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Remediation of Organic compounds in Wastewater by Integrated Anaerobiosis and Phyco-remediation Process

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Abstract

The cleaning or purification of wastewater is becoming increasingly important due to the increase in population and the growth of industries in all countries of the world, at the same time the requirements of wastewater treatment regulations are becoming more stringent, so it is necessary to create new purification techniques that are not only more efficient but also more sustainable and cleaner. The objective of the present study was to evaluate in the field the efficiency in the process of pollutant removal in wastewater in streams using the combination of anaerobiosis technique and microalgal consortium. For the process, an experiment was designed in a tank with the presence of anaerobic bacteria and the efficiency of the bacteria in the removal of pollutants was evaluated for 24 hours. After this time, the water was deposited in pools with the presence of microalgae consortium, leaving the process for 20 days. The presence of physical and chemical contaminants was evaluated before the experiment during anaerobiosis and microalgal consortium. The results of the in vivo test indicate that the removal process when subjected to microalgae consortium was more efficient showing a percentage of removal result higher than 62% for physical and chemical parameters. The microalgae consortia used in this study have the capacity to grow well in wastewater and show efficiency in the removal of pollutants after 10 days with high efficiency in the removal of pollutants and with the possible reuse of the water obtained from the process for other agricultural activities.

Keywords: *Wastewater, Anaerobic Bacteria, Microalgae Consortium, Removal, Decontamination*

Introduction

As indicated by Filho et al., (2022), the global water scarcity has emerged as a significant concern. Improper water management, growth in population, climate change, and other natural factors are the main factors that contribute to water scarcity.

Microalgae-based processes stand out as an advanced and sustainable technology for wastewater remediation. The utilization of microalgae proved its potential as an affordable and eco-friendly tool with high capacity and removal efficiency of emerging contaminants, such as persistent organics, pharmaceuticals, microplastics, and endocrine disruptors (Razzak et al., 2017). Microalgae are unique in their ability to thrive in wastewater environments by consuming the present organic and inorganic contaminants as a source of nutrients (Ali et al., 2023). It can also be essential as a biological carbon dioxide (CO_2) fixation method as it utilizes the CO_2 from wastewater and generates O2 through photosynthesis (Razzak et al., 2017).

In this respect this dual capability of pollutant removal and O2 generation is crucial as it produces clean water and reduces the carbon footprint of wastewater treatment processes. Furthermore, algal biomass is formed during the bioremediation of wastewater via microalgae. Algal biomass can be employed to prepare diverse bioproducts, including biofuels, biofertilizers, bioplastics, and livestock feed. The main types of microalgae include Chlorella sp., Scenedesmus sp., Spirulina sp., Chlamydomonas sp., Desmodesmus sp, and Nannochloropsis sp (Mehariya et al., 2021). Chlorella is widely employed due to its elevated removal efficiency of contaminants, fast growth rate and biomass productivity, and resistance to toxic substances and environments (Safi et al., 2014).

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Generally, the traditional practices used for wastewater include primary and secondary treatment approaches treatment targets the removal of solid particles, while secondary treatment aims to decompose organic matter via microbial processes. Yet, such treatments yield relatively high operational and maintenance costs (Crini G., E. Lichtfouse, 2019).

Considering the importance of wastewater treatment with microorganisms, it was proposed to evaluate in vivo the quality of stream wastewater using a combination of anaerobiosis technique with anaerobic bacteria and microalgal consortium.

Materials and Methods

The scheme of the remediation process using anaerobiosis followed by microalgae consortium performance in the present study followed the development of the following stages as illustrated in Figure 1.

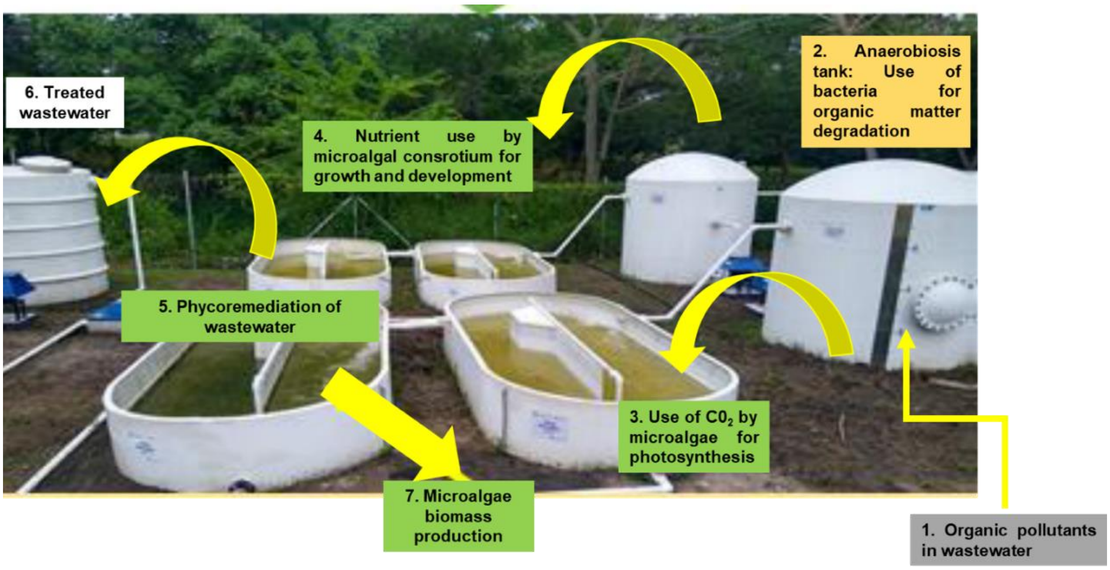

Figure 1. Overview of the Phenomenon of Wastewater Treatment by Microalgae.

Source: Phycoremediation Laboratory, Faculty of Agricultural Sciences, University of Sucre.

The contamination indicator parameters evaluated in pretreatment, treatment in anaerobiosis and with microalgal consortium are described in Table 1.

Table 1. Physical And Chemical Parameters Evaluated in the Field Test of The Wastewater Contaminant Removal Process.

Parameters	Units
Dissolved Oxygen (In situ)	mg/L
Turbidity	UNT
Salinity	UPS
Total Solids	mg/L
BOD5	mg O_2/L
COD	mg O_2/L
Nitrates	mg N-NO_3/L
Orthophosphate	mg P-PO_4/L
Phenols	mg /L
Total Phosphorus	mg P/L

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The physical and chemical parameters were evaluated at the beginning of the experiment, after 24 hours in the anaerobiosis process and after 5, 10, 15 and 20 days in the phycoremediation process with microalgal consortium.

Results and Discussion

Figure 2 shows the results of the remediation processes of organic pollutants in stream water by anaerobiosis technique. The results show the efficiency of the anaerobiosis process of the chemical parameters indicating contamination, observing a reduction of these compounds 24 hours after submitting the contaminated water sample to the presence of a consortium of anaerobic bacteria. As stated by Mara, (2004); Calijuri et al., (2009); Rojas et al., (2010), among the main advantages are: lower cost of facilities, no need to supply oxygen so the process is more economical and lower energy requirement, in addition to producing low amounts of sludge compared to aerobic technologies. It can also be implemented in compact systems that require less land area than lagoon systems. However, these systems have disadvantages such as: they require a longer contact or hydraulic retention time, as well as more time for acclimatization, which prevents the treatment of large volumes of wastewater and difficulties in treating wastewater with low organic loads. Generally, post-treatment is required either for discharge into receiving bodies or for reuse.

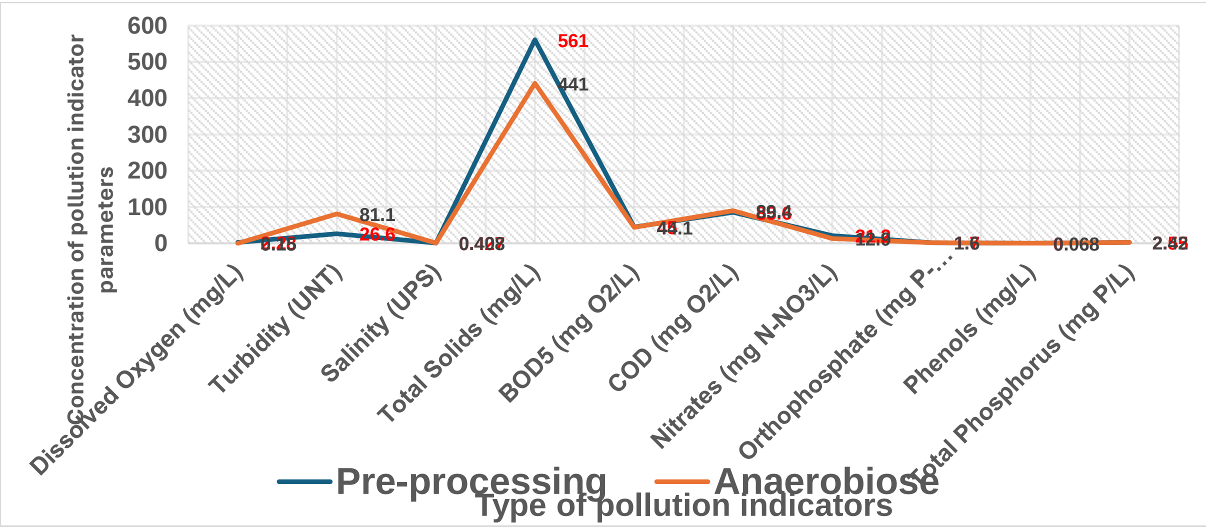

Figure 2. In Vivo Test for Remediation of Indicator Pollutants in Wastewater Using Anaerobic Bacteria Over A 24-Hour Time Period.

Table 2 shows the percentage of pollutant removal by anaerobiose process. The results of the present study indicate that the technique favors the reduction of nitrates by 39.15% and total solids by 21.39%, while for the other wastewater pollution indicator parameters the percentage of removal is less than 6%.

Table 2. Results Of Wastewater Anaerobiosis After 24 Hours of Treatment with Anaerobic Bacteria Consortium

Indicators	Pre-processing	Anaerobiose	% removal
Dissolved Oxygen (mg/L)	2,28	0,15	93,42
Turbidity (UNT)	26,6	81,1	negative
Salinity (UPS)	0,427	0,408	4,45
Total Solids (mg/L)	561	441	21,39
BOD5 (mg O2/L)	45	44,1	2
COD (mg O2/L)	85,6	89,4	negative
Nitrates (mg N-NO3/L)	21,2	12,9	39,15
Orthophosphate (mg P-PO4/L)	1,7	1,6	5,88
Phenols (mg/L)	0, 093	0,068	negative

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Total Phosphorus (mg P/L)	2,55	2,42	5,10

En la figura 3, se describen los resultados del preprocesamiento y el tratamiento con consorcio de microalgas. Table 3 shows the removal capacity of the microalgal consortia in wastewater. Note in the table that the percentage of removal for indicators of wastewater contamination was above 48%. The highest percentage of removal was for orthophosphates with 99%, followed by nitrates with 96.67%, total phosphorus with 92.55%, total solids with 75.65%. There was also an increase in dissolved oxygen and an increase in biological oxygen demand and chemical demand of over 62%.

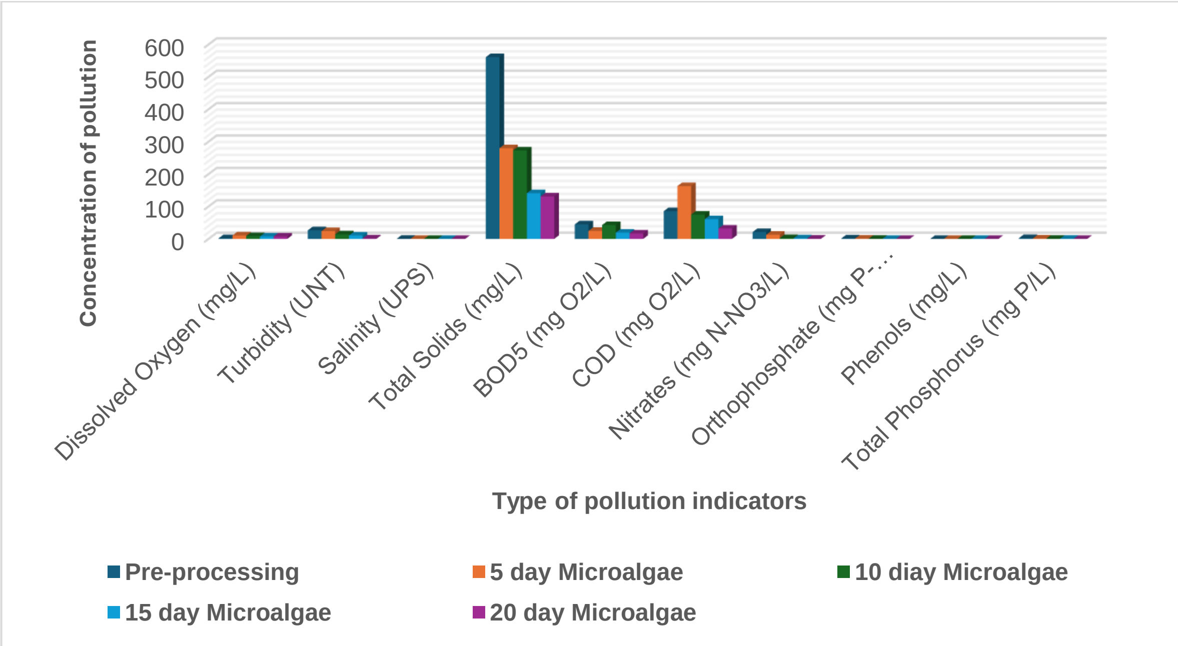

Figura 3. Ensayo in Vivo De Remediación De Contaminantes Indicadores En Aguas Residuales Utilizando Un Consorcio Microalgal Durante 20 Días.

Table 3. Results of the Percentage Removal of Physical and Chemical Indicators of Wastewater Contamination Using Microalgal Consortium.

Indicators	**Pre-processing**	**5 day Microalgae**	**10 day Microalgae**	**15 day Microalgae**	**20 day Microalgae**	**% removal**
Dissolved Oxygen (mg/L)	2,28	10,79	8,72	7,58	7,4	Increases
Turbidity (UNT)	26,6	24	14	10,5	1,4	94,74
Salinity (UPS)	0,427	0,185	0,192	0,201	0,189	55,74
Total Solids (mg/L)	561	280	273	141	131	76,65
BOD5 (mg O2/L)	45	24,9	42,8	19,5	16,7	62,89
COD (mg O2/L)	85,6	163	75	61	32	62,62
Nitrates (mg N-NO3/L)	21,2	12,9	2,72	1,79	0,706	96,67
Orthophosphate (mg P-PO4/L)	1,7	0,952	0,43	0,06	0,016	99,06
Phenols (mg/L)	0, 193	0,062	0,100	0,100	0,100	48,19

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Total Phosphorus (mg P/L)	2,55	1,16	0,55	0,42	0,19	92,55

As expressed by Garcia et al., (2019), un hybrid system consisting of bacteria and four microalgae species (*Chlamydomonas* sp*., C. kessleri, C. vulgaris,* and *Scenedesmus acutus*) can remove 85–91%, 91–93%, and 97–99% of nitrogen, phosphorous, and zinc from piggery wastewater *C. vulgaris* cultivated with bacteria belonging to different phyla (mainly Proteobacteria) can remove 93–95%, 100%, and 81–85% of TOC, TP, and Zn in municipal wastewater (Garcia et al., 2017).

From there, we sought to improve the Biological Oxygen Demand parameters since this is indicative of the levels of organic matter susceptible to aerobic biological degradation, which is determined by the consumption of oxygen and microalgae, as consumers of oxygen that they use to breathe, increase, precisely the BOD5. Biological oxygen demand (BOD_5) is a measure of the amount of dissolved oxygen needed by aerobic microorganisms to break down the organic matter present in the water. It is a parameter used to evaluate water quality according to its ability to support aquatic life. BOD_5 is used as an indicator of water quality and the level of organic pollution in the water. Elevated levels of BOD_5 in water can indicate the presence of organic pollutants, which can lead to oxygen depletion and have negative impacts on aquatic ecosystems.

As indicated by Pérez Silva and Vega-Bolaños, (2016); Ballén Segura et al., (2016); Saranya y Shanthakumar, (2019), with respect to nitrate and nitrite removal, the genus Scenedesmus, presents the ability to remove high levels above 90%, while Chlorella and Pseudochlorella reached a removal value of 65%.

As indicated by Pena el al., (2020); Ballén-Segura et al., (2016), the genera Chlorella and Pseudochlorella demonstrated a removal level of 100% (Saranya and Shanthakumar, 2019), followed by the genera Tetraselmis and Scenedesmus with values above 94%.

As suggested by Gonzalez-Fernandez et al., (2011), the term microalgae include both prokaryotic (cyanobacteria) and eukaryotic (green algae, diatoms) photosynthetic microorganisms. Being different, both microorganisms are produced in the same way and perform photosynthesis in the same manner. Microalgae are fast-growing microorganisms that are produced in water and can be cultivated under different conditions throughout the world. Microalgae include both autotrophic and heterotrophic species. Autotrophic microalgal species use sunlight as a source of energy for photosynthesizing their food. They are quite difficult to grow in wastewaters but their capability to supply oxygen to aerobic bacteria for degradation of organic pollutants makes them applicable in microalgae-based wastewater treatment systems for enhancement of pathogen and nutrient removal.

As stated by Yadav et al., (2021), microalgae remove pollutants from wastewater through certain biological and metabolic processes like glycolysis, oxidative phosphorylation, adsorption, accumulation, volatilization, immobilization. We have discussed here the most common and important mechanisms- adsorption, accumulation, biodegradation, and immobilization.

As indicated by Zhu et al., (2019); Huo et al., (2020), it has been reported that microalgae-based hybrid systems are more efficient in treating wastewaters as compared to single microalgae culture. The evidence shows as they put it Nguyen et al., (2020); Sun et al., 2020; Vasistha et al., (2020), microalgae are commonly integrated with bacteria, activated sludge, yeast, and nanoparticles to form a co-culture system aimed to provide more benefits during remediation. The remediation potential of hybrid systems depends upon certain factors like wastewater composition, operating conditions, the ratio of microalgae to inoculum (Zhu et al., 2019). In the following sub-sections, we have discussed few hybrid systems.

According to the evidence of Kumar and Singh, (2017), the combination of microalgae and bacteria affect each other's physiology and metabolism synergistically. The microalgae fix carbon through photosynthesis and convert it into organic carbon; the bacteria utilize the carbon source and convert it into CO_2. The released CO_2 is then used by microalgae. In this association, under any environmental circumstances, biomass growth is gushed up ascribed to the simultaneous exchange of inorganic and organic nutrients between respiration and photosynthesis processes performed by algae and bacteria. Similarly, as indicated by Jiang et al., (2021), bacteria also help in flocculation besides promoting algal growth. Since both these processes are vital in algal biotechnology, therefore cultivating algae with bacteria and exploiting their symbiotic relationship to treat nutrient-rich wastewater is extended over wider industrial applications.

Conclusion

Among the several technologies and methods employed for the elimination of contaminants from wastewater, Chlorella microalgae showed its high ability as a sustainable and cost-effective method with good performance. Chlorella vulgaris was the most studied species for its application in wastewater bioremediation and bioproduction over the past few years, simultaneously addressing both wastewater treatment challenges and renewable resource demand. The results show that a more efficient remediation process of organic pollutant load in water is the use of a previous treatment with anaerobic bacteria to reduce the pollutants through the use of some of these compounds by the bacteria and after 24 hours continue with microalgal consortium to guarantee the decontamination or elimination of the total pollutants from the water and to be able to reuse that water for other agricultural activities.

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Author Contribution. Alexander Perez Cordero: experiment execution, data analysis. Donicer Montes V and Yelitza Aguas M, conceptualization, writing - revision and editing. All authors have read and approved the manuscript.

Conflict of Interest. All the authors of the manuscript declare that they have no conflict of interest.

References

Ali A., Z. Khalid, A. Ahmed A, and J. S. Ajarem.2023. Wastewater treatment by using microalgae: Insights into fate, transport, and associated challenges, Chemosphere, 338:139501. https://doi.org/10.1016/j.chemosphere.2023.139501.

Ballén-Segura M, Hernández L, Parra D, Vega A, Pérez K. (2016). Using Scenedesmus sp. For the Phycoremediation of Tannery Wastewater, Tecciencia, Vol. 12 No. 21, 69-75. DOI: http:/ dx.doi.org.

Calijuri, M., Xavier, R.K., De Brito, T., Cesca, B., Oliveira, E.H. (2009). Tratamento de esgotos sanitários em sistemas reatores UASB/wetlands construídas de fluxo horizontal: eficiência e estabilidade de remoção de matéria orgânica, sólidos, nutrientes e coliformes. Eng Sanit Ambient., 14(3),421-430.

Crini G., E. Lichtfouse.2019. Advantages and disadvantages of techniques used for wastewater treatment, Environ. Chem. Lett. 17 (2019) 145e155.

Garcia, D., Posadas, E., Grajeda, C., Blanco, S., Martinez-Paramo, S., Acien, G., Garcia- Encina, P., Bolado, S., Munoz, R., 2017. Comparative evaluation of piggery wastewater treatment in algal-bacterial photobioreactors under indoor and outdoor conditions. Biores. Technol. 245 (A), 483–490.

Garcia, D., de Godos, I., Dominguez, C., Turiel, S., Boladoa, S., Munoz, R., 2019. A systematic comparison of the potential of microalgae-bacteria and purple phototrophic bacteria consortia for the treatment of piggery wastewater. Bioresour. Technol. 276, 18–27.

Gonzalez-Fernandez, C., Molinuevo-Salces, B., Garcia-Gonzalez, M.C., 2011. Nitrogen transformations under different conditions in open ponds by means of microalgae–bacteria consortium treating pig slurry. Bioresour. Technol. 102 (2), 960–966.

Jiang, L., Li, Y., Pei, H., 2021. Algal–bacterial consortia for bioproduct generation and wastewater treatment. Renew. Sustain. Energy Rev. 149, 111395.

Mara, D.D. (2004). Domestic Wastewater Treatment in Developing Countries. Earthscan, London, Sterling, VA, p 310.

Mehariya S., R. K. Goswami, O. P. Karthikeysan, and P. Verma. 2021. Microalgae for highvalue products: A way towards green nutraceutical and pharmaceutical compounds, Chemosphere, 280:130553, 2021. https://doi.org/10.1016/j.chemosphere.2021.130553.

Nguyen, T.T.D., Nguyen, T.T., Binh, Q.A., Bui, X.T., Ngo, H.H., Vo, H.N.P., Lin, K.Y.A., Vo, T.D.H., Guo, W., Lin, C., Breider, F., 2020. Co-culture of microalgae-activated sludge for wastewater treatment and biomass production: Exploring their role under different inoculation ratios. Bioresour. Technol. 314, 123754.

Pérez-Silva KR, Vega-Bolaños AM, HernándezRodríguez LC, Parra-Ospina DA, BallénSegura MA. (2016). Uso de Scenedesmus para la remoción de metales pesados y nutrientes de aguas residuales de la industria textil. Ingeniería Solidaria, vol. 12, no. 20, pp. 95-105. doi: http:// dx.doi.org/10.16925/in.v19i20.1418.

Pena AC, Agustini CB, Trierweiler LF, Gutterres M. (2020). Influence of period light on cultivation of microalgae consortium for the treatment of tannery wastewaters from leather finishing stage, Journal of Cleaner Production, doi: https://doi. org/10.1016/j.jclepro.2020.121618.

Rojas, N., Sánchez, A., Matiz, A., Salcedo, J.C., Carrascal, A.K. (2010). Evaluación de tres métodos para la inactivación de coliformes y Escherichia coli presentes en agua residual doméstica, empleada para riego. Universitas Scientiarum, 15(2), 139-149.

Safi C., B. Zebib, O. Merah, P.-Y. Pontalier, and C. Vaca-Garcia.2014. Morphology, composition, production, processing and applications of Chlorella vulgaris: A review, Renewable and Sustainable Energy Reviews, 35:265-278, 2014. https://doi.org/10.1016/j.rser.2014.04.007.

Saranya D, Shanthakumar S. (2019). Green microalgae for combined sewage and tannery effluent treatment: Performance and lipid accumulation potential. J. Environ. Manage. 241, 167–178. https://doi.org/10.1016/J.JENVMAN.2019.04.031

Singh, A., Sharma, R., Pant, D., Malaviya, P., 2021. Engineered algal biochar for contaminant remediation and electrochemical applications. Sci. Tot. Environ. 774, 145676.

Sun, J., Li, N., Yang, P., Zhang, Y., Yuan, Y., Lu, X., Zhang, H., 2020. Simultaneous antibiotic degradation, nitrogen removal and power generation in a microalgae bacteria powered biofuel cell designed for aquaculture wastewater treatment and energy recovery. Int. J. Hydrog. Energy. 45, 10871–10881.

Vasistha, S., Khanra, A., Rai, M.P., 2020. Influence of microalgae-ZnO nanoparticle association on sewage wastewater towards efficient nutrient removal and improved biodiesel application: An integrated approach. J. Water Process. Eng. 39, 101711.

W. Filho et al., 2022. Understanding responses to climate-related water scarcity in Africa, Science of The Total Environment, 806:150420, 2022. https://doi.org/10.1016/j.scitotenv.2021.150420

Razzak S. A., S. A. M. Ali, M. M. Hossain, H. de Lasa. 2017. Biological CO2 fixation with production of microalgae in wastewater – A review, Renewable and Sustainable Energy Reviews, 76: 379-390. https://doi.org/10.1016/j.rser.2017.02.038.

Yadav, G., Shanmugam, S., Sivaramakrishnan, R., Kumar, D., Mathimani, T., Brindhadevi, K., Pugazhendhi, A., Rajendran, K., 2021. Mechanism and challenges behind algae as a wastewater treatment choice for bioenergy production and beyond. Fuel. 285, 119093.

Zhu, S., Qin, L., Feng, P., Shang, C., Wang, Z., Yuan, Z., 2019. Treatment of low C/N ratio wastewater and biomass production using co-culture of Chlorella vulgaris and activated sludge in a batch photobioreactor. Bioresour. Technol. 274, 313–320.