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Biological and Bio- desalination treatments of Mixed Sewage Water

[1]Sayed Ismail, [2]Eman Marei, [3]Ahmad Hassan and [4]Abd Elghany El-Gindy

[1]Sanitary & Environmental Engineering, *Department of Public Works, Faculty of Engineering, Ain Shams University, Cairo, Egypt*
[2]*Department of Agricultural Microbiology, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.*
[3]*Department of Genetic Resource, Desert Research Center, Cairo, Egypt.*
[4]*Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.*

Address For Correspondence:
Eman Marei, Department of Agricultural Microbiology, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.
E-mail: wel_memo@yahoo.com

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ABSTRACT

Background: The wastewater is known as a mixture of one or more kinds of different water such as domestic, comprising hospitals, industrial wastewater and agricultural water. Hypersaline environments are important for both surface extension and ecological significance. As all other ecosystems, they are impacted by pollution. However, the available information on the biodegradation of organic pollutants by halophilic microorganisms in such environments are quite limited. Moreover, it is well known that 5% of industrial effluents are saline and hypersaline. The non-extremophilic microorganisms are unable to efficiently remove the organic pollutants at high salinity. Halophilic microorganisms are different metabolically and are adapted to high salinity. Therefore, these microorganisms are highly recommended to be used in bioremediation of hypersaline environments and treatment of saline effluents. Objective: This study aims to investigate the ability of different compounds in biological treatments of saline wastewater as a new technique for bio-treatment, bio-desalination and bio-removal of different heavy metals in nature circumstances. These compounds were compound I which contains mixture of different bacteria and compound II which contains mixture of different algae. These compounds were prepared under Lab condition. Results: The obtained results indicated that the removal efficiency for bio-treatment, the percentage of removal rate was found to be 79.8 and 83.5% for BOD, 82.4 and 86.3% for COD, 52.9 and 57.2 % for ammonia nitrogen and 85.8 and 98.51 % for phosphate. The high bio-removal to different heavy metals were found to reach 84.0 % and 78.50% for Al ion, 63.2 %, 85.50% for Fe ion, 85.0 % and 89.9 % for Mn ion and 78.9 % and 84.3 % for Zn ion. The results indicated that the high removal efficiency and high reduction for TDS were found to reach 39.0 % and 36.0% after 4 & 8 days in case of using compound I and compound II, respectively. The value of power equation > exponential equation for bacteria treated and algae. The correlation coefficient (R2) value of bacteria treated at 0.99, whereas for algae treated at 0. 89 for bio-desalination. Conclusion: On the basis of the obtained results it can be concluded that different biological treatments of saline wastewater with compound I and compound II were found to be effective in removal of heavy metals and reduction to TDS at 39.0 % & 36.0 % after 4 days incubation period at 40 º C and 8 days incubation at 27°- 30°C for compound I and compound II respectively.

INTRODUCTION

The wastewater is known as a mixture of one or more of: 1- domestic effluent which contains excreta, urine, fecal sludge, kitchen wastewater, bathing wastewater; 2- water from commercial organization and institutions, comprising hospitals; 3- industrial wastewater and; 4- agricultural, horticultural and aquaculture effluent (Corcoran *et al*., 2010).

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Organic and inorganic substances which were released into the environment as a result of domestic, agricultural and industrial water activities lead to organic and inorganic pollution. The normal primary and secondary treatment processes of these wastewaters have been introduced in a growing number of places, in order to eliminate the easily settled materials and to oxidize the organic materials present in wastewater.

Finally, a clear and clean effluent can be obtained and drained into natural water resource. This secondary effluent is loaded with nitrogen and phosphorus in inorganic forms and causes eutrophication and more long term problems because of refractory organics and heavy metals that are discharged. Cultures of microalgae can successfully be used in wastewater treatments, because they provide a tertiary bio-treatment plus production of huge amounts of biomass, which can be used for several purposes (Abdel-Raouf *et al*., 2012).

Hypersaline environments are important for both surface extension and ecological significance. As all other ecosystems, they are impacted by pollution. However, the available information on the biodegradation of organic pollutants by halophilic microorganisms in such environments are quite limited. Moreover, it is well known that 5% of industrial effluents are saline and hypersaline. The non-extremophilic microorganisms are unable to efficiently remove the organic pollutants at high salinity. Halophilic microorganisms are different metabolically and are adapted to high salinity. Therefore, these microorganisms are highly recommended to be used in bioremediation of hypersaline environments and treatment of saline effluents. On the basis of the above-mentioned information, it can be concluded that both the moderately halophilic bacteria and the extremely halophilic archaea have a broader catabolic versatility and capability than previously thought. A diversity of contaminating compounds is susceptible to be degraded by halotolerant and halophilic bacteria (Borgne *et al*., 2008).

Also, Elsergany *et al*. (2014) showed that can be removal efficiency for TDS from 80000 ppm up to 40000 ppm with several runs to get the TDS removal efficiency. The percentage of removal for TDS varied between 13 & 63% by algae under the nature circumstances. These variations were due to inlet TDS contents, retention time in the basin and the climatic conditions (sunlight duration & temperature). The efficient removal for TDS and the results in the highest inlet content was inside the allowed limits for safe discharge to the sea.

Halophiles are microorganisms that can grow well in moderate and high salt concentrations. They are found in all three domains of life: *Archaea*, *Bacteria* and *Eukarya*. Halophilic bacteria grow well over a wide range of salt concentrations (3–15% NaCl, w/v and higher), unlike the truly halophilic archaea whose growth is restricted to high salinity condition (Litchfield and Gillevet, 2002).

Growth of *Scendesmus* species in saline water was successfully obtained, since it absorbs salts to be used in its metabolism, Since, *Chlorella* and *Scenedesmus* are commonly exhibit extremely wide range of salt tolerance in their habitat, they are known as the most active algae in stabilization ponds (Gimmler, 1981).

Micro-algae have a high capacity for inorganic nutrient uptake and can be used in mass culture in outdoor solar bioreactors. Unicellular green algae such as *Chlorella* and *Scendesmus* have been widely used in wastewater treatment because the often colonize the ponds naturally, and they have fast growth rates and high nutrient uptake capabilities. However, one of the major drawbacks of using micro-algae in wastewater treatment is the harvesting of biomass (Laliberte *et al*., 1997).

The present work focused on the investigation of the possibility of using compound I (mixture of bacteria) and compound II (mixture of algae) in form of free cells as a bio-treatment, biological high desalination and bio-removal of heavy metals from saline wastewater under nature conditions.

MATERIALS AND METHODS

1. Source of water:

High salinity wastewater (sewage water) sample was collected from Ras-surd region, Ras-sudr research station, Egypt after primary treatment. The water sample was taken in sterilized bottles and kept at 4ºC in a refrigerator for further studies. The sewage water sample was transferred to the Central Lab, Desert Research Center for analysis. characteristics of the collected sewage water sample are presented in table (1).

2. Microorganisms used for wastewater treatments:

2. a. Compound I (Mixture of bacteria):

Bacterial species; halophilic bacteria and yeasts were supplied by Department of Microbiology & Virology Lab and Cairo MERCIN, Ain Shams University.

Each bacterial species and yeasts were grown on 25 ml of glucose nutrient broth for 48 hr at 35°C. Whereas, halophilic bacteria were grown on 25 ml of ATCC medium 217 liquid medium for 5 days at 41°C. The prepared liquid culture (10^8 cfu/ml) were mixed in a conical flask to form compound I.

2. b. Compound II (Mixed Algae):

Different halophilic micro algae were supplied by Department of Microbiology and Virology Lab., Ain Shams University. The algae were grown separately on BG-11 liquid medium at 27°C under continuous illumination of fluorescence 5500-6500 lux for 7 days (Roger and Kulasooriya, 1980). The algae liquid cultures were mixed together in a conical flask to form compound II.

Table 1: The chemical characters of the wastewater sample as reported by Central Lab, Desert Research Center.

Parameters	Unit (mg/L. Sewage water sample)
BOD	176
COD	339
Ammonia Nitrogen	142
Phosphate	90.15
Turbidity (Ntu)	123
TDS (%)	95.0
TDS (ppm)	21632
pH	7.1
Ca	528.2
Mg	280.1
Na	1200
K	120
SO_4	263.14
Cl	1724.11
HCO_3	250.90
Al	25.65
B	0.66
Cd	0.06
Co	0.03
Cr	0.60
Cu	0.02
Fe	60.86
Mn	4.14
Mo	0.001
Ni	0.09
Pb	0.03
V	0.24
Zn	1.19

3. Experimental Design and Treatments:

3.a. Compound I treatment:

Twelve conical flasks (500 ml) were prepared each contained 400 ml of sewage water. Fifty ml of compound I were added to each flask. The three flasks were incubated with shaking at 40°C. The contents of one flask (450 ml) were taken after 48 hrs and contents of another flask were collected after 96 hrs., whereas, the contents of the third one was collected after 192 hrs. The collected samples were centrifuged at 6000 rpm for 15 min to remove the bacterial cells and the supernatants were subjected to analysis.

3.b. Compound II treatment:

Twelve 500 ml flasks each contained 400 ml of sewage water were prepared. Fifty ml (10^8cfu/ml) of compound II (Mixed algae) were added to each flask. Flasks were incubated with shaking at 27°- 30° C for 12 days. The contents of one flask (450 ml) were taken after 4 days and contents of another flask were collected after 8 days, whereas, the contents of the third one were collected after 12 days. The collected samples were centrifuged at 6000 rpm for 15 min to remove the algae cells and the supernatants were subjected to analysis. The supernatants were kept for biochemical analysis at the Central Lab, Desert Research Center.

4. Adsorption equations:

Adsorption from aqueous solutions at equilibrium is usually correlated by power equation and exponential equation. The power equation calculated following equation (1):

$$q = K\,Ceq^{1/n}$$

In this model, K (l g-1) and 1/n are the constants to be determined from the data. A value of 1/n indicates of rather strong bond between the adsorbate and adsorbent. Exponential equation (2):

$$qe = a\,.e^{\,b\,.Ce}$$

where *q*e is the amount adsorbed at equilibrium(mg/g) and *C*e is the equilibrium concentration of metal ions in solution (mg/L) and *b* is a constant related to the energy of adsorption. The values of *R*2 are regarded as a measure of the goodness-of-fit of experimental data on these models.

RESULTS AND DISCUSSION

Bio-treatment by Compound I & Compound II of saline wastewater:

In this study different compounds were used as biological treatments of saline wastewater. The results showed that water contained organic, inorganic matter, high salt concentration and different concentrations of heavy metals.

Reduction of COD, BOD, ammonia nitrogen, phosphate and almonium, iron, manganese and zinc in wastewater were recorded in samples treated with compound I & II, respectively after different incubation periods at 41º & 27°- 30° C. Data presented in table (2- a & b) and figure (1-a & b) indicate that the highest removal percents of COD, BOD, ammonia nitrogen, phosphate and almonium, iron, manganese and zinc were achieved after 4 & 8 days. The pH value was found to be 7.1 to 8.1 during the experiment recorded as compared to untreated ones which was found to be pH 7.1. These results are in agreement with those found by (Kargi and Dinner, 2000; Awasthi and Rai, 2004; Borgne *et al*., 2008; Abou-Elela *et al*., 2010; Krishnan and Neera, 2013).

With increasing the incubation period, the removal efficiency increased in various characteristics of wastewater sample. After incubation for four & eight days the maximum removal of COD, BOD, Ammonia nitrogen, phosphate and different heavy metals were achieved. Percentage removal rate was found to be 79.8% & 83.5% (BOD) and 82.4 % &86.3% (COD), ammonia nitrogen 52.9% & 57.2%, phosphate 85.8% & 98.51 %, Al 84.0% & 78.50%, Fe 63.2 % & 85.50%, Mn 85.0% & 89.9% and Zn 78.9 % & 84.3% ions by compound I and compound II , respectively. Sorption and removal of heavy metals by algal bio-sorbents largely depend on the initial concentrations of metals in the solution. Metal sorption initially increases with increasing metal concentration in the solution, and then becomes saturated after a certain concentration of metal (Kant and Gaur, 2001). This may be due to the increase in the number of ions competing for the available binding sites in the biomass and also due to the lack of binding sites for the complication of these ions at higher concentration levels. At lower concentrations, all metal ions present in the solution would interact with the binding sites and thus facilitate maximum adsorption. At higher concentrations, more ions are left unabsorbed in solution due to saturation of binding sites (Ahalya *et al*., 2005).

Due to using compound I & II to reduction in salinity and removal percentages of high TDS and turbidity were found to be of wastewater was recorded as compared to untreated sample (control). The removal percentages of TDS at 39.0 % & 36.0 % and Turbidity at 49.46 (Ntu) & 37.01(Ntu) after 4 & 8 days Incubation period at 40 º C &27°- 30°C by compound I and compound II, respectively. Data presented in table (2-a & b) and figure (2- a & b). These results are in agreement with those found by (Kargi and Dinner, 2000; Elsergany *et al*., 2014; El-Nadi *et al*., 2014).

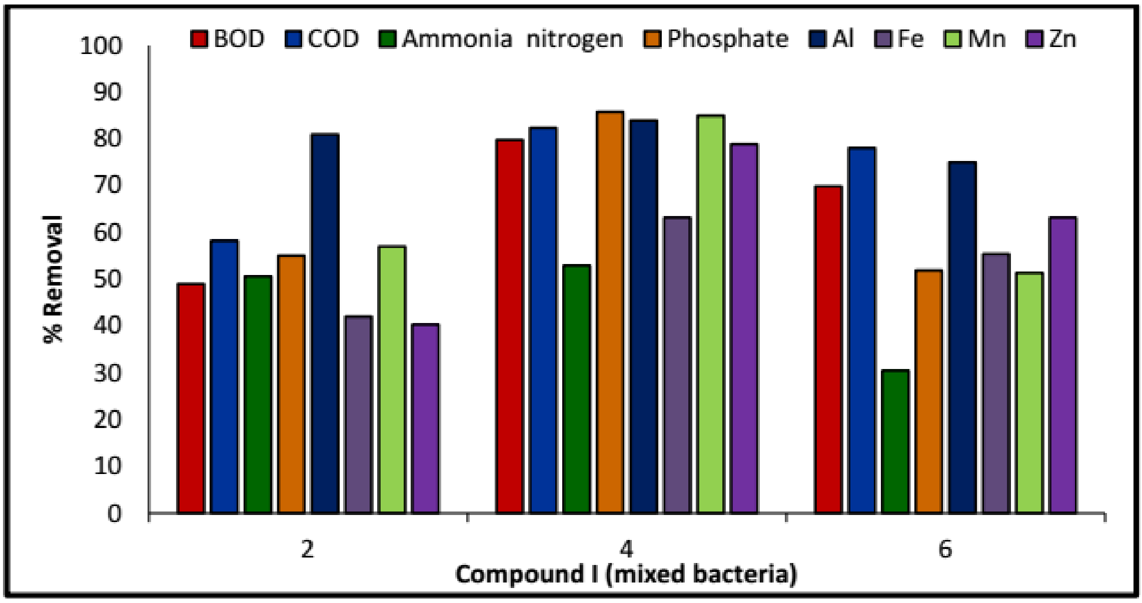
Table 2: Removal Percentages (%) of different bio-treatments after different incubation periods.

Parameters	Compound I (Mixed Bacteria)[a] Incubation period (day)			Compound II (Mixed Algae)[b] Incubation period (day)		
	2	4	6	4	8	12
BOD	49.0	79.8	69.9	59.9	83.5	72.1
COD	58.2	82.4	78.1	67.5	86.3	17.8
Ammonia- nitrogen	50.7	52.9	30.5	43.6	57.2	39.2
Phosphate	55.03	85.8	51.9	59.01	98.51	98.51
Turbidity (Ntu)	23.2	49.46	28.97	19.83	37.01	33.6
TDS (%)	95.0	36.0	43.0	83.0	39.0	41.0
pH	7.1	7.1	7.1	7.5	7.8	8.1
Al	81.0	84.0	75.0	60.70	78.50	72.10
Fe	42.0	63.2	55.4	67.95	85.50	70.9
Mn	57.0	85.0	51.4	66.4	89.9	71.1
Zn	40.33	78.9	63.2	50.7	84.3	78.9

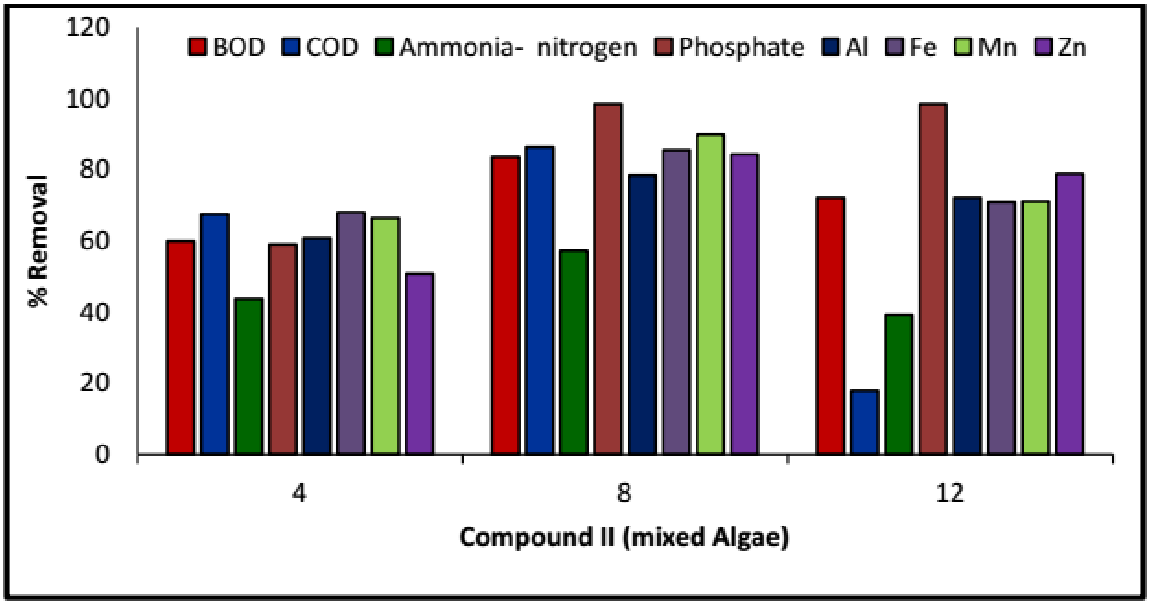
Adsorption equations:

In this study the value of NaCl reduction by power equation at (($1/n$ = 5.78 and 4.83, Kf (mg/g) = 0.0092 and 0.143 and the correlation coefficient (R2) value = 0. 99 and 0.89) for bacteria and algae treated respectively, whereas the value of NaCl reduction by exponential equation at (B= 0.278 and 0.247, Kt(L/mg) = 1161 and 1984 and the correlation coefficient (R2) value = 0.97 and 0.85) for bacteria and algae treated respectively, so power equation > exponential equation for bacteria treated and algae, data shown in table (3).

According to (Kadirvelu and Namasivayam, 2000; Krishna and Swamy, 2012), reported that, the n values between 1 and 10 represent beneficial adsorption. The value of n, which is related to the distribution of bonded ions on the sorbent surface, was found to be greater than unity indicating that adsorption is favorable. Tien (2002) found that the magnitude of K and n showed easy uptake of surface area and dry weight of algal cells. It was found to be the main factor influencing metal sorption and indicates favorable adsorption. Biosorption using biomass derived from fresh water, algae, marine seaweeds and fungi have recently attracted growing interest of researchers. Many potential binding sites occur in algal cell walls and alginate matrices (Saitoh *et al*., 2001; Tam *et al*., 1998).

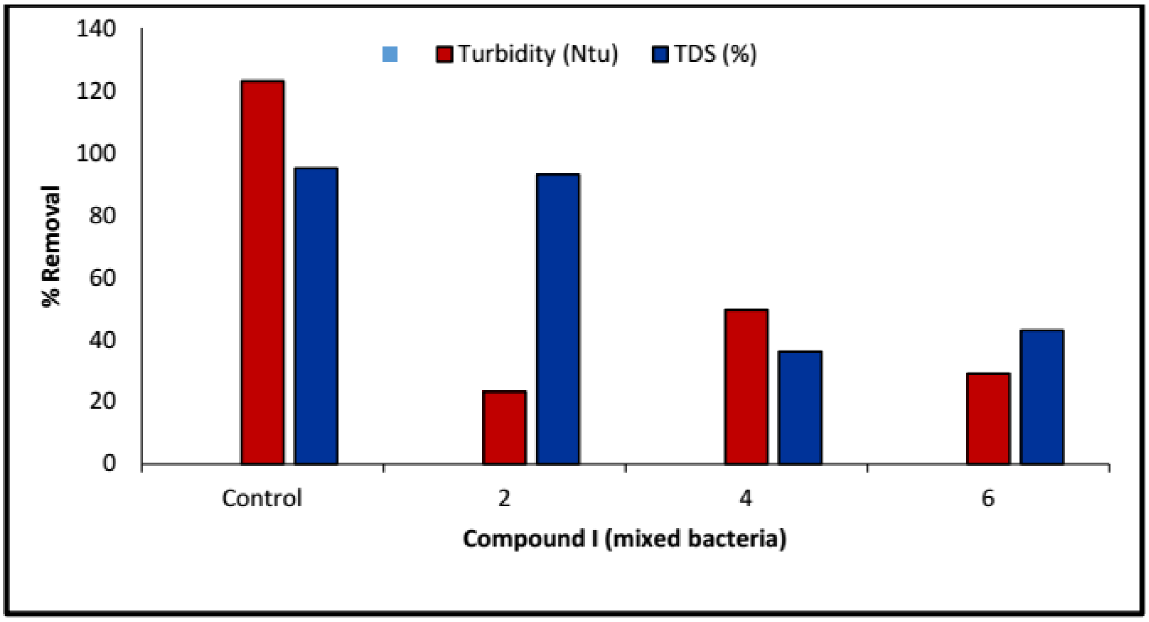


A

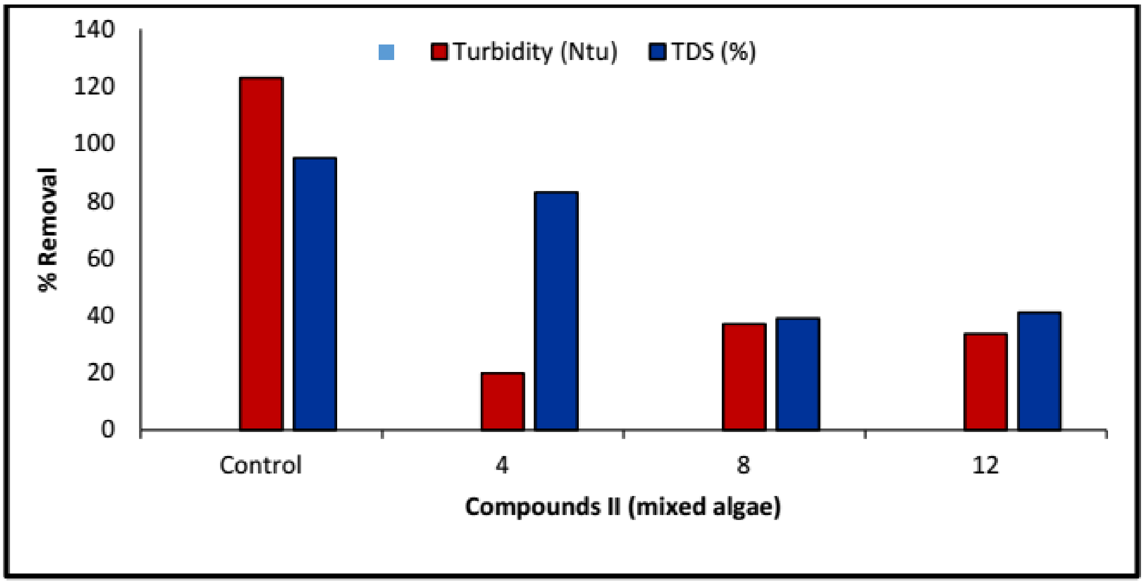


B

Fig. (1-A): Removal percentage at different incubation periods with Compound I (mixed bacteria & yeast).
(1-B): Removal percentage at different incubation periods with Compound II (mixed algae).



A



B

Fig. (2-A): Percentage reduction of salinity and turbidity by different incubation periods with compound I (mixed bacteria & yeast).

(2-B): Percentage (%) reduction of salinity and turbidity by different incubation periodswith compound II (mixed algae).

Table 3: Estimated different models and their constant values of different treatments for bio-desalination

Biosorbant	Power equation			Exponential equation		
	Days			Days		
	R^2	K	1/n	R^2	K	B
Bacteria	0.99	0.0092	5.78	0.97	1161	0.278
Algae	0.89	0.143	4.831	0.85	1984	0.247

Conclusion:

On the basis of the obtained results it can be concluded that different biological treatments of saline wastewater with compound I and compound II were found to be effective in removal of heavy metals and reduction of 82.4 % &86.3%, COD , 79.8% & 83.5%, BOD, ammonia nitrogen 52.9% & 57.2% phosphate 85.8% & 98.51 %, Al 84.0% & 78.50% , Fe 63.2 % & 85.50%, Mn 85.0% & 89.9% and Zn 78.9 % & 84.3% ions, TDS at 39.0 % & 36.0 % and Turbidity at 49.46 & 37.01 (Ntu) after 4 days Incubation period at 40 º C and 8 days incubation at 27°- 30°C for compound I and compound II respectively. Also, the value of NaCl reduction by power equation at ((1/n = 5.78 and 4.83, Kf (mg/g) = 0.0092 and 0.143 and the correlation coefficient (R2) value = 0. 99 and 0.89) for bacteria and algae treated respectively, whereas the value of NaCl reduction by exponential equation at (B= 0.278 and 0.247, Kt(L/mg) = 1161 and 1984 and the correlation coefficient (R2) value = 0.97 and 0.85) for bacteria and algae treated respectively, so power equation > exponential equation for bacteria treated and algae.

Therefore, the use of compound I and compound II is highly recommended for bio treatment and bio – desalination of wastewater high salinity. The importance of this research is due to the use of alternative and safe methods in treating salinity wastewater and reuse in re-irrigation of some types of trees and non-paper plants, which in turn helps reduce the tap water used.

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