Green Plants and Nature: Natural Wastewater Treatment Plants

Amir Hossein Hamidian

***Abstract*—** Our nature and natural resources are the real teachers of our engineers. In wastewater engineering, one of the most sophisticated methods of wastewater treatment is the tertiary treatment or biological treatment. Methods such as biodisc, biofiltration and activated sludge use tiny organisms to remove organic and inorganic pollutants from wastewater. Other higher levels of organisms, such as plants, have been also used for polluted water purification. In phytoremediation, with its different methods of purification, plants are used to remove pollutants from wastewater. Other organisms such as algae, shellfish and fish can be also applied for wastewater treatment. In this paper, the results of the research on using organisms to remove pollutants such as heavy metals from different kinds of wastewaters are presented. The researches were either based on the measurements on nature, or pilot studies in the laboratory. We used water hyacinth to remove nitrate, phosphate, BOD_5 and COD from municipal wastewater. The common reed and some other aquatic plants were used for the purification of wastewaters discharged from oil industries and gas purification factories. The concentrations of metals were measured in tissues of organisms exposed to polluted waters in nature; organisms such as algae, fish, shellfish, plants and worms. High concentrations of metals were observed in the organism tissues, suggesting they are favorable for wastewater treatment. The results suggest that a combination of methods would be the most appropriate and in most cases economic method for the treatment of different types of wastewater.

***Keywords*—**metals, nutrient, phytoremediation, wastewater

I. INTRODUCTION

THE earth and its ecosystems have been changed dramatically after the entrance of the human species into the cycle. One of the major problems, which has been accelerated especially after the industrial revolution is environmental pollution, among them water pollution. Water as one of the major resources for the development of human societies, has being used and then polluted by human bodies. While there are limited water resources which are available and appropriate for different kinds of development, the increase in the population and decrease in the quality of available water has magnified the magnificent of the problem. In particular, significant concentrations of heavy and hazardous metals are released into water bodies, mostly through industrial wastewaters and these can cause numerous environmental problems [1]. The adverse effects associated with metals can include the alteration of the structure of crops and functions of organisms and their effects can be observed in food chains. High metal concentrations can be toxic to some organisms and metal imbalance in plant tissues can be critical for different kinds of diseases [2 and therein]. On the other hands, the increase in the concentration of nutrients such as nitrogen and phosphorus in water causes eutrophication of surface water resources [3].

The capability of some plant species in to absorb and accumulate high levels of metals and nutrients in their organs can be used for the purification of polluted environments; in a process known as phytoremediation. Aquatic macrophytes exhibit a high potential for heavy metal phytoremediation due to their rapid growth and high biomass [4].

Among the different possible methods of wastewater treatment, phytoremediation is an environmental friendly and economic method. Phytoremidation is an emerging technology using plants for the removal of heavy metals from contaminated areas [5] that could offer a purifier technology with less cost and less technology requirements [6]. Plants, which are good accumulators; have high tolerance to high contaminant concentrations; and have the ability tosurvive and produce biomass can be proper for the phytoremidation [7]. Aquatic macrophyte can have high capability of metal accumulation depends on the biological (such as species, age) and non biological (salinity, pH, temperature, season) factors [8]; and can act as biological barrier to prevent heavy metals distribution in environment [9].

Different plant species have been used for the phytoremediation of pollutants such as heavy metals and nutrients from polluted water. The results of the effects of phytoremediation in the removal of metals and nutrients from industrial and municipal wastewater are presented in this paper. Furthermore, the concentrations of metals in different abiotic and biotic parts of the ecosystems will be presented, especially in the surrounding environment of two dams, which are in the vicinity of a mining area. This is to reveal the bioconcentration factor of the organisms for metals and metalloids, discussing their ability for bioremediation.

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II. MATERIALS AND METHODS

In the research either the samples were collected from the environment and their metal concentrations were measured; or the wastewater samples were collected and in the laboratory were treated using plant species. In the laboratory, concentrations of metals or nutrients were measured in plants and wastewater before and after treatment period. For the measurement of metals in environmental samples, all plastic and glassware were washed with soap and hot water, rinsed three times with distilled water and stored in a solution of 10% HNO_3 and HCl for 2 weeks; and rinsed three times with dionized water afterwards. The plant tissues were dried in an oven for 48 to 72 hours in 110°C and ashed in a furnace in 450°C for 48 hours. Wet and dry weights of the samples were recorded. Ashed samples were digested using concentrated Analar grade HNO_3 (Merck, Germany) and diluted by %1 HNO3. The concentrations of the metals were measured using an ICP-OES instrument. (PerkinElmer, USA). For certifying the analysis method, for each 20 root samples 2 blanks and 2 homogenised and spiked samples were analyzed under the same laboratory conditions. The detection limits, blanks (for controlling the contamination) and the recoveries were measured and calculated.

Statistical analyses were performed using SPSS 16. The normalization of data was checked using Kolmogorov Smirnov test. ANOVA and Duncan tests were used to compare the average concentrations of the metals in different treatment times (0, 2, 6 and 10 days). Pearson correlation coefficients were used for determination of any correlation between concentrations of the metals in the common reed tissues.

The difference of metal concentration between sediment and plant was analyzed by t-test. Linear correlations between metals were tested through the Pearson's r coefficient. The analysis of regression was also conducted. All statistical analysis carried out using the SPSS Version 19.0 for windows statistical software package.

Metal concentrations in samples were reported in mg/kg based on the dry weight. Bioconcentration factor (BCF) was calculated by,

BCF = C*P.australis*/ Csediment

Where C*P.australis is* the metals concentration in the plant, Csediment is concentration metals in sediment.

A section of one of the treatment pilots is shown in Fig.1.

Fig. 1 The pilot of using water hyacinth for the removal of N&P from Shiraz municipal wastewater

III. RESULTS

In one research, the potential of common reed was investigated for the phytoremediation of Cd, Pb and V in wastewater from the BidBoland gas refinery in Iran. Common reed is one of the aquatic macrophyte is used in phytoremidation studies. Properties such as worldwide spread in different environmental condition [8,10], fast growth and high biomass production makes it possible to use this plant for eliminate heavy metals from contaminated water, soil and sediment economically [9]. The results of the study were illustrated in TABLE I and Fig. 2 to 4.

TABLE I
MEANS AND STANDARD DEVIATIONS OF CD, PB AND V CONCENTRATIONS IN COMMON REED TISSUES IN DIFFERENT RETENTION TIMES; N=36

E	0		2		6		10	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cd	0.61	0.25	1.53	0.84	1.95	0.74	1.21	0.59
Pb	1.78	1.20	13.25	5.03	14.28	7.46	9.38	3.96
V	11.54	6.39	29.24	8.47	40.83	7.65	24.75	7.18

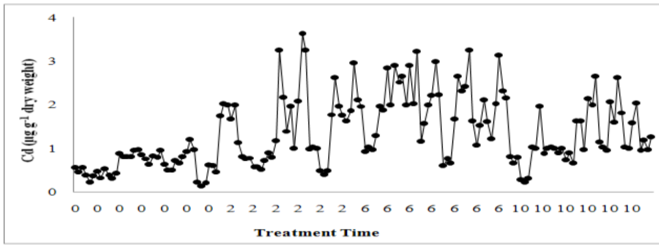

Fig. 2 Cd Concentrations in Common reed samples (µg g^{-1} dry weight); n=36

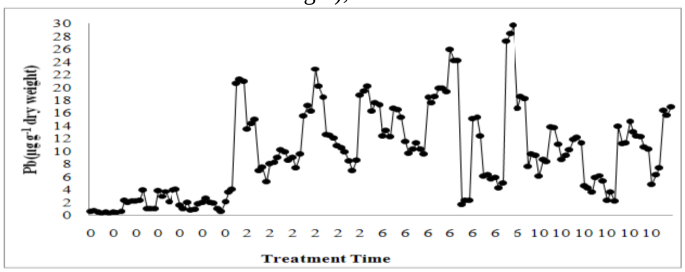

Fig. 3 Pb Concentrations in Common reed samples (µg g-1 dry weight); n=36

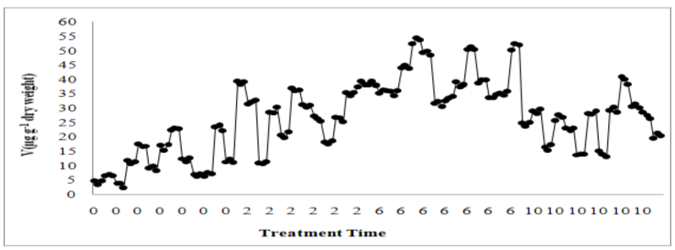

Fig. 4 V Concentrations in Common reed samples (µg g-1 dry weight); n=36

In another research; cadmium, copper and arsenic concentrations were measured in sediment and roots of common reed (Phragmites australis) samples collected from the vicinity of two dams in East Azarbayjan, Iran. Metal concentrations were higher in Phragmites australis than from the sediment. The BCF of metals were ranged from 1.2 to 2.7; and As concentrations were higher than Cd and Cu concentrations.

Heavy metal concentrations in sediments and plants of the dams are shown in Fig. 5 to 7. Metal concentrations decreased in order As> Cu> Cd in sediment and plant of the dams. Concentrations of metals in Khodaafarim dam were higher than those of Sattarkhan dam. The BCF values of As, Cd and Cu was 2.78, 2.38 and 1.84, respectively. Significant differences in accumulation of metals were observed between sediment and plant ($P < 0.001$). Positive linear correlations were found between heavy metal concentrations in sediments ($P < 0.01$). No correlation was observed between the concentrations of metals in sediment and plant samples.

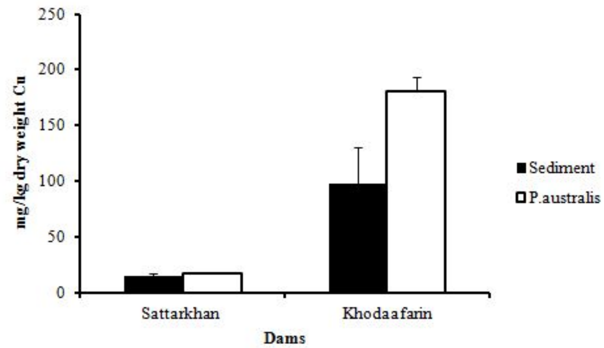

Fig. 5 Cu concentrations in sediment and plant (common reed) samples (mg kg-1 dry weight); n=60

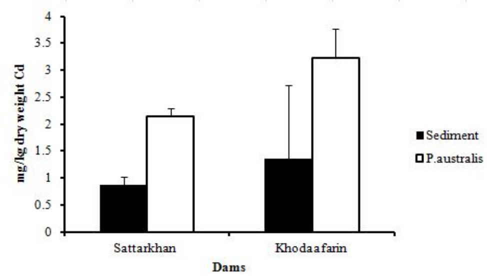

Fig. 6 Cd concentrations in sediment and plant (common reed) samples (mg kg-1 dry weight); n=60

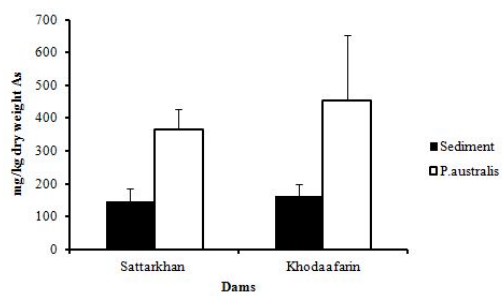

Fig. 7 As concentrations in sediment and plant (common reed) samples (mg kg^{-1} dry weight); n=60

The reductions of nitrogen, phosphorus, BOD_5 and COD using water hyacinth (*Eichhornia crassipes*) were also measured in Shiraz municipal wastewater, which the data of N and P in this paper are presented in Fig. 8 and 9.

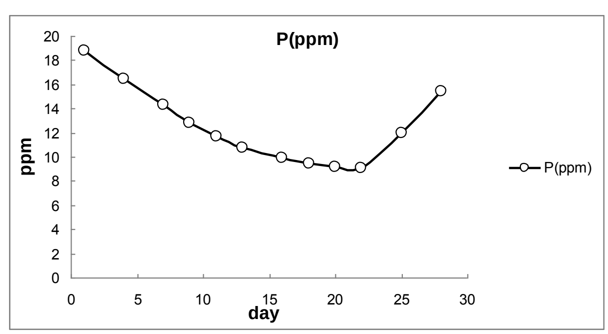

Fig. 8 P concentrations (ppm) in wastewater treated by water hyacinth during 28 days; n=30

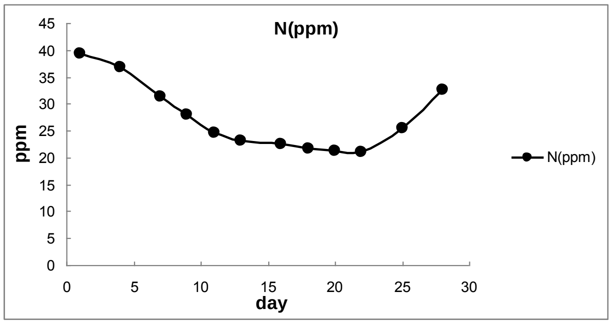

Fig. 9 N concentrations (ppm) in wastewater treated by water hyacinth during 28 days; n=30

IV. DISCUSSION

THE first study showed that a treatment time of 6 days is the best for the removal of Cd, Pb and V from wastewater using common reed. This is in agreement with a treatment time of 7 days that was found for *Typha domingensis*[11]. After 10 days of treatment, the concentrations of metals in plant tissues were decreased, which might be due to metal release and that uptake rate might have reached to higher levels than the tolerant threshold of the plant. A retention time of 12 days as the proper time for the removal of nutrient and metals was previously suggested [12].

Balancing heavy metals in plant organs is very important and necessary; and affect their physiology and consequently their growth. In this study, significant correlations ($P< 0.01$) were found between the concentrations of Pb and Cd; Pb and V; and Cd and V in plant tissues with correlation coefficients of 0.40, 0.51 and 0.41, respectively. The interaction between metals is one of the major causes of their toxicity. For example, it was reported that uptake of Mn by plant can be reduced in presence of Cd [13]. When plants uptake metals to the concentrations higher than their tolerance or toxic threshold, there might be interactions between the metals; and their metabolic functions might be interfered. For instance, excessive uptake of Zn by plant might affect Fe metabolic function, and even in normal concentrations of Fe, the plant might suffer from chlorosis [14].

In the second research in the dams the concentrations of metals decreased in the order of As> Cu> Cd. Concentrations of arsenic in two dams were very high. This suggests that *Phragmites australis* could be useful for environmental health monitoring and phytoremidiation objectives. High BCFs of the metals showed their bioavailability for biota of the region. Reed can be defined as an As tolerant plant. It might be a proper bioaccumulator and biomonitor of Cd, Cu and As in freshwater in natural conditions

The focus of the third research was on the removal of nutrients from wastewater. Nitrate and phosphate are among the most important pollutants that their discharge into the water resources causes eutrophication and degradation of water quality. Different methods used for the removal of nitrate and phosphate from wastewater are usually expensive. Aquatic plants need nitrate and phosphate for their growth, and consequently they absorb these complexes. The main purpose of this study was to investigate the efficiency of water hyacinth in removing nitrate and phosphate from Shiraz municipal wastewater. The reduction rates of BOD_5 and COD were also measured and calculated. Samples of wastewater were treated using water hyacinth during a 28-day period. The percentages of the removal were 69.48%, 72.52%, 68.07% and 62.31% for nitrate, phosphate, BOD_5 and COD, respectively. This indicates the high potential of water hyacinth for treatment of Shiraz municipal wastewater.

V. CONCLUSION

Phytoremediation is a natural method for wastewater treatment with numerous benefits such as its easy processing, energy saving, environmental conservation; e.g. improving local biodiversity, enhancing the quality of local weather, less emission of CO_2, using natural resources of energy (such as solar radiation and wind) and soil, plants and animals in wastewater treatment, control of soil erosion and increasing available water supply [15]. Due to our observed uptake rates of Pb, V and Cd by common reed plant during wastewater treatment (compared to other studies) and because it is a native plant species in the area (due to appropriate climate conditions), and because this plant species has a very high growth rate in this region, it is suggested to use common reed for the removal of heavy metals from this specific wastewater. However, in similar situations when common reed is regarded to be used for the treatment of wastewater, the source and type of pollutants should be investigated and a pilot study is needed before any further investment. High concentrations of metals in plants collected from a polluted area suggested that these plants can bioaccumulate metals from the environment, which in turn suggests that they are proper species for phytoremediation. Similar results were observed in our laboratory and field observations for species such as shellfish and fish (are not presented in this paper), which suggests they can also be used for bioremediation and biomonitoring purposes. Phytoremediation of nutrients from wastewater using native plant species can be also regarded as a cheaper option. Besides, easy administration, low technology requirements and low energy consumption compared to conventional filtration methods make it a proper way for the removal of nitrate and phosphate from polluted waters.

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