Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 23(4): 1 – 9 (2019)
www.ejabf.journals.ekb.eg

Floating macrophytes efficiency for removing of heavy metals and phenol from wastewaters

Elsayed M. Ali Nafea
Aquatic Environment Department, Faculty of Fish Resources, Suez University, Suez, Egypt

ARTICLE INFO

Article History:
Received: June 18, 2019
Accepted: Aug.28, 2019
Online: Sept. 2019

Keywords:
Macrophytes
Lemna gibba
Pistia stratiotes
Phenol
wastewater treatment

ABSTRACT

This study evaluates the use of free floating aquatic macrophytes (*Lemna gibba* L., Lemnaceae. and *Pistia stratiotes* L., Araceae) for the treatment and purification of waste polluted water in a laboratory experiment. The results revealed that *Lemna gibba* L. has a higher removal efficiency reached to about 88 % for the tested heavy metals and phenol from the waste polluted water, while *Pistia stratiotes* L. has a removal efficiency reached to about 83% for heavy metals and phenol. They are considered good models in assessing Eco- toxicity and efficiency for toxins removal from polluted environment and wastewater purification and treatment.

INTRODUCTION

According to an anthropogenic impact and human activities on the biosphere herbicides, pesticides, fertilizers, and other hazardous organic and inorganic chemicals take their way into water environment (Shreadah *et al.*, 2006; Younis *et al.*, 2014; El Zokm *et al.*, 2015; Amin *et al.*, 2018; Soliman *et al.*, 2018; Younis, 2018).

On the basis of production volume, exposure and biological effects ninety five chemicals have been defined as toxic materials including heavy metals, oil, phenols, sulphide, sulphate, nitrate, phosphate, dissolved solids, suspended solids which are released in to water environment. (Asamudo *et al.*, 2005; Said *et al.*, 2006; Nayyef *et al.*, 2012; Younis and Nafea 2012; Younis *et al.*, 2018; Soliman *et al.*, 2019; El-Naggar *et al.*, 2019).

Phenol and Phenolic compounds have a wide distribution and detection in the effluent of various industrial operations, including petrochemicals, textiles, dyeing , phenolic resin manufacturing and steel plant (Metcalf and Eddy 2003),Where it has high toxicity effects to most microorganisms, plants, fishes and other animals as well as it can cause considerable damage to the environment and are listed among priority organic pollutants by the US environmental protection agency (Muftah *et al.*, 2009). Also they are of potential human carcinogen and considerable health concern, even at a low concentration (Nayyef *et al.*, 2012), So it is necessary to be removed or treated from the industrial waste water before drained in to the drainage system.

Many technologies have been investigated for removing and degradation of phenolic compounds in wastewater including; adsorption (Frieda and Nava1997;

Saleh *et al.*, 2019), solvent extraction *(*Ruey *et al.*,2009*)*, activated carbon adsorption, chemical oxidation (Wang 1992) and biodegradation (Azin and Katayon 2002) but it suffer from serious drawbacks as high costs, incompleteness of purification, formation of hazardous by-products, low efficiency and applicability to a limited concentration range and are often ineffective .

Many plants can thrived the metal enriched environments and some of them can accumulate very high concentrations of toxic metals in their tissues up to high levels, which are essential for their growth and development. These metals include As, Mg, Fe, Mn, Pb, Zn, Cu, Mo , Ni, Cr and Co . However, excessive accumulation of these heavy metals can be toxic to some plants .

Among various methods available, biodegradation is economically and environmentally friendly, (Pichiahet *et al.*, 2008). Biological treatment of phenol is an important process in pollution prevention. Biodegradation of phenol has been studied under both aerobic (Rontaniet *et al.*,1999), and anaerobic conditions (Grossiet *et al.* , 1998).

Phytoremediation has emerged as a green, passive, solar energy driven and sustainable cost effective approach for environmental cleanup when compared to physico-chemical and even other biological methods (Rahul 2015) and can be considered as a highly promising method in using various plants and their associated microbes to degrade, accumulate, or immobilize contaminants from soil and water (Dietz *&* Schnoor 2001) . It has been adopted widely to clean up metals, pesticides, petroleum compounds, explosives, poly-aromatic hydrocarbons and other organic compounds and Phytoremediation is relatively inexpensive to apply and simple to be managed (Meagher 2000; LeDuc and Terry 2005). The plant materials used in phytoremediation can be reprocessed into wood chips, pulp, or bioenergy resources (Stanton *et al.,* 2002). Phytoremediation is likely to attract public support and the plants can be easily monitored for effective performance.

Lemna gibba L. is a small (1-15 cm) free floating aquatic macrophytes that grow in shallow, brackish and stagnant water. It is a monocotyledons belonging to the Family Lemnaceae which classified as higher plant or Macrophytes, (FAO 2010). It also has a high bio removal capacity for exogenous chemicals and toxins from polluted wastewater, (Younis *et al.*, 2016). Also, it shows promising value for the removal of heavy metals (Fe, Mn, Cd, Se, Co, Ni, Cr, Pb and Cu from contaminated wastewater since it accumulates high concentrations of these metals**.**

Pistia stratiotes L**.** is a free floating aquatic macrophytes belonging to family Araceae, present and grow in fresh and brackish shallow water with high nutrient contents, where it can absorb and accumulate heavy metals and elements in its tissues by high rate (Rhizofiltration).

So, the major concern of this study is to investigate the efficiency of free floating aquatic macrophytes “*Lemna gibba* L. and *Pistia stratiotes* L.” as a Bio-materials for removing of phenolic compounds and heavy metals from wastewater as a sustainable treatment strategy for the polluted waste water in the laboratory as a trial to be used in a wide scale treatment strategy.

MATERIALS AND METHODS

The working solutions were prepared from an aqueous phenol stock standard solution by diluting with doubly distilled water to the required concentrations.

Solutions of heavy metals were prepared for each metal by dissolving salts of the metal in distilled water. The species associated with the tested plants was recorded with their life form and life span.

The free floating aquatic plants *(Lemna gibba* L *.and Pistia stratiotes* L.*)* Were collected from the natural water habitat (east north of lake Manzala).Then samples were washed with fresh and distilled water to remove particles and possible parasites, where plants with similar size and growth stage were selected for the experiment. The water qualities of the original water habitat were measured in the field to know the ideal conditions for culturing the tested plants.

The determination of phenol concentrations at aqueous solution was conducted by putting *Lemna gibba L.* fresh and clean fronds (20 frond for each glass Jar) and five plants of *Pistia stratiotes* L. with different initial concentrations of phenol ranging (0.1, 0.25, 0.50, 1 g/L) for time observed . After separation, the final concentrations of phenol in the solutions was measured by spectrophotometer every 12 hrs. The results were represented by Figures.

The determination of heavy metals concentrations at aqueous solution was conducted by putting equal amounts of *Lemna gibba* L. fresh and clean fronds (20 frond for each glass tank) and 5 fronds of Pistia stratiotes L. with different initial concentrations of Cadmium, Lead, Arsenic,
Zinc and Manganese ranging (0.1, 0.25, 0.50, 1 g/L) for time observed.

The samples were put in Teflon beakers after washing it with diluted Nitric acid, then evaporated on a hotplate at (80 to 90 degree Celsius),after that added Nitric acid (65%) to the samples and filtered with filter paper,

The final concentrations of Cadmium, Lead, Zinc and Manganese in the solutions was measured by Atomic Absorption spectroscopy every (6, 12,18,24,30 hours) for determination the conduct time. The results were tabulated and represented by Figures.

RESULTS AND DISCUSSION

The free floating aquatic plants *(Lemna gibba* L *.and Pistia stratiotes* L.*)* were collected from the natural water habitat (east north of lake Manzala). which have the following physic-chemical water characteristics; pH 6.7, salinity 6700 mmhos/cm, Dissolved Oxygen 3.5mg/l, Biological Oxygen demand 22mg/l, K 133mg/l, Mg 950 mg/l, Ca 47 mg/l, Na 195 mg/l, PO4 10mg/l,HCo3 130 mg/l and NH4(TKN) 13mg/l. which are the ideal conditions for their growth and dominance , as in Table (1).

Table 1: The Physico chemical characteristics of water habitats for the collected *Lemna gibba* and *Pistia stratiotes*.

water characteristics	*Lemna gibba* L.	*Pistia stratiotes* L.
water depth Cm	26	110
water temperature °C	27	26
transparency Cm	22	25
Water pH	7.2	7.3
Salinity mmhos /cm	4000	3000
Dissolved Oxygen mg/l	3.4	7.1
Biological oxygen demand mg/l	21	13
K mg/l	133	150
Mg mg/l	950	730
Ca mg/l	47	54
Na mg/l	190	176
HCO3 mg/l	130	142
PO4 mg/l	8	6
NH4 (TKN) mg/l	14	9

Table (2) shows the floristic list for the aquatic plants associated with *Lemna gibba* and *Pistia stratiotes* where 11 species belonging to 11 genuses and represented by 9 families are recorded. The life forms, life span and habitat for each recorded species were detected as 4 species floating, 2 species submerged and 5 species are emerged aquatic plants.

Table 2: Floristic list for the Associated species present in water habitats at east north lake Manzala.

Family	species	life span	life form	habitat
Lemnaceae	*Lemna gibba* L.	helophyte	per.	free floating
Araceae	*Pistia stratiotes* L.	helophyte	per.	free floating
Pontederiaceae	*Eichhorniacrassipes* L.	helophyte	per.	free floating
Azollaceae	*Azollafiliculoides* Lam.	helophyte	per	free floating
Ceratophyllaceae	*Ceratophyllumdemersum* L.	helophyte	per.	submerged
Potamogetonaceae	*Potamogetonpectinatus* L.	helophyte	per.	submerged
	*Phragmitesaustralis***(Cav)Trin**	helophyte	Per.	emerged
Poaceae	*Echinochloastagnina* L.	helophyte	per.	emerged
	Paspalumpaspalidum L.	helophyte	per.	emerged
Typhaceae	*Typhadomingenssis*Pers.	helophyte	per.	emerged
Polygonaceae	*Persicariasalicifolia* (Brouss. ex Willd.) Assenov	hemicryptophytes	per.	emerged

Per.= Perennial

Bioremediation is a "treatment that uses naturally occurring organisms to break down hazardous substances into less toxic or non-toxic substances" which included bioaccumulation, bio sorption and phytoremediation as mentioned by Vijayaraghavan *et al*.(2015), Phytoremediation is a natural and direct use of green plants to uptake/absorption of the pollutants through roots and translocation to the upper part of the plant as mentioned by Sharma *et al.* (2015) .Organic and/or inorganic pollutants (metals, pesticides, persistent organic pollutants) can be removed from contaminated soil, sludge, sediments and water as confirmed by Bhatia, *et al*.(2014**)** and Bauddh *et al*. (2015)**.** In remediation of contaminated soil and water, a wide range of plant species are used.

The removal efficiency of phenol from the aqueous solution by the tested aquatic Macrophytes was represented in Fig. (1) where the *Lemna gibba* plant is most efficient in removal of phenol from aqueous solution than the *Pistia stratiotes*, but both the tested plants are efficient in removal of the phenol from water and could be used in treatment of the polluted water which contain high and low amounts of phenols if they used in a controlled pond for purification and treatment, where the removal efficiency reach 90% in case of *Lemna gibba* and 79% in case of Pistia stratiotes after 30 hours of cultivation. Renee *et al*. (2015) assured the monitoring and present of phenols at the red sea water and this leads to use aquatic plants for treating it.

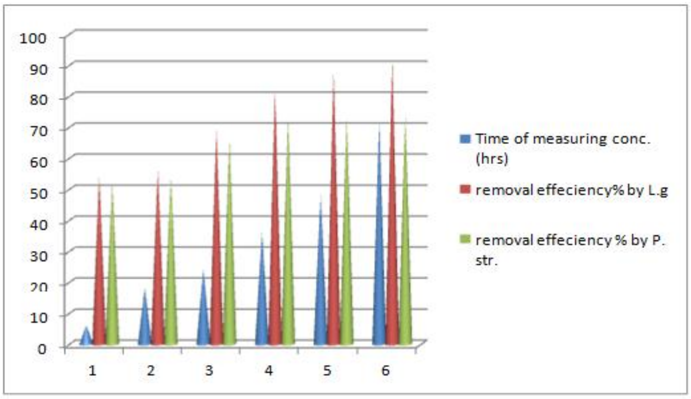

Fig. 1: Removal efficiency (%) of phenols by *Lemna gibba* and *Pistia stratiotes* plants.

The results of removal efficiency of heavy metals from the polluted water demonstrated that the *Lemna gibba* and *Pistia stratiotes* plants have the ability for purification and treatment of waste polluted water after 30 hours of planting and they can accumulate and absorb metals from water by high rate especially after 24 hours of planting as shown in Figs. (2, 3, 4 & 5).

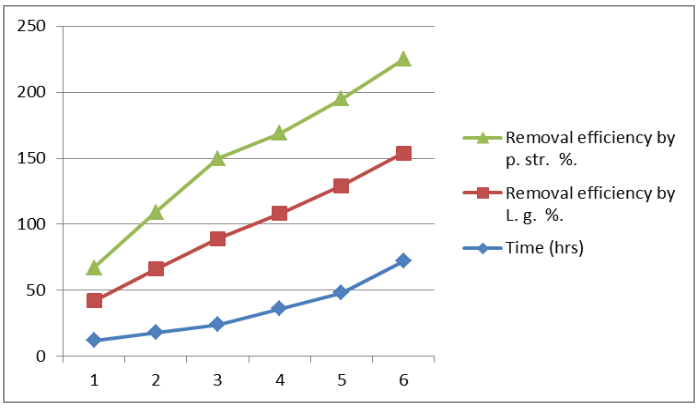

Fig. 2: Removal efficiency % of Cd by *Lemna gibba* and *Pistia stratiotes* aquatic plants

The removal efficiency % of Cd by *Lemna gibba* was 82% where it was 71% in case of *Pistia stratiotes*. So the Lemna gibba can be used in the treatment and removal of Cd from waste water before it used or disposed in to the drains. Shafqat *et al.* (2018) estimated the bioremoval efficiency of heavy metals by Lemna minor species from the landfill leachate and proved that L. minor significantly reduced the concentration of heavy metals in landfill leachate and the removal efficiency reached 70% with maximum 91% with Copper.

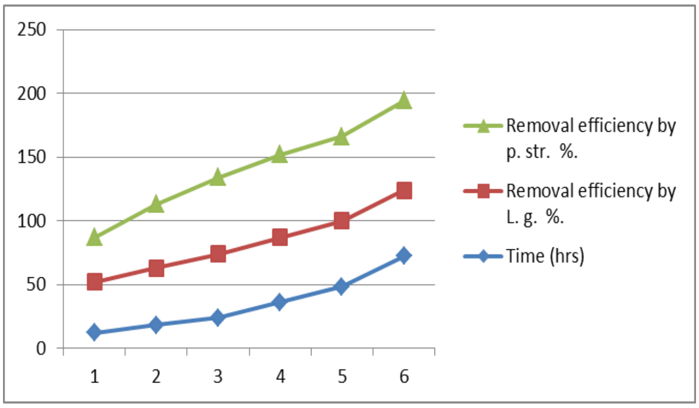

Fig. 3: Removal efficiency (%) of Pb by *Lemna gibba* and *Pistia stratiotes* aquatic plants.

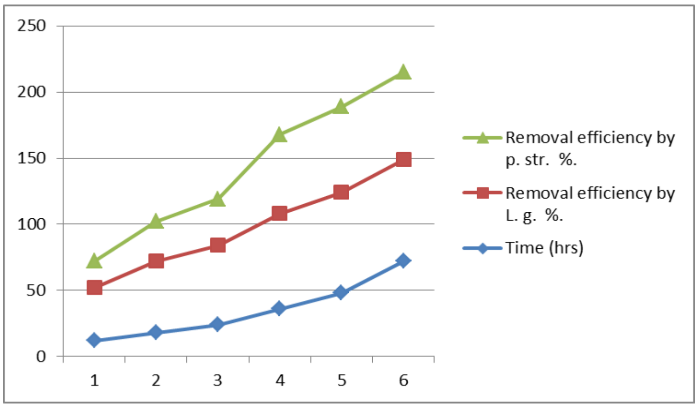

Fig. 4: Removal efficiency (%) of Zn by *Lemna gibba* and *Pistia stratiotes* aquatic plants

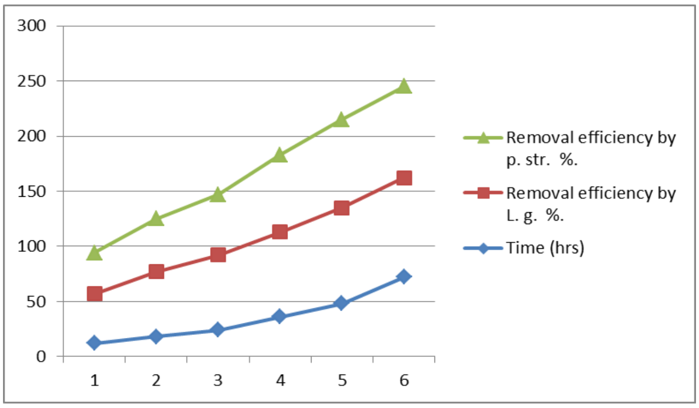

Fig. 5: Removal efficiency (%) of Mn by *Lemna gibba* and *Pistia stratiotes* aquatic plants.

The effi ciency (%+) of Pb removal from water was 70 % at the *Pistia stratiotes* and 52% with *Lemna gibba.*

The ability of *Lemna gibba* plant for removal and absorbing heavy metals from the water unit low concentrations leading to decreasing their concentration in water and became very low then the water could be used again in irrigation of wood trees and gardens this could be confirmed by the findings of Amin *et al*. (2014) where they confirmed the ability of duck weed *Lemna gibba* in absorbing and accumulating the heavy metals in its tissues .Also the duck weed *Lemna minor* L. is potential in removal and accumulation of nutreints from waste water as confirmed by Patel and Kanungo (2010) and Younis *et al.,* (2016).

The ability of Pistia stratiotes plant for removal and absorbing heavy metals from the water unit low concentrations leading to decreasing their concentration in water and became very low then the water could be used again in irrigation of wood trees, gardens and as fertilizers (Nafea; 2016).

The potentiality of aquatic Macrophytes as a low cost bio removal of heavy metals from the Textile waste water were studied by Sudharshi and Chandramali (2018) where they used the aquatic Macrophytes *Eichhorina crassepis, Pistia stratiotes and salvinia molesta* in phytoremediation of Textile waste water and they found that these aquatic Macrophytes had a great power for removal of heavy metals from waste polluted water.

Ugya *et al*. (2016**)** confirmed the use of phytoremediation in remediation of industrial waste water by using Aquatic Macrophytes Eichhorina crassepis , Pistia stratiotes and lemna minor for good remediation and purification of waste industrial water. Rezania *et al.*, 2016; Younis and Nafea 2015) make a review on the ability of aquaticplants for removal of meavy metals from waste water and mention that phytoremediation is a cost effective remediation technology environmental friendly and free floating plants are more efficient in removal of heavy metals from waste water in comparison with emerged and submerged plants.

CONCLUSION

The *Lemna gibba* and *Pistia. stratiotes* are a potential candidate for the removal of phenol compounds and heavy metals (Zn, Cd, Pb , As and Mn) From waste polluted water in a sustainable system and they could be used to treat water containing high concentrations of these elements. Overall, the phytoremediation efficiency of these plants may be improved by periodically harvesting the plant from the site being remediated, to minimize the chances of attaining lethal concentration.

The harvested plant could be ashed and packed in a safe place. The metals accumulated could also be recovered for commercial uses if so desired.

REFERENCES

Amin, H. F.; Ahmed, O. M.; Rasmey, A. M.; Younis, A. M. and Bekhit, A. A. (2018). Effect of technological processing on the safety of Indian mackerel (*Rastrelliger kangurata*) from Suez, Egypt. Egyptian Journal of Aquatic Biology & Fisheries, 22(5): 273- 284.

Amin, M. T.; Alazba, A. A. and Manzoor, U. (2014). Review of Removal of Pollutants from Water/Wastewater Using Different Types of Nanomaterials, Advances in Materials Science and Engineering, 2: 2014- P24.

Asamudo, N. U.; Daba, A. S. and Ezeronye, O. U. (2005). Bioremediation of textile effluent using Phanerochaetechrysosporium, African Journal of Biotechnology, 4(13): 548-1553.

Azin, I. and Katayon, S. (2002). Degradation of phenol in wastewater using anolyte produced from electrochemical generation of brine solution, Global Nest International journal, 4(2-3):139-144.

Bauddh, K.; Singh, K.; Singh, B. and Singh, R.P. (2015) Ricinus communis: a robust plant for bio-energy and phytoremediation of toxic metals from contaminated soil, Ecol. Eng., 84 (2015) 640–652

Bhatia, M., D. and Goyal, A. (2014). Analyzing remediation potential of wastewater through wetland plants: a review, Environ. Prog. Sustain. Energy, 33: 9–27.

Dietz, A.C. and Schnoor, J. L. (2001). Advances in phytoremediation, Environ Health Prospect, V1(9): 163-168.

El-Naggar, M.; Younis, A. M. ; Amin, H. F. ; Ahmed, O. M. and Mosleh, Y. Y. (2019). Assessment of Polycyclic Aromatic Hydrocarbons and Heavy Metals Contamination in the Egyptian Smoked Herring (Clupeaharengus), Polycyclic Aromatic Compounds, DOI: 10.1080/10406638.2018.1555173.

El Zokm, G.M.; Okbah, M.A. and Younis, A. M. (2015). Assessment of Heavy Metals Pollution Using AVS-SEM and Fractionation Techniques in Edku Lagoon Sediments, Mediterranean Sea, Egypt. Journal of Environmental Science and Health, Part A, 50: 1-14.

El-Zokm, G.M.; Okbah, M. A. and Younis, A.M. (2015). Heavy metals fractionation and acid volatile sulfide (AVS) in the Bardawil Lagoon Sediments, Northern Sinai, Egypt. Dev Anal Chem, 2: 1–9

FAO "Food and Agriculture Organization" (2010). 3-Floating aquatic macrophytes – Duckweeds P29

Frieda, O. and Nava, N. (1997). Characteristics of organic removal by PACT simultaneous adsorption and biodegradation, Water Research, 31(3): 391-398.

Grossi, V.; Hirschler, A.; Raphel, D.; Rontani, J. F.; De Leeuw, J. W. and Bertrand, J. C. (1998). Biotransformation pathways of phytol in recent anoxic sediments, Org. Geochem., 29: 845-861.

LeDuc, D. and Terry, N. (2005). Phytoremediation of toxic trace elements in soil and water, J Ind Microbiol Biotechnol, 32: 514–520.

Meagher, R. B. (2000). Phytoremediation of toxic elemental and organic pollutants, Curr Op in Plant Biol, 3: 153-162.

Metcalf and Eddy (2003). Wastewater Engineering "Treatment and Reuse" Mc. GrawHill International Edition, New York.

Muftah, H E, Shaheen A A and Souzan, M. (2009). Biodegradation of phenol by Pseudomonas putida immobilized in polyvinylalcohol (PVA) gel, Journal of hazardous material, 164: 720-725.

Nafea, E. M. A. (2016). Characterization of environmental conditions required for production of livestock and fish fodder from duckweed (*Lemna gibba* L.) Journal of Medtera-nean Ecology, 14 2016.

Nayyef, M, Azeez, and Amal, A. S. (2012). Efficeincy of Lemna minor L in thePhytoremediation of waste water pollutants from Basrah oil refinery, Journal of Applied Biotechnology in Environmental Sanitation, 1(4): 163-172.

Patel, D. K. and Kanungo, V. K. (2010). Phytoremediation Potential of Duckweed (Lemna minor L: A tiny Aquatic plant) in the Removal of Pollutants from Domestic Wastewater with Special Reference to Nutrients, The Bio Sci., 5(3): 355- 358.

Pichiah, S, ; Kannan, A. P. and Prabirkumar, S. (2008). Kinetics ofphenol and m-cresol biodegradation by an indigenous mixed microbial culture isolated from a sewage treatment plant, Journal of Environmental Sciences, 20: 1508-1513.

Rahul, V, Khandare (2015). Phytoremediation of textile dyes and effluents Current scenario and future prospects, Biotechnology Advances, 33(8): 1697–1714.

Renee, I, A., Khalil, N. M. and Roushdie, M. I, (2015). Monitoring of pollution in Egyptian Red Sea, Egyptian Journal of Petroleum, 24(1): 59-70.

Rontani, J.F.; Bonin, P. C. and Volkman, J .K. (1999). Production of wax esters during aerobic growth of marine bacteria on isoprenoid compounds, Appl. Environ. Microbiol, 65: 221-230.

Ruey, S. J.; Wen, C. H. and Ya, H. H. (2009). Treatment of phenol in synthetic saline wastewater by solvent extraction and two phase membrane biodegradation, Journal of Hazardous Materials, 164(1): 46-52.

Rezaniaa, S.; Shazwin, b. ; Taibb, M.; Fadhil Md Dina, M.; Farrah Aini Dahalanc, b, and Kamyaba, H. (2016). Comprehensive review on phytotechnology: Heavy metals removal by diverse aquatic plants species from wastewater. Journal of Hazardous Materials, 318 (2016) 587–599.

Said, T. O.; Farag, R. S.; Younis, A. M. and Shreadah, M. A. (2006). Organotin Species in Fish and Bivalves Samples Collected from the Egyptian Mediterranean Coast of Alexandria, Egypt. Bulletin of Environmental Contamination and Toxicology, 77: 451- 458.

Sally, N. J. (2012). Extraction of Phenol from Industrial Water Using Different Solvents, Research Journal of Chemical Sciences, 2(4): 1-12.

Saleh,S., Younis, A., Ali, R. and Elkady. E. (2019). Phenol removal from aqueous solution using amino modified silica nanoparticles. Korean J. Chem. Eng., 36(4): 529-539.

Shafaqat A.; Daud, M. K.; Ihsan, Z.; Zaheer, E.; Ahsan Riaz, M.; Malik, A.; Hussain, A.; Rizwan, M; Zia-ur-Rehman, M. and Jin Zhu, S. (2018). Potential of Duckweed (Lemna minor) for the Phytoremediation of Landfill Leachate. journal of Chemistry, Volume 2018.

Sharma, S.; Singh, B. and V. K. (2015). Manchanda, Phytoremediation: role of terrestrial plants and aquatic macrophytes in the remediation of radionuclides and heavy metal contaminated soil and water, Environ. Sci. Pollut. Res., 22: 946–962.

Shreadah, M. A.; Said, T. O.; Younis, A. M.; Farag, R. S. (2006). Speciation of Organotin Compounds in Sediments of Semi-Closed Areas along the Mediterranean Coast of Alexandria," Chemistry and Ecology, 22 (5): 395-404.

Soliman, N. F.; Younis, A. M. and Elkady, E. M. (2019). An insight into fractionation, toxicity, mobility and source apportionment of metals in sediments from El Temsah Lake, Suez Canal. Chemosphere, 222:165-174.

Soliman, N. F.; Younis, A. M. ; Elkady, E. M. and Mohamedein, L. I. (2018). Geochemical associations, risk assessment, and source identification of selected metals in sediments from the Suez Gulf, Egypt. Hum Ecol Risk Assess, 1-17. DOI: 10.1080/10807039.2018.1451301

Stanton, B.; Eaton, J.; Johnson, J.; Rice, D.; Schuette, B. and Moser, B. (2002). Hybrid poplar in the pacific northwest the effects of market-driven management, J. For., 100: 28–33.

Sudharshi, W. and Chandramali, K. J. (2018). Potential of Aquatic Macrophytes *Eichhornia crassipes*, *Pistia stratiotes*, in treatment of Textile waste water Journal of Water Security, Vol. 4.

Ugya, A. Y. 1. ; Imam, T. S. I. and Tahir, S. M. (2016). The role of phytoremediation in remediation of industrial wastes. World J. Pharmaceutical Research, 5: 12.

Vijayaraghavan, K. R. (2015). Balasubramanian, is biosorption suitable for decontamination of metal-bearing wastewaters? A critical review on the state-of-the-art of biosorption processes and future directions, J. Environ. Manage., 160: 283–296.

Wang, Y. T. (1992). Effect of chemical oxidation on anaerobic biodegradation of model phenolic compounds, Water Environment Research, 64(3): 268-273.

Younis A. M., Elsayed M. A. Nafea, Yahia Y. I. Mosleh and Mohamed S. Hefnawy (2016). Low cost biosorbent (*Lemna gibba* L.) for the removal of phenol from aqueous media Journal of Mediterranean Ecology, 14 .

Younis, A. M. (2018). Environmental Impacts on Egyptian Delta Lakes' Biodiversity: A Case Study on Lake Burullus. A.M. Negm *et al*. (eds.), Egyptian Coastal Lakes and Wetlands: Part II-Climate Change and Biodiversity, Hdb Env Chem, DOI 10.1007/698_2017_120.

Younis, A. M. and Nafea, E. M. A. (2015). Heavy Metals and Nutritional Composition of Some Naturally Growing Aquatic Macrophytes of Northern Egyptian Lakes. J. Biodiversity and Envir. Sci. (JBES), 6: 16-23.

Younis, A.M. and Nafea, S.M. (2012). Impact of Environmental Conditions on the Biodiversity of Mediterranean Sea Lagoon, Burullus Protected Area, Egypt. World Applied Sciences Journal, 19: 1423-1430.

Younis, A. M., El-Zokm, G. M. and Okbah, M. A. (2014). Spatial Variation of Acid-Volatile Sulfide and Simultaneously Extracted Metals in Egyptian Mediterranean Sea Lagoon Sediments. Environmental Monitoring and Assessment, 186: 3567-3579.

Younis, A. M., Soliman Y. A.; Elkady E. M. and El-Naggar M. H. (2018). Assessment of polycyclic aromatic hydrocarbons in surface sediments and some fish species from the Gulf of Suez, Egypt. Egyptian Journal of Aquatic Biology & Fisheries, 22(4): 49- 59.