

Primary treated domestic wastewater analyzed for the study was collected from an urban STP of India with 120 MLD capacity. The volume of the microalgal solution added in the present study was 30% of the reactor's total volume, as it was found to be the optimum amount of algae for domestic wastewater treatment from previous experimental analysis (Moondra et al., 2020). The study was conducted with two containers of the same capacity; one contained the mixture of 5 L of *Chlorella vulgaris* in 10 L of primary treated domestic wastewater, making a total volume of 15 L and the other container holds the 15 L primary treated wastewater (a control system) as shown in Figure 1. Intermittent artificial aeration was provided in both the containers for continuous mixing of the wastewater and maintaining the minimum DO concentration (around 3 mg/L) in the control system to replicate it with the secondary treatment system incorporated in the STP.

Figure 1: Experimental setup for the study

The study was conducted for 7 hours in which the first 2.5 hours aeration was provided in both the beakers and then the sample was allowed to settle for 30 minutes; then again, aeration was provided for 2 hours, followed by 2 hours of settlement. After the final settling, the supernatant was collected for physico-chemical analysis. Parameters analyzed during the study were ammoniacal nitrogen ($\text{NH}_3\text{-N}$), nitrate ($\text{NO}_3\text{-N}$), phosphate ($\text{PO}_4\text{-P}$), chemical oxygen demand (COD), electrical conductivity (EC), pH, dissolved oxygen (DO), solids such as total dissolved solids (TDS), total suspended solids (TSS) and total solids (TS) as per the procedure mentioned in APHA 2012. Duplicates were performed for each parameter for a given sample to minimize the human and instrumental error, and the average was considered for analysis. The analysis was also done for filtered effluent (passed the non-filtered effluent to 4-5.5 μm coarse filter). One-way ANOVA analysis ($p < 0.05$) was also conducted using IBM-SPSS-25 software to determine the significance of the treatment on various parameters statistically.

3. RESULTS

Removal efficiency obtained for various parameters after treatment was the determining criteria for the effectiveness of *Chlorella vulgaris* in domestic wastewater treatment for the study. Wastewater collected for the study showed massive variation in the characteristics, which helped understand whether the microalgal treatment could efficiently handle the fluctuations in influent characteristics. The mean and standard deviation of influent and effluent wastewater for all the parameters (except pH) were analyzed in both conditions, i.e., microalgal treatment and the control (only aeration) for both non-filtered and filtered effluent is shown in Table 1.

Table 1: Variation in parameters studied for both non-filtered and filtered samples for PST treated wastewater of STP at 7 hours HRT					
Parameter	Raw w/w	30% M (NF)	30% M (F)	Aeration (NF)	Aeration (F)
pH	7.28	8.15	8.32	7.83	7.98
EC (mS/cm)	1.28±0.16	1.15±0.20	1.12±0.19	1.16±0.17	1.14±0.17
TS (mg/L)	1971.15±291.53	1431.50±284.68	1215.08±251.03	1625.20±301.04	1398.13±279.76
TDS (mg/L)	637.00±79.90	571.08±95.11	554.23±92.02	578.30±79.60	564.33±76.78
TSS (mg/L)	1333.98±298.8	859.75±277.08	659.75±232.99	1046.75±298.39	833.23±275.09
DO (mg/L)	0.19±0.09	6.29±0.63	6.29±0.63	3.15±0.36	3.15±0.36
COD (mg/L)	279.80±40.20	59.04±20.46	43.28±18.98	130.99±32.03	114.98±29.72
$\text{PO}_4\text{-P}$ (mg/L)	4.23±0.49	0.45±0.44	0.41±0.40	2.17±0.53	2.08±0.47
$\text{NH}_3\text{-N}$ (mg/L)	21.9±1.66	2.54±2.11	2.07±2.00	10.48±4.43	9.60±4.07
$\text{NO}_3\text{-N}$ (mg/L)	0.01±0.02	4.65±2.90	4.54±2.83	0.55±0.50	0.51±0.47

M: microalgal, NF: non-filtered, F: filtered

Higher removal was obtained in the microalgal system at an HRT of 7 hours for different parameters analyzed than the control system, depicting the excellent effect of phycoremediation on domestic wastewater treatment. Effluent resulted due to microalgal treatment had high DO and pH concentration. pH reached 8.49 and 8.95 in the case of non-filtered and filtered effluent when treated with *Chlorella vulgaris*. However, in the control system (aeration and no microalgae), pH concentration reached 8.19 and 8.52 for non-filtered and filtered effluent, which was higher than influent (ranging between 6.95 to 7.94) but lower than the microalgal system. DO concentration increased in both the systems irrespective of the very low DO concentration in the influent (between 0.1 mg/L to 0.4 mg/L). An increase in the DO concentration for the microalgal system was higher than the control and reached 7.10 mg/L for both filtered and non-filtered effluent. However, in the control system, DO concentration reached 3.60 mg/L.

An increase in DO and pH also led to a remarkable removal of organic matter and nutrients. COD concentration in influent ranged from 172.00 mg/L to 371.00 mg/L, showing a considerable variation. When treated with microalgae, COD concentration lowered to 32.00 mg/L for non-filtered effluent with a maximum efficiency of 88.24% and 19.20 mg/L (92.94%) for filtered effluent. In the case of a control system (only aeration, no microalgae), COD concentration lowered to 80.00 mg/L (70.00%) for non-filtered effluent and 67.20 mg/L (74.07%) in the case of filtered effluent, as shown in Figure 2.

Figure 2: COD reduction in microalgal system and control system for non-filtered and filtered effluents.

$\text{NH}_3\text{-N}$ concentration in the influent during the study ranged from 18.56 mg/L to 26.88 mg/L. Reduced $\text{NH}_3\text{-N}$ concentration at 7 hours HRT, when treated with microalgae, for non-filtered effluent reached 0.28 mg/L (98.81%), and for filtered effluent concentration, the maximum removal efficiency was 100 %. In the control system, the lowest $\text{NH}_3\text{-N}$ concentration observed was 5.21 mg/L (77.40%) and 5.04 mg/L (78.21%) for non-filtered and filtered effluent, respectively, as shown in Figure 3(a). $\text{NO}_3\text{-N}$ found in influent during the study was almost nil. After treatment, nitrate reached 10.29 mg/L for non-filtered and 10.75 mg/L for filtered effluent in the microalgal system.

However, the highest nitrate concentration for the control reactor's effluent was 2.60 mg/L and 2.51 mg/L for non-filtered and filtered effluent, as shown in Figure 3(b). Similarly, $\text{PO}_4\text{-P}$ reduction was also quite promising as that of $\text{NH}_3\text{-N}$. Primary treated wastewater had $\text{PO}_4\text{-P}$ in the range of 3.12 mg/L to 4.90 mg/L. Microalgal treatment resulted in 97.89% and 98.00% reduction in $\text{PO}_4\text{-P}$ for non-filtered and filtered effluent with a minimum concentration of 0.10 mg/L and 0.09 mg/L, respectively. However, only aeration (in the control system) led to $\text{PO}_4\text{-P}$ reduction to 1.47 mg/L (68.23%) and 1.43 mg/L (69.25%) for non-filtered and filtered effluent, respectively, as shown in Figure 3(c).

Figure 3: Variation in nutrients (a) Ammonia (b) Nitrate and (c) Phosphate concentration before and after treatment in microalgal system and control system for non-filtered and filtered effluents.

The system also helped in removing solids, but lesser reductions were observed than nutrients and organic matter. Among the solids analyzed (TS, TSS and TDS), TSS showed a maximum reduction of 59.15% (478.00 mg/L) and 41.76% (518.00 mg/L) for a non-filtered effluent when treated with microalgae in the presence of external aeration and the control system, respectively. In contrast, TSS concentration in primary treated wastewater was in the range of 620.00 mg/L to 1851.00 mg/L, as shown in Figure 4(a). TS concentration in the influent ranged between 1320.00 mg/L to 2546.00 mg/L. After treatment with microalgae, TS concentration lowered to 890.00 mg/L (45.23%) and 980.00 mg/L (45.31%) when treated only in the presence of external aeration (control system), as shown in Figure 4(b).

Figure 4: Variation in (a) TSS and (b) TS concentration before and after treatment in microalgal system and control system for non-filtered and filtered effluents.

Among the solids, TDS removal showed the least efficiency. TDS concentration in the influent varied between 519.00 mg/L to 780.00 mg/L. TDS removal for both microalgal system and control was similar, proving that microalgae don't majorly affect the TDS removal. TDS concentration in the non-filtered effluent of the microalgal system and control system was reduced to 419.00 mg/L (30.37%) and 436.00 mg/L (28.52%), as shown in Figure 5(a). The removal of EC concentration was similar to TDS. EC concentration in the influent varied from 1.06 mS/cm to 1.57 mS/cm. When treated with 30% microalgae at 7 hours HRT, EC concentration in non-filtered and filtered effluent lowered to 0.84 mS/cm (31.21%) and 0.82 mS/cm (33.33%) respectively. In the control system (only aeration, no microalgae), the minimum EC concentration was 0.88 mS/cm (26.43%) and 0.85 mS/cm (30.50%) in the case of non-filtered and filtered effluent, as shown in Figure 5(b).

Figure 5: Variation in (a) TDS and (b) EC concentration before and after treatment in microalgal system and control system for non-filtered and filtered effluents.

One-way ANOVA conducted for different parameters analyzed during the study revealed that microalgal treatment significantly removed the various parameters studied, as shown in Table 2.

Table 2: One-way ANOVA for influent and effluent of various parameters

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
EC	Between Groups	.662	4	.166	5.137	.001
	Within Groups	6.286	195	.032		
	Total	6.948	199			
TSS	Between Groups	10506748.150	4	2626687.038	34.109	.000
	Within Groups	15016857.725	195	77009.527		
	Total	25523605.875	199			
TDS	Between Groups	169470.030	4	42367.507	5.863	.000
	Within Groups	1409078.925	195	7226.046		
	Total	1578548.955	199			
$\text{PO}_4\text{-P}$	Between Groups	393.732	4	98.433	455.962	.000
	Within Groups	42.097	195	.216		
	Total	435.829	199			
pH	Between Groups	25.533	4	6.383	124.571	.000
	Within Groups	9.992	195	.051		
	Total	35.525	199			
DO	Between Groups	1050.558	4	262.639	1221.404	.000
	Within Groups	41.931	195	.215		
	Total	1092.489	199			
$\text{NO}_3\text{-N}$	Between Groups	869.688	4	217.422	64.357	.000
	Within Groups	658.787	195	3.378		
	Total	1528.475	199			
$\text{NH}_3\text{-N}$	Between Groups	10322.441	4	2580.610	272.000	.000
	Within Groups	1850.072	195	9.488		
	Total	12172.513	199			
COD	Between Groups	1405299.413	4	351324.853	408.436	.000
	Within Groups	167733.536	195	860.172		
	Total	1573032.949	199			
TS	Between Groups	13405136.930	4	3351284.233	42.108	.000
	Within Groups	15519552.350	195	79587.448		
	Total	28924689.280	199			

4. DISCUSSIONS

An increment in the pH of wastewater also acts as a disinfectant by releasing antibacterial substances making unfavorable conditions for toxic substances (Schumacher and Sekoulov, 2003). The light/dark phase enhances photosynthesis in the system; hence the algal system can effectively work all day long (Markou and Georgakakis, 2011). pH variation impacts algal cell physiology and affects nutrients removal by increasing alkalinity, affecting the algal intake capacity of nutrients (Rawat et al., 2011). The micro-environment created by algal biofilm shields cells from environmental stress variation in influent concentration and even converts organic matter into biofilms. In addition to this organic matter, removal was contributed because of the low F/M ratio of the algal system and ample DO concentration to biodegrade the wastewater (Choi and Lee, 2012).

Reduction in $\text{NH}_3\text{-N}$ led to increased $\text{NO}_3\text{-N}$ concentration due to the nitrification process. However, $\text{NO}_3\text{-N}$ formation due to nitrification suppressed COD removal (Sawyer et al., 2003). Adsorption in the microalgal surface, precipitation at high pH and temperature resulted in phosphorus removal during the study (Moondra et al., 2021). Phosphorus contributes to about 1% of the total microalgal cells and results in ATP and RNA generation (Su et al., 2011). Nitrogen contributes to nearly 10% of the total microalgal cells. Among the different forms of nitrogen, $\text{NH}_3\text{-N}$ is the most utilized form of nitrogen in phycoremediation treatment. Nitrogen is necessary for building up the algal cells, for example, genetic material, enzymes, proteins, hormones, vitamins, alkaloids, amides, and energy transfer molecules. Cellular uptake and nitrification are the way that helps in the elimination of nitrogen (Goncalves et al., 2017).

Algal biofilms, comprised of algae and heterotrophic microscopic organisms living in symbiosis, resulted in high removal in all parameters, primarily organic matter and nutrients in comparison to only heterotrophic bacteria present in the control system (Schnurr and Allen, 2015). Mixed populations give robustness to ecological fluctuations, stability for the individuals, the capacity to share metabolites and climate and protection from intrusion by different species, upgrades the steadiness of the system, improving the efficiency of nitrogen and phosphorus expulsion from secondary effluent (Delgadillo-mirquez et al., 2016; Subashchandrabose et al., 2011). Microalgae, combined with bacteria, lead to auto-flocculation, enhance the TSS removal and reduces the need for harvesting (Nambiar and Bokil, 1981).

Researchers found that vitamins discharged by bacteria advantageously affect microalgal development. Some intermediate metabolites of microalgae are discharged, which acts as a natural carbon for bacterial growth. Secondly, bacterial metabolisms quicken the breakdown of solid organics in wastewater and give more digestible nutrients for microalgae development, and even bacterial availability enhances microbial growth (Liang et al., 2013; Brenner et al., 2008). A small photosynthetic cell, microalgae, can fill in as an air circulation gadget to give oxygen to the bacteria if incorporated in the conventional system, reducing the cost of wastewater treatment in an STP.

External aeration was mainly provided in the study to keep the mix in suspension to avoid temperature variation within the reactor; every cell is exposed to sunlight and proper gaseous transfer and also have a control system as that in the STP for better understanding of the impact of microalgae in treatment (Goncalves et al., 2017). Sunlight enhanced the efficiency of the algal system by acting as a catalyst in the process. Unlike the conventional system, the microalgal system works on a low F/M ratio; hence it doesn't lead to secondary pollution by generating sludge (Aslan and Kapdan, 2006).

5. CONCLUSION

Microalgae effectively remove nutrients, organic matter, and solids from domestic wastewater compared to secondary treatment in STP. The effluent characteristics of the microalgal system were within the norms at the identical HRT practiced for secondary treatment in STPs. The maximum removal observed for $\text{PO}_4\text{-P}$, $\text{NH}_4\text{-N}$ and COD for non-filtered effluents was 97.89%, 98.81% and 88.24%, respectively. However, reduction further increased for filtered effluent and reached 98.00%, 100% and 92.94% for $\text{PO}_4\text{-P}$, $\text{NH}_4\text{-N}$ and COD, respectively. The study proves that if *Chlorella vulgaris* is incorporated in sewage treatment plants, sludge generation would be minimal and tertiary treatments would not be needed. The present work was confined to a batch mode lab-scale study. However, a similar study could be conducted in a continuous mode at a pilot scale in the future. Biological parameters can also be studied along with physico-chemical parameters. In addition to this treatability of

various other microalgal species can also be studied for domestic wastewater treatment. Also, the feasibility of phycoremediation can be studied for industrial wastewater and greywater to explore the working of the system when applied in the real world.

CONFLICT OF INTEREST

The authors report no conflicts of interest.

ACKNOWLEDGMENT

The authors wish to thank Phycolinc Technologies Pvt. Ltd. for providing critical suggestions during the study. The authors are also thankful to all technical and non-technical staff of the institute for helping in every possible way.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper.

FUNDING

No funding was provided for the work

REFERENCES

- Abdel-Raouf, N., Al-Homaidan, A.A., Ibraheem, I.B.M., 2012. Microalgae and wastewater treatment. Saudi J. Biol. Sci. 19, Pp. 257-275. <https://doi.org/10.1016/j.sjbs.2012.04.005>.
- Aslan, S., Kapdan, I.K., 2006. Batch kinetics of nitrogen and phosphorus removal from synthetic wastewater by algae. Ecol. Eng. 28, Pp. 64-70. <https://doi.org/10.1016/j.ecoleng.2006.04.003>.
- Brenner, K., You, L., Arnold, F.H., 2008. Engineering microbial consortia : A new frontier in synthetic biology. Trend Biotechnol. 26, Pp. 483-489. <https://doi.org/10.1016/j.tibtech.2008.05.004>.
- Caporgno, M.P., Taleb, A., Olkiewicz, M., Font, J., Pruvost, J., Legrand, J., Bengoa, C., 2015. Microalgae cultivation in urban wastewater: Nutrient removal and biomass production for biodiesel and methane. Algal Res. 10, Pp. 232-239. <https://doi.org/10.1016/j.algal.2015.05.011>.
- Choi, H.J., Lee, S.M., 2012. Effects of microalgae on the removal of nutrients from wastewater: Various concentrations of *Chlorella vulgaris*. Environ Eng. Res. 17, Pp. 3-8. <https://doi.org/10.4491/eer.2012.17.S1.S3>.
- Delgadillo-mirquez, L., Lopes, F., Taidi, B., Pareau, D., 2016. Nitrogen and phosphate removal from wastewater with a mixed microalgae and bacteria culture. Biotechnol. Rep. 11, Pp. 18-26. <https://doi.org/10.1016/j.btre.2016.04.003>.
- Delrue, F., Alvarez-Díaz, P.D., Fon-Sing, S., Fleury, G., Sassi, J.F., 2016. The environmental biorefinery: Using microalgae to remediate wastewater, a win-win paradigm. Energies. 9, Pp. 132-150. <https://doi.org/10.3390/en9030132>.
- Goncalves, A.L., Pires, J.C.M., Simoes, M., 2017. A review on the use of microalgal consortia for wastewater treatment. Algal Res. 24, Pp. 403-415. <https://doi.org/10.1016/j.algal.2016.11.008>.
- Kube, M., Jefferson, B., Fan, L., Roddick, F., 2018. The impact of wastewater characteristics, algal species selection and immobilisation on simultaneous nitrogen and phosphorus removal. Algal Res. 31, Pp. 478-488. <https://doi.org/10.1016/j.algal.2018.01.009>.
- Liang, Z., Liu, Y., Ge, F., Xu, Y., Tao, N., Peng, F., Wong, M., 2013. Efficiency assessment and pH effect in removing nitrogen and phosphorus by algae-bacteria combined system of *Chlorella vulgaris* and *Bacillus licheniformis*. Chemosphere, 92, Pp. 1383-1389. <https://doi.org/10.1016/j.chemosphere.2013.05.014>.
- Markou, G., Georgakakis, D., 2011. Cultivation of filamentous cyanobacteria (blue-green algae) in agro-industrial wastes and wastewaters : A review. App. Energy. 88, Pp. 3389-3401. <https://doi.org/10.1016/j.apenergy.2010.12.042>.

- Moondra, N., Jariwala, N.D., Christian, R.A., 2020. Sustainable treatment of domestic wastewater through microalgae. *Int. J. Phytoremediation*. 22, Pp. 1480-1486. <https://doi.org/10.1080/15226514.2020.1782829>.
- Moondra, N., Jariwala, N.D., Christian, R.A., 2021. Integrated approach of phycoremediation in wastewater treatment: An insight. *WCM*. 5, Pp. 8-12. <https://doi.org/10.26480/wcm.01.2021.08.12>.
- Nambiar, K.R., Bokil S.D., 1981. Luxury uptake of nitrogen in flocculating algal-bacterial system. *Water Res.* 15, Pp. 667-669. [https://doi.org/10.1016/0043-1354\(81\)90158-5](https://doi.org/10.1016/0043-1354(81)90158-5).
- Neveux, N., Magnusson, M., Mata, L., Whelan, A., de Nys, R., Paul, N.A., 2016. The treatment of municipal wastewater by the macroalga *Oedogonium* sp. and its potential for the production of biocrude. *Algal Res.* 13, Pp. 284-292. <https://doi.org/10.1016/j.algal.2015.12.010>.
- Quijano, G., Arcila, J.S., Buitron, G., 2017. Microalgal-bacterial aggregates: Applications and perspectives for wastewater treatment. *Biotechnol. Adv.* 35, Pp. 772-781. <https://doi.org/10.1016/j.biotechadv.2017.07.003>.
- Rawat, I., Ranjith Kumar, R., Mutanda, T., Bux, F., 2011. Dual role of microalgae: Phycoremediation of domestic wastewater and biomass production for sustainable biofuels production. *Appl. Energy*. 88, Pp. 3411-3424. <https://doi.org/10.1016/j.apenergy.2010.11.025>.
- Samori, G., Samori, C., Pistocchi, R., 2014. Nutrient removal efficiency and physiological responses of *Desmodesmus communis* at different HRTs and nutrient stress condition using different sources of urban wastewater effluents. *Appl. Biochem. Biotechnol.* 173, Pp. 74-89. <https://doi.org/10.1007/s12010-014-0792-7>.
- Sawyer, C.N., McCarty, P.L., Parkin, G.F., 2003. *Chemistry for environmental and engineering science*, fifth ed. McGraw Hill Inc, New York.
- Schnurr, P.J., Allen, D.G., 2015. Factors affecting algae biofilm growth and lipid production: A review. *Renew. Sust. Energ. Rev.* 52, Pp. 418-429. <https://doi.org/10.1016/j.rser.2015.07.090>.
- Schumacher, G., Sekoulov, I., 2003. Improving the effluent of small wastewater treatment plants by bacteria reduction and nutrient removal with an algal biofilm. *Water Sci. Technol.* 48, Pp. 373-380. <https://doi.org/10.2166/wst.2003.0143>.
- Shaker, S., Nemati, A., Montazeri-Najafabady, N., Mobasher, M.A., Morowvat, M.H., Ghasemi, Y., 2015. Treating urban wastewater: Nutrient removal by using immobilized green algae in batch cultures. *Int. J. Phytoremediation*. 17, Pp. 1177-1182. <https://doi.org/10.1080/15226514.2015.1045130>.
- Su, Y., Mennerich, A., Urban, B., 2011. Municipal wastewater treatment and biomass accumulation with a wastewater-born and settleable algal-bacterial culture. *Water Res.* 45, Pp. 3351-3358. <https://doi.org/10.1016/j.watres.2011.03.046>.
- Subashchandrabose, S.R., Ramakrishnan, B., Megharaj, M., Venkateswarlu, K., Naidu, R., 2011. Consortia of cyanobacteria/microalgae and bacteria: Biotechnological potential. *Biotechnol. Adv.* 29, Pp. 896-907. <https://doi.org/10.1016/j.biotechadv.2011.07.009>.
- Sydney, E.B., Silva, T.E., Tokarski, A., Novak, A.C., Carvalho, J.C. De, Woiciechowski, A. L., Larroche, C., Soccol, C.R., 2011. Screening of microalgae with potential for biodiesel production and nutrient removal from treated domestic sewage. *Appl. Energy*. 88, Pp. 3291-3294. <https://doi.org/10.1016/j.apenergy.2010.11.024>.