BIO-TREATMENT OF WASTEWATER USING MIXED ALGAL CULTURES

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ABSTRACT

This study was carried out to evaluate the efficiency of mixed algal cultures for wastewater treatment. Free and alginate-immobilized forms of mixed algal culture were used. The highest removal percentages of biological oxygen demand (BOD) were 86.4% and 71.2 % after 32 hrs and 48 hrs, in the case of free and immobilized cells, respectively. Moreover, the highest values of chemical oxygen demand (COD) removal were 83.74% and 59.71% after 32 hrs and 48 hrs for free and immobilized cells, respectively. Treatment with free cells showed removal values for total dissolved salts (TDS), phosphorus and NH3-N were 20.5%, 34.6% and 43.8% respectively after 32 hours. While in case of immobilized cells the highest removal values were18.4%, 34% and 58.5%, for TDS, Phosphorus and NH3-N, respectively recorded after 48 hrs. Generally, concentration of heavy metals decreased due to treatment with algal free and immobilized cells. As a result of treatment with algal free and immobilized cells, 100% and 95.9% of Cu wastewater content was removed after 8 hrs and 48 hrs, respectively. Moreover, 96.2% and 98.1% of Fe was removed after 32 and 48 hours due to application of free and immobilized cells, respectively. Furthermore, high removal percentages for Mn, Pb and Zn were recorded due to application of algae. Accordingly, treatment of wastewater with mixed algal free or immobilized cells is a fruitful method to produce an effluent of high quality to be used for irrigation. Whereas, the algal free cells were found to be more efficient than the immobilized ones.

Keywords: Bio-treatment, Microalgae, Immobilized cells, Waste water

1- INTRODUCTION

Water pollution is the cause of uncontrolled release of domestic, industrial and agriculture refuse (wastewater) into the environment. Microalgae cultures offer an environmentally friend solution for wastewater treatment due to the ability of microalgae to use inorganic nitrogen and phosphorus for their growth and also, for their capacity to remove heavy metals, as well as some toxic organic compounds. Microalgae show advantages in many applications such as renewable energy and biopharmaceutical industries, it is renewable, sustainable, and economical sources of biofuels, bioactive medicinal products, and food ingredients (Khan et al 2018). Palmer 1969 listed the algae in the order of their tolerance to organic pollutants as reported by 165 authors. The list was compiled for 60 genera and 80 species. The most tolerant eight genera were found to be, Oscillatoria, Chlamydomonas, Euglena, Scenedesmus, Chlorella, Nitzschia, Navicula and Stigeoclonium.

The microalgae immobilization on Ca-alginate are commonly used in treatments of wastewater for removal of nitrogen, phosphate, organic carbons, pharmaceutical compounds, toxic textile dye compounds and heavy metals (Moreno Garrido, 2008; El-Sheekh et al 2016; Wang et al 2016 and Salam et al 2017). Microorganism immobilization is a common approach using consortia of bacteria and algae to purification of hazardous contaminants. In this purification system, microalgae could produce oxygen that would be benefit for bacteria.
to biodegrade hazardous pollutants (Mun˜oz and Quielyse, 2006). Immobilized cells are characterized by their stability because the cells are entrapped in the matrix and protected from toxic compounds in wastewater; therefore, they have a higher efficiency for the removal of nutrients (Hernandez et al 2006 and El-Sheekh et al 2016), dye (Huang et al 2000 and Revathi et al 2017), and heavy metals (Tam et al 1998; El-Sheekh and Mahmoud, 2017) than free cells. Many benefits support the potential of microalgae-based treatments, such as low operating costs, ability to reduce atmospheric CO2 level and/or capture of CO2 from industrial flue gases, and production of valuable end bioproducts (Oilgae, 2010). Free and immobilized cultures of Spirulina maxima were used for swine waste treatment and the study of the best dilution of the wastewater for maximum biomass production and for removal of (COD), ammonia and phosphorous to the microalgae has been studied by Canizares et al 1993.

This study was carried out to evaluate the efficiency of mixed algal cultures with different forms such as free cells and alginate immobilized cells of this mixture as a bio-treatment and bio-sorbert of heavy metals from wastewater, the use of these microorganisms for wastewater treatment as alternative for chemical and physical treatments is highly recommended, because it is less expensive and environmentally friendly.

2- MATERIAL AND METHODS

2.1- Collection of wastewaters

Wastewater samples were collected after primary treatment from Sarpium forest site-Ismailia Governorate, Ismailia, Egypt (October 2017). It is the site were the sustainable forestry in desert lands of Egypt using treated sewage water project (Implemented by Ain Shams Univ. and funded by Science and Technology development fund-STDF (18660) is conducted. The sample was transferred to the central lab. of wastewater and industrial wastes, water and waste water company canal provinces for analyses of chemical and physical parameters.

2.2- Analytical Methods

The wastewater was analyzed for pH, biological oxygen demand (BOD), chemical oxygen demand (COD), phosphate and nitrate before and after algal treatments using the standard techniques (APHA, 1998).

2.3- Source of mixed algal cultures

The mixed algal cultures was used in this study were kindly supplied by algae lab –Faculty of Science-Helwan University, Helwan-Egypt.

2.4- Culturing characterization

The different 4 algal species used in this study fall under two algal divisions Chlorophyta and Cyanophyta (Commercial product, under national registration) each type was grown in BG11 medium under (16 h light \ 8h dark) at 28±2°C and 30 μmol photon m2 s-1 light intensity. The different algal species were harvested at their exponential phase of growth which is 15th day and the mixed algal cultures were prepared.

2.5- Experimental design

2.5.1- Preparation of mixed algal cultures in free cells inoculums

All of different algal species was grown separately in liquid BG11 medium for 15 days under the optimum growth conditions. Then liquid cultures were mixed in equal proportions.

2.5.2-Preparation of mixed algal cultures in alginate immobilized inoculums

One hundred ml of algal liquid cultures mixture were added to an equal volume of a sterile solution of sodium alginate (2% w/v). The mixture was added drop-wise into 200 ml of 2% CaCl2 sterile solution using a sterilized Pasteur pipette. Beads of approximately 2 mm in diameter were obtained and hardened in 2% CaCl2 solution for 2 hrs. The beads were then rinsed with sterilized water and maintained at 4°C. All steps were conducted under aseptic conditions (Marei and Elmaghraby, 2016).

2.5.3-Experimental design and treatments

The un-inoculated wastewater (control) compare with the treatments treated in photo-bioreactor of 60 L volume capacity and made of Perspex column with a thermostat and an air diffuser. The temperature of the reactor was adjusted at 25 ± 2°C in each treatment.

2.5.3.1- First photo-bioreactor cycle

In the treatments inoculated with free cells(normal mobilized cells), 1400 ml of the prepared mixed algal cultures in free cells inocula were added to 28 liters of wastewater. The experi-
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The experiment was conducted under controlled conditions (Temp 25± 2º C) for 72 hours and the samples were collected (three replicates) at intervals of 4 hrs. up to the end of the cycle. Three for each treatment were involved. Algal cells were removed from the samples by filtration throw filter membrane. The filtrated samples were kept at 4ºC,

2.5.3.2- Second photo-bioreactor cycle

In the second cycle of this study fixed weight of immobilized mixed algal cells was added to the sewage wastewater in the photo-bioreactor. The duration was 72 hrs. Samples were collected at intervals of 4 hrs. Algal beads were removed from the samples by filtration. The filtrated samples were kept as previously mentioned at 4ºC.

The filtrates from first and second cycles subjected to physico-chemical analyses using standard methods of Biochemical analysis (APHA, 1998) at the Central Lab. of Wastewater and Industrial Wastes, Water and Wastewater Company Canal Provinces

2.6- Wastewater characteristics

According to APHA, 1998, The wastewater collected from Sarpium forest site-Ismailla Governorate, was filtered and subjected to physico-chemical analyses using standard methods Biochemical analysis and the parameters measured are listed in the following Table (1).

2.7- Statistical analysis

Data were statistically analyzed according to Gomez and Gomez, 1976 using Honesty Significant Difference (H.S.D) at 5%. This test was equal Tukey test for mean separation using two ways analysis of variance with interaction.

3- RESULTS AND DISCUSSION

3.1-Physical and chemical pollutants

Data presented in (Table 2) and illustrated by Fig. (1 and 2) indicated that due to inoculation of wastewater with mixed algal cultures in free cells form the, BOD value reduced from 273 mg/l to 36.77 mg/l after 32 hours. This reduction represents the highest removal percentage (86.4%) along the experimental period using free cells inoculum. Whereas, when using mixed algal cultures in immobilized cells, the highest removal percentage (71.2 %) was achieved after 48 hours, since, the immobilized cells reduced BOD from 273 mg/l to 77.8 mg/l after 48 hours. These results agree with those obtained by El-Bestawy (2008) who recorded 89.29% removal of BOD by using mixture of Anabaena variabilis, Anabaena oryzae and Tolypothrix ceylonicain. On the other side, the obtained BOD removal values in this study via either algal free or immobilized cells inocula were higher than those obtained by Ganapathy et al (2011) who recorded 53.5% reduction in BOD from distilleries effluent in 30 days by Nostoc muscorum. Phormidium tenue removed 17.6% of BOD from paper mill effluent in 20 days. (Nagasathy and Thajuddin, 2008) Moreover, the highest removal percentage (83.74%) of COD from wastewater by mixed algal cultures in free cells inoculum was recorded after 32 hours. (Table 2), i.e. application of algal free cells mixture inoculum to wastewater resulted in reduction of COD from 351.67 mg/l to 57.17 mg/l after 32 hours. Similar results 73.68% COD removal percentage with Anabaena oryzae (El-Bestawy, 2008). Furthermore, the removal efficiency of COD was 20-57.1% obtained by using cyanobacteria (N. muscorum or A. subcylindrica and mixed culture of both) (El Sheekh et al 2014).

The highest removal percentage of TDS (20.5%) in wastewater treated with mixed algal cultures in free cells form was achieved after 32 hours, while in case of treatment with immobilized cells the highest removal percentage 18.4% was recorded after 48 hours. The removal percentage of TDS from sewage water ranged between 4.4-23.3% due to using (N. muscorum or A. subcylindrica and mixed culture of both) (El-Sheekh et al 2014). The turbidity of wastewater also decreased with treatment by mixed algal cultures in free cells from 21 to 19.3 after 72 hours, in case of mixed algal cultures in immobilized cells after 8 hours it decreased from 21 to 18.23 these results are lower than 40% to 96.4% obtained by N.muscorum or A. subcylindrica and mixed culture of both used for wastewater treatment (El-Sheekh et al 2014).

Phosphorus in untreated wastewater was found to be 3.47 mg/l, this value reduced to 2.27 mg/l after 32 hours which represents the highest removal percentage (34.6%) for mixed algal cultures in free cells form and 34% in case of mixed algal cultures in Immobilized cells form after 48 hours. Four freshwater green microalgae species, (Chlamydomonas reinhardtii, Scenedesmus obliquus, ...
Table 1. The biochemical and physical characters of the sewage wastewater sample without any treatments (control) represented by means ±SD

| Parameters | Unit (mg/l. wastewater sample) | Parameters | Unit (mg/l. wastewater sample) |
|------------|--------------------------------|------------|--------------------------------|
| BOD        | 270±2.64                      | HCO₃       | 152.7±1.18                     |
| COD        | 351.67±2.12                   | Total alkaline | 250.7±1.25                    |
| Turbidity (NTU) | 21.0±0.36                       | Al         | 0.00                           |
| Ammonia Nitrogen | 26.1±0.26                       | B          | 0.00                           |
| Phosphate  | 3.47±0.23                      | Cu         | 0.073                          |
| TDS        | 700±2.08                       | Fe         | 0.266                          |
| pH         | 7.5±0.17                       | Mn         | 0.366                          |
| Cl         | 191.3±1.7                      | Mo         | 0.003                          |
| Ca         | 85.77±0.76                     | Ni         | 0.001                          |
| Mg         | 17.02±0.22                     | Pb         | 0.073                          |
| Na         | 146.2±1.22                     | V          | 0.0                            |
| K          | 16.89±0.12                     | Zn         | 0.076                          |
| SO₄        | 149.5±1.41                     | Cd         | 0.00                           |

Table 2. The concentration (mg/ l) of physical and chemical pollutants after treatment with mixed algal compound in free and Immobilized cells

| Treatments | BOD | COD | P | NH₄ | TDS | Turbidity |
|------------|-----|-----|---|-----|-----|-----------|
| Time (hrs) | Free cells | Immobilized cells | Free cells | Immobilized cells | Free cells | Immobilized cells | Free cells | Immobilized cells | Free cells | Immobilized cells |
| 0 (control) | 270.00± | 270.00± | 351.67± | 3.47± | 3.47± | 26.10± | 700.00± | 21.00± | 21.00± |
| 4          | 55.00± | 98.67± | 81.33± | 2.63± | 2.63± | 2.64± | 22.20± | 24.13± | 608.00± |
| 8          | 47.23± | 95.67± | 76.67± | 190.67± | 2.63± | 2.63± | 2.64± | 22.00± | 23.90± | 607.67± |
| 12         | 45.27± | 94.17± | 76.00± | 178.67± | 2.53± | 2.53± | 2.64± | 22.00± | 23.63± | 591.00± |
| 24         | 42.27± | 93.47± | 74.33± | 161.00± | 2.45± | 2.45± | 2.64± | 20.03± | 21.76± | 589.00± |
| 48         | 40.57± | 93.57± | 70.00± | 145.67± | 2.47± | 2.47± | 2.64± | 19.40± | 21.60± | 581.67± |
| 72         | 36.77± | 91.40± | 57.17± | 143.67± | 2.27± | 2.27± | 2.64± | 14.67± | 18.87± | 556.33± |
| 50         | 38.47± | 90.93± | 68.33± | 142.33± | 2.43± | 2.43± | 2.64± | 14.90± | 18.70± | 557.13± |
| 72         | 38.43± | 77.80± | 69.61± | 141.67± | 2.45± | 2.45± | 2.64± | 14.90± | 18.70± | 557.13± |
| 52         | 39.48± | 83.63± | 69.00± | 143.33± | 2.63± | 2.63± | 2.64± | 15.23± | 13.63± | 598.00± |
| 56         | 40.43± | 87.67± | 74.00± | 150.00± | 2.67± | 2.67± | 2.64± | 15.24± | 13.90± | 593.33± |
| 60         | 41.43± | 95.67± | 78.00± | 165.67± | 2.70± | 2.70± | 2.64± | 16.03± | 16.00± | 596.50± |
| 72         | 65.28± | 95.33± | 104.33± | 177.33± | 2.70± | 2.70± | 2.64± | 16.83± | 16.83± | 610.33± |

The values having different letters are significantly different at p< 0.05
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**Fig. 1.** Removal percentage of physical and chemical pollutants from wastewater treated with mixed algal cultures in free cells form

**Fig. 2.** Removal percentage of physical and chemical pollutants from wastewater treated with mixed algal cultures in Immobilized cells form
Chlorella pyrenoidosa and Chlorella vulgaris) used for 7 days for wastewater treatment 67.5–82.2% of Total phosphorus was removed (Guang et al. 2014). Phosphorus removal from wastewater recorded 20.8-95% as a result of treatment with N. muscorum or A. subcyllindrica and mixed culture of both (El-Sheekh et al. 2014).

The concentration of NH3-N in untreated wastewater was found to be 26.1 mg/l, this value reduced to 14.67 mg/l, after 32 hours which represents the highest removal percentage (43.8%) due to application of mixed algal cultures in free cells form and 58.5% in case of mixed algal cultures in Immobilized cells form after 48hrs. Ruiz-Marin et al. (2010) reported that the microalgae C. vulgaris and S. obliquus showed preferences for ammonium to any other form of nitrogen present in wastewater. Ammonia nitrogen elimination efficiency by cyanobacterial system was 20.9-96% (El-Sheekh et al. 2014).

### 3.2-Heavy metals

Data presented in Table (3) and illustrated by Fig. (3) and (4) indicated that the concentration of heavy metals in general decreased due to treatment with mixed algal cultures in free and immobilized cells forms. Concentration of Cu in untreated wastewater (control) was estimated to be 0.073 mg/l and decreased to zero mg/l as a result of treatment with mixed algal cultures in free cells after 8 hours and still zero up to 48 hours and increased again. The recorded increase of Cu after 48 hours may be due to the decay of algal cells and release their Cu contents. On the other hand the mixed algal cultures in immobilized cells decreased Cu concentration in wastewater from 0.073 mg/l to 0.003 mg/l (95.9% removal) after 48 hours. Alison et al. (2014) showed that Chlorella vulgaris, Spirulina maxima, and a naturally growing algae sample found in the wastewater from a wastewater treatment plant (containing Synechocystis sp. (dominant) and Chlorella sp. (common) and a few cells of Scenedesmus sp.) removed up to 81.7% of the copper after 10 days.

The concentration of Fe in untreated wastewater (control) was found to be 0.266 mg/l, and 96.2% removal percentage was achieved after 32 hours due to application of mixed algal cultures in free cells. Whereas, the mixed algal cultures in immobilized cells decreased Fe concentration and the highest percentage of removal (98.1%) was recorded after 48 hours. Noor Maisara et al. (2015) used Scenedesmus sp. in waste water treatment and the highest percentage of Fe removal was 65.76%.

Mn concentration in untreated wastewater (control) was 0.366 mg/l, as a result of inoculation with the mixed algal cultures in free cells. 99.4% of Mn content was removed after 32 hours. Whereas, in case of using the immobilized cells 97.8% of Mn content was removed after 48 hours.

Concentration of Pb in untreated wastewater (control) was found to be 0.073 mg/l, 98.6% and 89.0% of Pb content was removed after 8 and 48 hours using mixed algal cultures in free and immobilized cells, respectively. The removal percentages of Pb in this study were higher those recorded by Rajiv and Dinesh (2010) who stated that Chlorella sp. causes lead removal up to 66.3%.

Zn content in untreated wastewater (control) was estimated to be 0.076 mg/l, due to application of mixed algal cultures infree and immobilized cells, Zn content was removed by 84.2% and 97.37% after 32 and 48 hours, respectively. Rajiv and Dinesh (2010) showed that Chlorella sp. removed 60-70%, of Zn. Using microalgae would not only improve the overall wastewater treatment but would also generate biomass that has high energy value.

In our results Pb and Cu were removed faster than Zn, these results was compatible with Qari and Hassan (2014) which found that Dunaliella has removed 95% of Zn and Cd after 108 hours, and 90% of Cu after 60 hours of incubation. Moreover, 93% of Pb, Ni and Cr were removed after 36 hours of incubation.

Generally, concentrations of heavy metals in wastewater were decreased due to treatment with mixed algal cultures infree and immobilized cells. Whereas, in wastewater treatment the mixed algal cultures infree cells form were found to be more efficient than the immobilized one, this may be due to presence of mixture algal cells inside alginate beads which may reduce the transmitted light to the immobilized cells and hence growth and activity of algal cells could be affected negatively.
Table 3. The concentration (mg/l) of Heavy metals after treatment with mixed algal cultures in free and immobilized cells

| Treatments Time (hrs) | Cu    | Fe    | Mn    | Pb    | Zn    |
|-----------------------|-------|-------|-------|-------|-------|
|                       | Free cells | Immobilized cells | Free cells | Immobilized cells | Free cells | Immobilized cells | Free cells | Immobilized cells | Free cells | Immobilized cells | Free cells | Immobilized cells |
| 0 control             | 0.073b | 0.073b | 0.266a | 0.266a | 0.366a | 0.366a | 0.073a | 0.073a | 0.076bcdef | 0.076bcdef |
| 4                     | 0.001c | 0.010c | 0.046b | 0.046b | 0.217bcdef | 0.333ab | 0.007a | 0.073a | 0.063bcdef | 0.063bcdef |
| 8                     | 0.000c | 0.006c | 0.023b | 0.040b | 0.167cdef | 0.233abc | 0.001a | 0.050a | 0.058bcdef | 0.033bcdef |
| 12                    | 0.000c | 0.006c | 0.023b | 0.033b | 0.133cdef | 0.190bcdef | 0.001a | 0.050a | 0.016e | 0.023bcdef |
| 24                    | 0.000c | 0.006c | 0.030b | 0.020b | 0.120def | 0.073cdefgh | 0.001a | 0.030a | 0.013e | 0.020def |
| 28                    | 0.000c | 0.005c | 0.020b | 0.017b | 0.010h | 0.027fgh | 0.001a | 0.015a | 0.013e | 0.17e |
| 32                    | 0.000c | 0.005c | 0.010b | 0.007b | 0.002h | 0.027fgh | 0.001a | 0.020a | 0.012e | 0.005f |
| 36                    | 0.000c | 0.005c | 0.020b | 0.008b | 0.003h | 0.018h | 0.001a | 0.030a | 0.061bcdef | 0.005f |
| 48                    | 0.000c | 0.003c | 0.023b | 0.005b | 0.004h | 0.009h | 0.001a | 0.008a | 0.087bcdef | 0.002f |
| 52                    | 0.010c | 0.006c | 0.020b | 0.007b | 0.005h | 0.009h | 0.001a | 0.009a | 0.093abcd | 0.014ef |
| 56                    | 0.020c | 0.007c | 0.020b | 0.013b | 0.008b | 0.018b | 0.001a | 0.035a | 0.096abc | 0.033bcdef |
| 60                    | 0.040c | 0.025c | 0.023b | 0.016b | 0.010h | 0.027fgh | 0.001a | 0.037a | 0.100ab | 0.047bcdef |
| 72                    | 0.043c | 0.035c | 0.023b | 0.030b | 0.047cdefgh | 0.029 | 0.001a | 0.041a | 0.167a | 0.063bcdef |

The values having different letters are significantly different at p< 0.05

Fig. 3. Removal percentage of heavy metals from wastewater treated with mixed algal cultures in free cells form
Fig. 4. Removal percentage of heavy metals from wastewater treated with mixed algal cultures in immobilized cells form

4- CONCLUSION

Algae can be used in wastewater treatment for a range of purposes, including; reduction of BOD, removal of N and P and removal of heavy metals. On the basis of the obtained results it can be concluded that the mixed algal cultures were found to be of high efficiency in wastewater as a bio-treatment and bio-sorbtent of heavy metals from wastewater. The immobilized systems could facilitate the separation of the biomass from the treated wastewater but the free mixture of algal cells is highly recommended due to its efficiency in wastewater treatment by produce an effluent of high quality to be used for irrigation.

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REFERENCES

Alison C., Hamidreza S. and McBean E.D. 2014. Heavy metal removal (Copper and Zinc) in secondary effluent from wastewater treatment plants by microalgae. ACS Sustainable Chem. Eng., 2(2), 130-137.

American Public Health Association 1998. Standard method for examination of water and waste water, 20th Ed., American Public Health Association, Washington DC., USA, pp. 773-774.

Canizares R.O., Dominguez A.R., Rivas L., Montes M.C. and Travieso L. 1993. Free and immobilized cultures of spirulina maxima for swine waste treatment. Biotechnol. Lett. 15, 321-325.

El-Bestawy E. 2008. Treatment of mixed domestic-industrial wastewater using cyanobacteria. J. Ind. Microbiol. Biotechnol. 35, 1503-1516.

El-Sheekh M.M., El-Shouny W.A., Osman M.E., and El-Gamal E.W. 2014. Treatment of Sewage and Industrial Wastewater Effluents by the Cyanobacteria Nostoc muscorum and...
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Anabaena cylindrica. J. Water Chemistry and Technology. 36(4), 190-197.

El-Sheekh M.M., Farghl A., Gala H.R. and Bayoumi H.S. 2016. Bioremediation of different types of polluted water using microalgae. Rend Fis Acc Lincei. 27(2), 401-410.

El-Sheekh M.M. and Mahmoud Y.A.G. 2017. Technological Approach of Bioremediation using Microbial Tools: bacteria, fungi, and algae. In: Handbook of Research on inventive Bioremediation Techniques. Bhakta J.N. (Ed.) IGI Global, USA, pp. 134-154.

Ganapathy S.G., Baskaran R. and Mohan P.M. 2011. Microbial diversity and bioremediation of distilleries effluent. J. Res. Biol. 3, 153-162.

Gomez K.A. and Gomez A.A. 1976. Statistical Procedures for Agricultural Research with Emphasis on Rice, The international Rice Research Institute, Los-Banos, Manila, Philippines., pp. 75-88.

Guang-Jie Zhou, Guang-Guo Y., Shan Liu, Li-Jun Zhou, Zhi-Feng Chen and Fu-Qiang P., 2014. Simultaneous removal of inorganic and organic compounds in wastewater by freshwater green microalgae. Environ. Sci., Processes Impacts, 16, 2018-2027.

Hernandez J.P., de-Bashan L.E. and Bashan Y., 2006. Starvation enhances phosphorus removal from wastewater by the microalgae Chlorella sp. co-immobilized with Azospirillum brasilense. Enzyme Microbial Technol. 38, 190-198.

Huang G.L., Sun H.W. and Cong L.L. 2000. Study on the physiology and degradation of dye with immobilized algae. Artif. Cells Blood Substitutes Immobil. Biotechnol. 28, 347-363.

Khan M.J., Shin J.H. and Kim J.D. 2018. The promising future of microalgae: current status, challenges, and optimization of a sustainable and renewable industry for biofuels, feed, and other products. MICROB CELL FACT, pp. 17-36.

Marei E.M. and Elmaghrraby, I. 2016. Protection of Bacillus subtilis Against Bacteriophage Attack. Curr. Res. Bacteriol. 9, 1-8.

Moreno-Garrido I. 2008. Microalgae immobilization: current techniques and uses. Bioreour Technol. 99, 3949-3964.

Munoz, R. and Guileysse B. 2006. Algal-bacterial processes for the treatment of hazardous contaminants a review. Water Res. 40, 2799-2815.

Nagashathy A. and Thajuddin N. 2008. Decolorization of paper mill effluent using hypersaline cyanobacterium. Res. J. Environ. Sci., 2, 408-414.

Noor MairabteJais, Radin Maya Saphira bteRadinMohamed, Wan Asma Wan Mohammad Apandi, Hazel Monica Matias Peralta, 2015. Removal of Nutrients and Selected Heavy Metals in Wet Market Wastewater by Using Microalgae Scenedesmus sp. Appl. Mech. Mater., pp. 1210-1214.

Oligae 2010. Oligae guide to algae-based wastewater treatment: A sample report. Retrieved from http://repositorio.uobabylon.edu.iq/2010_2011/4_6558_416.pdf

Palmer C.M. 1969. Composite rating of algae tolerating organic pollution. J. Phycology. 5, 78-82.

Qari H.A. and Hassan I.A. 2014. Removal of pollutants from waste water using Dunaliella alga. Biomed. Pharmacol. J. 7(1), 147-151.

Rajiv K. and Dinesh G. 2010. Waste water treatment and metal (Pb²⁺, Zn²⁺) removal by microalgal based stabilization pond system. Indian. J. Microbiol. 50(1), 34-40.

Revathi S., Kumar S.M., Santhanam P., Kumar S.D., Son D. and Kim M.K. 2017. Bioremoval of the indigo blue dye by immobilized microalga Chlorella vulgaris (PSBDU06). J. Sci. Ind. Res. 76(1), 50-56.

Ruiz-Marin A., Mendoza-Espinosa L.G., Stephenson T. 2010. Growth and nutrient removal in free and immobilized green algae in batch and semi-continuous cultures treating real wastewater. Bioresour. Technol. 101, 58-64.

Salam E., Kurade M.B., El-Dalatony M.M., Yang I.S. Min B., Jeon B.H., 2017. Recent progress in microalgal biomass production coupled with wastewater treatment for biofuel generation. Renew Sustain Energy Rev. 79, 1189-1211.

Tam N.F.Y., Wong Y.S. and Simpson C.G., 1998. Repeated removal of copper by alginate beads and the enhancement by microalgae. Biotechnol. Tech. 12, 187-190.

Wang Y., Ho S.H., Cheng C.L., Guo W.Q., Nagarajan D., Ren N.Q., Lee D.L. and Chang J.S. 2016. Perspectives on the feasibility of using microalgae for industrial wastewater treatment. Bioreosour Technol. 222, 485-497.
المعالجة الحيوية لمياه الصرف باستخدام خليط من الطحالب في مستنبتاته

الموجز

جرت هذه الدراسة تحقيق كفاءة خليط من الطحالب المستنبتة باستخدام مياه الصرف الصحي. وقد تم استخدام الطحالب على صورتين: طحالب حرة وطحالب مرتبطة بالالجينات (المثبتة). وتحت تعميمه، تمت إزالة بـ68% وفي حالة الفسفور 34.6%، بينما تمت إزالة 112% من النحاس بعد 6 ساعات و46 ساعة على التوالي. نتيجة للمعالجة، تمت إزالة 78.2% والذهب sulfate في حالة الخلايا المرتبطة بالالجينات. وعامة، إنخفض تركيز المعادن الثقيلة بسبب العلاج بالخلايا الحرة والمثبتة.

الكلمات الدالة: المعالجة الحيوية، ميكروبيولوجي، الخلايا المتحركة، مياه الصرف

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