Review Article

ISSN 2766-2624

Advances in Earth and Environmental Science

Assessment of Biological Treatment for Ammonia Removal from Water Resources, Egypt

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Submitted : 2 June 2023 ; Published : 18 Aug 2023

Citation: Noama Shareef(2023). Assessment of Biological Treatment for Ammonia Removal from Water Resources, Egypt. Adv Earth & Env Sci; 4(3):1-7. DOI : https://doi.org/10.47485/2766-2624.1035

Abstract

Egypt is depending entirely on the Nile water. The Rosetta branch of the river Nile serves as a vital freshwater source for domestic, agricultural, industrial, fisheries, and recreational purposes in several western Delta governorates of Egypt, with a daily flow averaging 21,500,000 m3/day. The branch faces significant challenges due to escalating ammonia concentrations stemming from agricultural drains along the river, industrial effluents from industrial activities, and fish farming cages. One particular issue arises during low-demand periods when the flow in the Rosetta branch diminishes. Annually, Egyptian authorities close water flows in a series of channels to facilitate maintenance, resulting in reduced water levels. This winter closure has impacted Kafr El Sheikh and El Beheira, located in northern Egypt, as the drainage of industrial wastes during this period has led to a high pollution load of ammonia and other pollutants. The elevated ammonium content has hindered coagulation, encouraged algal growth, and impeded the chlorine breakpoint during water chlorination processes. Laboratory experiments were conducted to investigate the ability of blue-green algae species (Anabaena sp., Scyndesmos sp., Chlorella sp.) and bacteria (Lactobacillus sp.) to uptake ammonia. This study revealed that single algal species achieved a maximum removal percentage of 30% for ammonia concentrations ranging from 5 to 7.5 mg/l, and mixed algal species attained removal percentages between 6% and 12% at constant retention times of 15 to 60 minutes. For single algal species, retention times exceeding 1 hour (2 and 5 hours) resulted in removal percentages ranging from 85% to 100%. For mixed algal species, removal percentages between 9% and 20% were observed for various retention times ranging from 15 minutes to 1 hour. When comparing the use of algal species mixtures, removal percentages of up to 30-50% were achieved. Additionally, the study found that the application of bacterial species (Lactobacillus sp.) to raw water samples with an average ammonia concentration of 7.8 mg/l resulted in a maximum removal percentage of 100% when using a bacterial content of 100-200 ml per 1-liter raw water sample volume, with varied retention times up to 2 hours.

Keywords: River Nile, Rosetta Branch, Water Quality, Ammonia Removal.

Introduction

Out of the Nile's average natural flow of 84 BCM/y reaching Aswan, a transboundary incoming surface flow from Sudan of 55.5 BCM/y is allowed to pass according to the mutual Nile water agreement between Egypt and Sudan 1959. Nile River is the main source of freshwater used for drinking water, agricultural activities, industrial purposes, navigation, recreation, and fish production in Egypt. So, it is of dominating influence on different aspects (economic, cultural, public health, social and political) (Ibrahim et al., 2018). The Nile receives enormous amounts of environmental pollutants including fertilizers, fishing activities, pesticides, and great amounts of industrial wastes, and municipal and domestic materials which drained directly or indirectly into it. Due to their limitation, freshwater resources worldwide required more attention, especially in Egypt, to overcome the harmful effects of such pollution against all vital activities. Nile pollutants are derived from sources such as industrial wastewater, oil pollution, municipal wastewater, and agricultural drainage (Abou-Elela, 2017). The pollution status of the water of the Nile River is an important indicator of water quality (Ibrahim et al., 2018).

The Rosetta branch of the Nile River serves as a source of drinking water, fishing, and irrigation, with a daily flow averaging 21,500,000 m3/day (Abdelazim M. Negm, 2017). However, the branch is also affected by the discharge of domestic, industrial, and agricultural wastes without any treatment, which poses serious environmental and health risks. Reports indicate that over 900 MCM of organic, domestic, and industrial wastes from Greater Cairo are discharged monthly into the Rosetta branch without any treatment (Barbary et al., 2008). El-Rahawy drain has been identified as a major source of contamination, recent studies showed that it is highly polluted by organic and inorganic contaminants (Ezzat et al., 2012).

The pollution from these contaminants results in damage to aquatic life (Raju et al., 2009) (Singh et al., 2007) (L Belkhiri, 2010).

The quick development of human activities has greatly increased the input of ammonia into water bodies (Dong & Xu, 2020). This input induces eutrophication and causes deterioration in natural water quality. As such, the removal of nitrogen from water sources is a fundamental way to prevent eutrophication and water bloom (Mishra, 2022).

Effluents from secondary domestic and agricultural wastewater treatment plants contain high concentrations of inorganic nitrogen that may lead to eutrophication of the water bodies that they discharge (Martínez et al., 2000); (Mallick, 2002); (De-Bashan et al., 2004); (Tanwar et al., 2007).

Blue green algae offer a low-cost and effective approach to removing the excess nutrients and other contaminants because of their high capacity for inorganic nutrient uptake, while producing potentially valuable biomass (Martínez et al., 2000); (Chevalier et al., 2000). However, one of the major drawbacks of using algae in wastewater purification is the harvesting of biomass (Mallick, 2002) (Aslan & Kapdan, 2006).

Earlier studies have consistently indicated efficient and rapid removal of nitrogen from wastewater by immobilized algae (Zhang et al., 2008). Carrageenan, chitosan, and alginate are the polymers often used in these algal systems (Hoffmann, 2002), with alginate beads being used most frequently (Moreira et al., 2006); (Tam & Wong, 2000).

Algae have many advantages in the removal of nitrogen; these include:

1. low cost due to sufficient solar energy,
2. simultaneous CO_2 fixation,
3. Non-requirement for extra-organic carbon (as compared to biological nitrification–denitrification),
4. oxygenated effluents discharge into water bodies,
5. lac of sludge handling problems and
6. high economic potential for harvested algal biomass (for feedstock, fertilizers, biogas, biofuels, and so on) (Aslan & Kapdan, 2006).

A.chroococcum and *B.megatherium* were considered as algae growth-promoting bacteria (MGPB), these bacteria are capable of fixing atmospheric nitrogen and solubilizing phosphorus; it demonstrated that the observed growth promotion might improve the capabilities of algae to remove nutrients from natural wastewater (Ali et al., 2012); (Hernandez et al., 2009). Smaller beads/capsules have the advantage of a higher surface-to-volume ratio allowing good transport of essential nutrients and are less fragile. Diffusion limitations within larger beads may limit cellular metabolism as the lack of essential substances like oxygen supply to the interior of the beads may lead to cell death because of consumption from the surrounding cells, better dispersion, better mechanical strength, easier implantation, and potential access to new implantation sites. Therefore, good control of bead size and shape is crucial and should be carefully controlled (Melvik & Dornish, 2004).

The process of biological removal of organic matter from sedimented wastewater is carried out by microorganisms, which are capable of decomposing organic matter through two different biological processes: biological oxidation and biosynthesis (Gray, 2005).

This investigation aims to evaluate the use of algae and bacteria in the removal of ammonia from polluted water resources.

Methodology

Area of Study

The study area represented in Rosetta branch of the Nile River, which extends from the Delta Barrage at 30° 11’ 04.4” N and 31° 07’ 00.4” E for about 256 km on the western boundary of the Nile Delta(Kaiser et al., 2013), (Figure1). It ends with the Edfina barrage at 31° 18’ 22.8” N and 30° 31’ 07.9” E with a distance of 30 km upstream of the Mediterranean Sea(Omar et al., 2022)(El-Amier et al., 2015). Rosetta Branch has an average width of 180 m and provides water for agricultural, industrial, domestic, and fishery sectors(Nada et al., 2021). The collection and disposal of drainage water into the Rosetta Branch are facilitated by five primary drains, shown in Fig (1), including El Rahawy, Zaweit El Bahr, El Tahrir, Sabal, and Tala, which receive effluents from secondary drains(Mostafa et al., 2015)(Eissa et al., 2022).

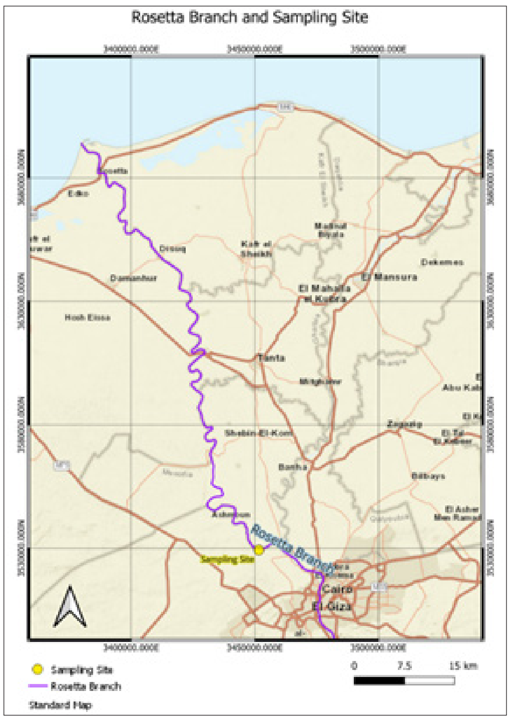

Figure1: Rosetta Branch & agricultural drains

Pollution along the branch mainly originates from these five main drains(Sayed et al., 2020). The Rosetta branch is subjected to various forms of pollution stemming from diverse sources, including but not limited to the discharge of sewage and domestic effluents from the El-Rahaway drains, which is estimated to produce more than 5 × 108 m3 of effluent daily. Discharging agricultural wastes from the Soble drain and industrial effluents from El-Malya and Soda Companies in Kafr El-Zayat City significantly impacts the Rosetta Branch aquatic environment.

Samples Collection and Analysis

Subsurface water samples were collected from the sampling site "Ezbet-Sherif" at 5 km before El-Rahawy drain.

Different blue-green algae species (*Anabaena sp., Scyndesmos sp., Chlorella sp.*) & bacteria (*Lactobacillus sp.*) have been investigated for ammonia removal in raw water samples containing different concentrations of ammonia.

Algal Sp.:	A = Anabaena sp.
	S = Scenedesmus sp.
	C= Chlorella sp.
	M= Mix (A +S)
Bacterial Sp.:	B= Bacteria
	Lact. = lactobacillus

Water samples were collected during 2022 during an interval of 10 months, from January to October 2022. Samples containing ammonia were tested for efficiency of biological treatment for removal of ammonia by means of:

- Isolating certain types of algae (*Anabaena sp., Scyndesmos sp. & Chlorella sp.* and cultivating them in media.
- Isolate bacteria (Lactobacillus sp.).
- Studying the effect of bacteria in the removal of ammonia.
- Studying the effect of algae in the removal of ammonia.
- Studying the effect of mixing algae & bacteria in the removal of ammonia.

The present study involved the preparation and testing of raw water samples containing varying concentrations of algal species. The concentration of the algal species was determined based on the chlorophyll content within the samples. To prepare the algal species, different species were inoculated into a 5-liter volume of prepared BG-11 media, which was then incubated for a duration of 5 days at a temperature of 28°C. Subsequently, the chlorophyll content in 1 ml of the incubated media was quantitatively detected using a spectrophotometric method employing a DR6000 spectrophotometer.

To ensure consistent testing conditions, the volume of raw water samples was calculated to achieve a final concentration of 100 mg chlorophyll per 1 liter of the tested sample. These prepared raw water samples, with a concentration of 100 mg chlorophyll per 1 liter, were then subjected to testing for residual ammonia concentration at various time intervals, ranging from 15 minutes to 24 hours, following the preparation of the samples. The removal efficiency was determined by comparing the calculated percentage of ammonia removal to the ammonia content present in the raw water (i.e., the matrix of the tested samples).

In addition to the investigation of algal species, this study encompassed the analysis of raw water samples containing varying volumes of bacterial species. To achieve this, two isolates from lactobacillus bacteria were prepared and cultivated by inoculating cells into growth media. Burk's medium was selected as the cultivation medium to support the mass production of microbial cells for the purpose of inoculant generation.

Results & Discussion

The water samples underwent testing after their inoculation with various algal and bacterial species for different retention intervals, utilizing different doses contingent upon the Chlorophyll content, as samples were tested for reduction in ammonia content compared to raw water samples considering the following factors:

1. Different algal types prepared and tested on constant retention time intervals.
2. Different Retention times.
3. Content of Algal & bacterial species.

Effect of using different types of Algae sp.

Samples were tested for 3 algal types, S, C & A, content is correspondent to 100 mg chlorophyll /l, and there was an obvious reduction in ammonia concentration in reference to raw water ammonia concentration (7.5 mg/l), resulting in the reduction of 25.9 %, 30.2%, and 26.7%, for A, C & S sp., respectively, shown in figure (2).

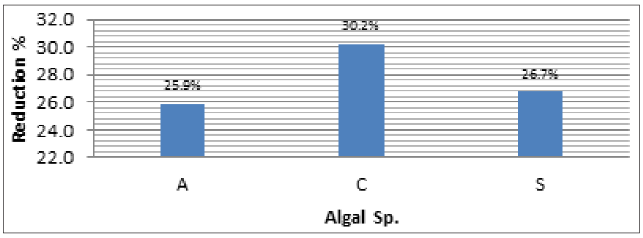

Figure 2: Ammonia Reduction Percentage with Different Algal Species.

For samples of raw water of ammonia content of (6.492 mg/l), containing single microbial sp. & Bacterial Sp., A, S & B reduction percent was 20.6 %, 14.7 % & 11.3 %, respectively. For using samples with mixed species of A & S sp., no change in reduction percent was observed compared to samples containing single A sp., while an increase in the efficiency of S sp. was observed when being mixed with A sp. (reduction percent increased from 14.7 % to 20%), as shown in figure (3).

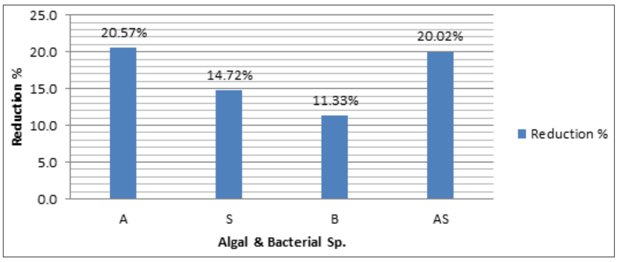

Figure 3: Ammonia Reduction Percentage with Different Algal Species.

Effect of increasing retention time interval & algal sp. content

Increasing doses of algal species, where tested samples were inoculated with (100 mg/l & 500 mg/l) and samples were tested for the reduction in ammonia concentration after incubation intervals of (1=15 min, 2=30 min, 3= 60 min) as shown in Table (1) where there was a slight reduction in ammonia concentration in reference to raw water ammonia concentration (4.98 mg/l) as follows.

Content of algal sp.	The retention time interval for the sample	Sample Reduction %		
		S	A	M (Mix of S & A)
100 mg/l	15 min	5.8	3.4	3.7
	30 min	2.2	2.9	6.4
	60 min	4.3	-	-
500 mg/l	15 min	4.3	6.4	9.9
	30 min	3.3	9.0	9.8
	60 min	3.1	11.2	11.9

Table 1: Reduction in Ammonia concentration with Varied Retention Time interval, Algal Species, and content.

2-1-For increasing Algal content from 100 mg/l to 500 mg/l, at constant retention time intervals (15,30 & 60 min) (1)retention time interval =15 min.

On increasing the content of algal sp. from 100 mg/l to 500 mg/l, in reference to raw water ammonia content (6.8 mg/l), an obvious increase in reduction percent for sample M containing a mixture of S & A sp. was observed, with 9.9% for retention time interval of 15 min., as shown in Figure (4).

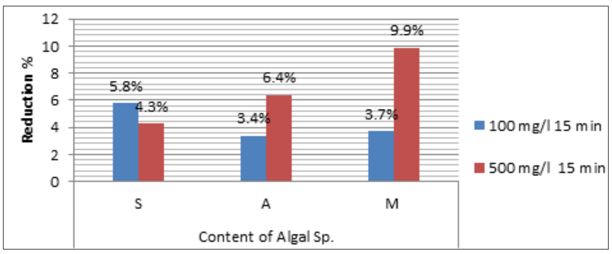

Figure 4: Ammonia Reduction Percentage for Retention Time=15 min, and different Algal Species and content

(2) retention time interval =15 min,

On increasing the contention of algal sp. from 100 mg/l to 500 mg/l, in reference to raw water ammonia content (6.8 mg/l), an obvious increase in reduction percent, 9% and 9.8% for Sample A & sample M (containing a mixture of S & A sp.), respectively, for a retention time interval of 30 min., as shown in Figure (5).

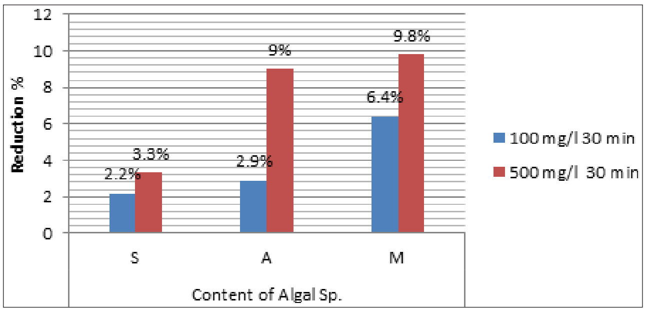

Figure 5: Ammonia Reduction Percentage for Retention Time=30 min, and different Algal Species and content

(3) retention time interval =60 min,

On increasing the content of algal sp. from 100 mg/l to 500 mg/l, about raw water ammonia content (6.8 mg/l), an increase in reduction percent, 11.2 % and 11.9% for sample A & sample M (containing a mixture of S & A sp.), respectively, for a retention time interval of 60 min., as shown in Figure (6).

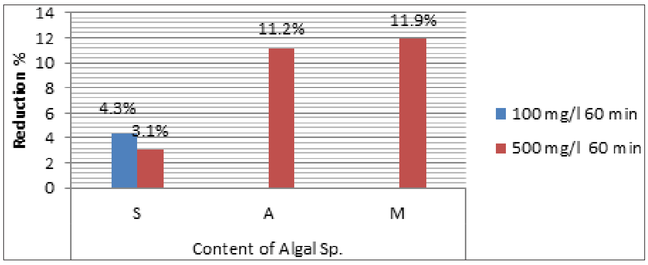

Figure 6: Ammonia Reduction Percentage for Retention Time=60 min, and different Algal Species and content

For increasing the retention time interval

From 15 to 60 min, at constant algal content for different algal sp. (100 & 500 mg/l)

For Algal content of 100 mg/l, & increased retention time interval from 15 to 60 min.

On increasing the content of algal sp. from 100 mg/l to 500 mg/l, about raw water ammonia content (6.8 mg/l), an obvious increase in reduction sample M (containing a mixture of S & A sp.) was observed, 6.4 % for increasing retention time interval from 15 to 60 min., as shown in figure (7).

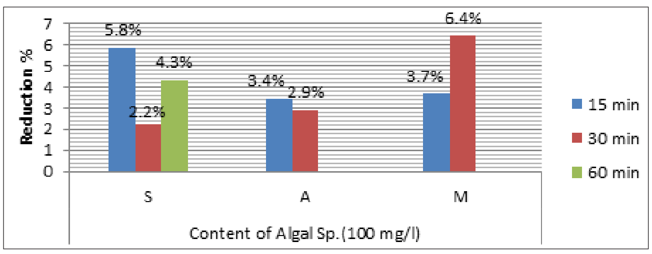

Figure 7: Ammonia Reduction Percentage with Varied Retention Time, and different Algal Species of content 100 mg/l

For Algal content of 500 mg/l, & increased retention time interval from 15 to 60 min

On increasing the content of algal sp. from 100 mg/l to 500 mg/l, about raw water ammonia content (6.8 mg/l), an obvious increase in reduction sample M (containing a mixture of S & A sp.) was observed, 11.2 % & 11.9 %, for retention time intervals 30 min & 60 min, respectively, as shown in figure (8) .

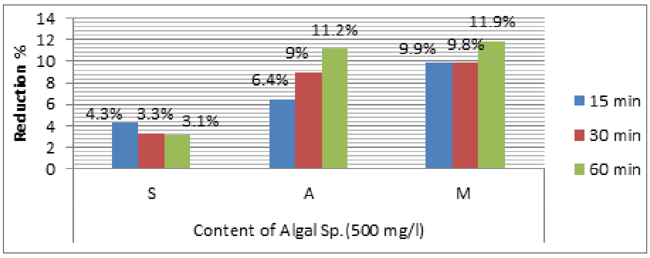

Figure 8: Ammonia Reduction Percentage with Varied Retention Time, and different Algal Species of content 500 mg/l

Increasing retention time from 1 to 5 hrs.

On increasing retention time intervals to 2 &5 hrs. for different types of algal sp. of the same content 100 mg/l, about raw water ammonia content (5.95 mg/l), an obvious increase in a reduction for all species by increasing retention time to 2 hrs. & 5 Hrs. was observed, resulting in a maximum reduction % of 93.22%, 99.6% & 85.03% for A, C & S, respectively, at 5 hr. retention time. Shows obvious increase in reduction %, C > A > S for increased retention time exceeding 1 hr., as shown in figure (9).

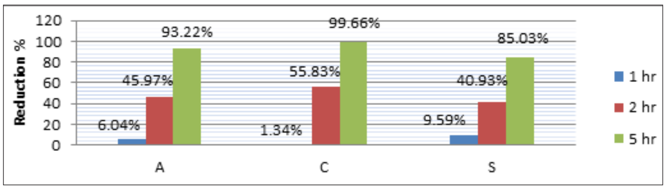

Figure 9: Ammonia Reduction Percentage with Varied Retention Time, and different Algal Species.

Effect of using mixtures of Algal sp.

For samples of raw water of ammonia content of (7 mg/l), containing single microbial sp. A, C & S, reduction percent was 37 %, 43.6 % & 31.5 %, respectively. For using samples with mixed species, an increase in reduction percent was observed for samples containing mixed A&C sp. (compared to samples containing single A sp. reduction % increased from 37% to 45.2%), the same case for using samples containing mixed C&S sp. (compared to samples containing single S sp. reduction % increased from 31.5% to 47.8%), Whereas no significant change for using samples containing mixed A&S sp. (compared to samples containing single A sp. reduction % increased from 37% to 30.8% and compared to samples containing single S sp. reduction % decreased from 31.5% to 30.8%), and the maximum increase in reduction percent (49.2%) was observed on using samples containing mixed A&C&S sp., shown in figure (10).

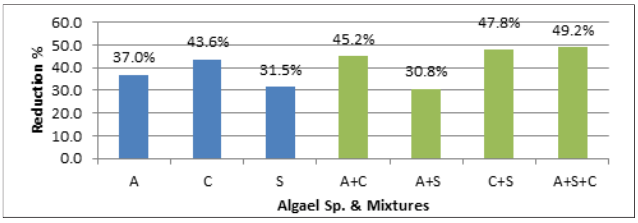

Figure 10: Ammonia Reduction Percentage with different Algal Species & their mixtures.

Effect of using Bacterial sp.

In different experimental trials for using different content of bacterial species reaching (100 -200 ml/l of raw water) for varied retention time intervals of 2 hrs., it was observed that maximum reduction percent reaching 100% was observed for different contents at constant retention time intervals of 2 hrs., indicating that bacterial sp. The tendency for reduction of ammonia is exceeding double that for algae sp. with maximum removal of 100%.

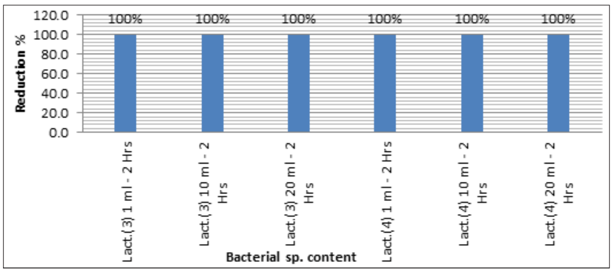

Figure 11: Ammonia Reduction Percentage with different Bacterial Species content, (Lact. (3) 10 ml & Lact. (4) 20 ml added to 100 ml raw water.).

Conclusions

- In Egypt, the implementation of an economically and environmentally friendly approach is necessary during periods of low water demand. One promising strategy is the utilization of biological treatment methods to mitigate the ammonia concentration in raw water intended for water treatment plants. This alternative presents an opportunity to address water quality challenges sustainably.
- By employing biological treatment, the aim is to leverage natural processes and the metabolic activities of microorganisms to effectively reduce ammonia levels. This approach entails harnessing the capabilities of various biological agents, such as bacteria and algae, which possess the ability to assimilate and remove ammonia from water sources.
- In this study, various algal and bacterial species were employed to assess their efficacy in reducing ammonia concentrations in water samples. The experiments focused on three key factors: different types of algae, varying retention times, and the content of algal and bacterial species.
- The results demonstrated that the use of different algal species led to a significant reduction in ammonia concentration compared to raw water samples. Specifically, algae species A, C, and S achieved reduction percentages of 25.9%, 30.2%, and 26.7%, respectively.

When examining samples with mixed algal species, it was observed that combining species A and S resulted in an increased efficiency compared to using a single species, with a reduction percentage of 20%.

- Furthermore, increasing the content of algal species and extending the retention time interval contributed to higher reduction percentages. For example, at a retention time of 60 minutes, an increase in algal content from 100 mg/l to 500 mg/l led to reduction percentages of 11.2% and 11.9% for species A and a mixed species (S & A), respectively. Similarly, extending the retention time to 2 and 5 hours resulted in maximum reduction percentages of 93.22%, 99.6%, and 85.03% for species A, C, and S, respectively.
- When examining the use of mixed algal species, it was found that combining species A and C as well as C and S led to increased reduction percentages compared to using a single species. However, combining species A and S did not significantly enhance the reduction percentage.
- Additionally, the study investigated the effectiveness of bacterial species. It was observed that the application of bacterial species, specifically Lactobacillus, resulted in a maximum reduction percentage of 100% when using varying bacterial content for a retention time interval of 2 hours. This finding suggests that bacterial species exhibit a higher propensity for ammonia reduction compared to algal species.
- In conclusion, the results highlight the potential of utilizing different algal and bacterial species for ammonia reduction in water samples. The findings demonstrate the influence of factors such as algal type, retention time, and species content on the effectiveness of ammonia reduction. These insights contribute to the development of sustainable and efficient biological treatment approaches for water quality improvement, particularly in scenarios of low water demand. Further research and optimization of these biological treatment methods are warranted to enhance their practical application in water treatment plants and environmental management.

References

1. Abdel Wahaab, R.& Badwy, M.(2004)"Water Quality Assessment of the River Nile System: An Overview". *Inter. Journ. Biomedical and Environmental Sciences*. vol.19.
2. Abdelazim M. Negm. (2017). The Nile River (Vol. 56). https://doi.org/10.1007/978-3-319-59088-2
3. Abou-Elela, S. (2017). Constructed Wetlands: The Green Technology for Municipal Wastewater Treatment and Reuse in Agriculture. In Handbook of Environmental Chemistry. https://doi.org/10.1007/698_2017_69
4. Ali, S. M., Nasr, H. S., & Abbas, W. T. (2012). Enhancement of Chlorella vulgaris growth and bioremediation ability of aquarium wastewater using diazotrophs. *Pakistan Journal of Biological Sciences : PJBS, 15*(16), 775–782. https://doi.org/10.3923/pjbs.2012.775.782
5. Aslan, S., & Kapdan, I. K. (2006). Batch kinetics of nitrogen and phosphorus removal from synthetic wastewater by algae. *Ecological Engineering, 28*(1), 64–70. https://doi.org/10.1016/J.ECOLENG.2006.04.003
6. Barbary, A. A. El, Yehia, M., & Bouraie, M. El. (2008). Evaluation of Organochlorine Pesticides (OCPs) in Surface Water and Bed Sediment Samples from the River Nile at Rosetta Branch, Egypt.
7. Chevalier, P., Proulx, D., Lessard, P., Vincent, W. F., & De La Noüe, J. (2000). Nitrogen and phosphorus removal by high latitude mat-forming cyanobacteria for potential use in tertiary wastewater treatment. *Journal of Applied Phycology, 12*(2), 105–112. https://doi.org/10.1023/A:1008168128654/METRICS
8. De-Bashan, L. E., Hernandez, J. P., Morey, T., & Bashan, Y. (2004). Microalgae growth-promoting bacteria as "helpers" for microalgae: a novel approach for removing ammonium and phosphorus from municipal wastewater. *Water Research, 38*(2), 466–474. https://doi.org/10.1016/J.WATRES.2003.09.022
9. Dong, Y., & Xu, L. (2020). Anthropogenic intensification of urban reactive nitrogen inputs and potential to mitigate nitrogen pollution in Guangzhou, China. Resources, Conservation and Recycling, 159, 104847. https://doi.org/ https://doi.org/10.1016/j.resconrec.2020.104847
10. Eissa, F., Al-Sisi, M., & Ghanem, K. (2022). Occurrence and ecotoxicological risk assessment of pesticides in sediments of the Rosetta branch, Nile River, Egypt. *Journal of Environmental Sciences* (China), 118, 21–31. https://doi.org/10.1016/J.JES.2021.08.047
11. El-Amier, Y. A., Zahran, M. A. E.-K., & Al-Mamory, S. H. (2015). Assessment the physico-chemical characteristics of water and sediment in Rosetta Branch Egypt. *Journal of Water Resource Protection, 7*(13), 1075. https://doi.org/10.4236/jwarp.2015.713088
12. Ezzat, S., Mahdy, H., Abo-State, M., Abd, E., & El-Bahnasawy, M. (2012). Water quality assessment of River Nile at Rosetta Branch: impact of drains discharge. *Middle East J Sci Res, 12*(12), 413–423.
13. Hernandez, J.-P., de-Bashan, L. E., Rodriguez, D. J., Rodriguez, Y., & Bashan, Y. (2009). Growth promotion of the freshwater microalga Chlorella vulgaris by the nitrogen-fixing, plant growth-promoting bacterium Bacillus pumilus from arid zone soils. *European Journal of Soil Biology, 45*(1), 88–93. https://doi.org/https://doi.org/10.1016/j.ejsobi.2008.08.004
14. Hoffmann, J. (2002). Wastewater Treatment With Suspended and Nonsuspended Algae. *Journal of Phycology*, 34, 757–763. https://doi.org/10.1046/j.1529-8817.1998.340757.x
15. Ibrahim, M., Al-Zyoud, S., & Elhaddad, E. (2018). Surface Water Quality Monitoring for River Nile, Egypt Using GIS-Techniques. *Open Journal of Geology*, 08, 161–173.
16. Kaiser, M. F., El Rayes, A., Ghodeif, K., & Geriesh, B. (2013). GIS Data Integration to Manage Waterlogging Problem on the Eastern Nile Delta of Egypt. *International Journal of Geosciences, 04*(04), 680–687. https://doi.org/10.4236/ijg.2013.44063
17. L Belkhiri, A. B. L. M. (2010). Groundwater quality and its suitability for drinking and agricultural use in Ain Azel plain, Algeria. *J Geogr Reg Plan, 3*(6), 151–157.

18. Mallick, N. (2002). Biotechnological potential of immobilized algae for wastewater N, P and metal removal: A review. *Biometals 2002 15:4, 15*(4), 377–390. https://doi.org/10.1023/A:1020238520948
19. Martínez, M. E., Sánchez, S., Jiménez, J. M., El Yousfi, F., & Muñoz, L. (2000). Nitrogen and phosphorus removal from urban wastewater by the microalga Scenedesmus obliquus. *Bioresource Technology, 73*(3), 263–272. https://doi.org/10.1016/S0960-8524(99)00121-2
20. Melvik, J. E., & Dornish, M. (2004). Alginate as a Carrier for Cell Immobilisation (pp. 33–51). https://doi.org/10.1007/978-94-017-1638-3_2
21. Mishra, R. (2022). The Effect of Eutrophication on Drinking Water. British Journal of Multidisciplinary and Advanced Studies, 4. https://doi.org/10.37745/bjmas.2022.0096
22. Moreira, S., Moreira-Santos, M., Guilhermino, L., & Ribeiro, R. (2006). Immobilization of the marine microalga Phaeodactylum tricornutum in alginate for in situ experiments: Bead stability and suitability. Enzyme and Microbial Technology, 38, 135–141. https://doi.org/10.1016/j.enzmictec.2005.05.005
23. Mostafa, M. K., Elshafei, M. M., Peters, R. W., Mostafa, M. K., Elshafei, M. M., & Peters, R. W. (2015). Improve Water Quality at the El-Rahawy Drain and the Rosetta Branch, Egypt. *Journal of Environmental Protection, 6*(10), 1139–1148. https://doi.org/10.4236/JEP.2015.610101
24. Nada, A., Zeidan, B., Hassan, A. A., & Elshemy, M. (2021). Water quality modeling and management for Rosetta Branch, the Nile River, Egypt. *Environmental Monitoring and Assessment, 193*(9), 1–17. https://doi.org/10.1007/S10661-021-09357-8/METRICS
25. Omar, M. E. M., Ghareeb, M. A., & El Sherbini, S. (2022). Effectiveness of dredging and drains' treatment on water quality of Rosetta branch. *Environmental Engineering Research, 27*(1). https://doi.org/10.4491/EER.2020.525
26. Raju, N. J., Ram, P., & Dey, S. (2009). Groundwater quality in the lower Varuna River basin, Varanasi district, Uttar Pradesh. *Journal of the Geological Society of India, 73*(2), 178–192. https://doi.org/10.1007/S12594-009-0074-0
27. Sayed, S. M. El, Hegab, M. H., Hesham, R., Mola, A., Ahmed, N. M., & Goher, M. E. (2020). An integrated water quality assessment of Damietta and Rosetta branches (Nile River , Egypt) using chemical and biological indices.
28. Singh, A. K., Mondal, G. C., Singh, S. K., Singh, P., Singh, T. B., Tewary, B. K., & Sinha, A. (2007). Aquatic Geochemistry of Dhanbad, Jharkhand: Source Evaluation and Quality Assessment. *Journal of Geological Society of India*, 69, 1088–1102.
29. Tam, N. F. Y., & Wong, Y. S. (2000). Effect of immobilized microalgal bead concentrations on wastewater nutrient removal. *Environmental Pollution, 107*(1), 145–151. https://doi.org/10.1016/S0269-7491(99)00118-9
30. Tanwar, P., Nandy, T., Khan, R., & Biswas, R. (2007). Intermittent cyclic process for enhanced biological nutrient removal treating combined chemical laboratory wastewater. *Bioresource Technology, 98*(13), 2473–2478. https://doi.org/10.1016/J.BIORTECH.2006.09.006.
31. Zhang, E., Wang, B., Wang, Q., Zhang, S., & Zhao, B. (2008). Ammonia–nitrogen and orthophosphate removal by immobilized Scenedesmus sp. isolated from municipal wastewater for potential use in tertiary treatment. *Bioresource Technology, 99*(9), 3787–3793. https://doi.org/10.1016/J.BIORTECH.2007.07.011