Depuration of tannery effluent by phytoremediation and infiltration percolation under arid climate

Mandi L., Tiglyene S., Jaouad A.

in

El Moujabber M. (ed.), Mandi L. (ed.), Trisorio-Liuzzi G. (ed.), Martín I. (ed.), Rabi A. (ed.), Rodríguez R. (ed.).
Technological perspectives for rational use of water resources in the Mediterranean region

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 88

2009
pages 199-205

Depuration of tannery effluent by phytoremediation and infiltration percolation under arid climate

Laila Mandi[1], Souad Tiglyene[1] and Abderrahim Jaouad[2]

[1] University Cadi ayyad, Faculty of Sciences Semlalia, Department of Biology, Morocco
[2] University Cadi ayyad, Faculty of Sciences Semlalia, Department of Chemistry, Morocco

Abstract. The specific aims of this work were to investigate the potential of *Phragmites australis* to remove chromium from diluted tannery wastewater (50%) in comparison to unplanted soil, under arid climate conditions. Dilution is made by well water. The other aim was to study the treatment of raw tannery effluent by infiltration percolation system. The results indicated that during 13 months of experiment, total chromium undergoes an overall removal of 99% for the two plots, which provides limpid purified water. The results of the distribution of total chromium in the various strata of constructed reed bed indicated a significant accumulation of total Cr reaching 80% in the surface strata for two systems. Furthermore, the results showed that Cr could migrate also towards deeper levels of the soil. After 13 months of experiment, the soil accumulated high content of chromium: 94% and 98% for the planted and unplanted systems, respectively. However, 5% of Cr accumulated in Phragmites australis. The results also showed that Phragmites australis accumulated 1690 mg/kg dry matter of chromium in the roots. The study of the treatment of raw tannery wastewater by infiltration percolation system showed that, over seven months of experiment, the mean elimination rate for total chromium was 98%. The treatment of tannery effluent by reed bed combined with infiltration percolation system is a clean approach from an ecological point of view and constitutes a viable economic alternative in comparison to the purely chemical approaches for the treatment of tannery effluents.

Keywords. Tannery – Chromium – *Phragmites australis* – Infiltration – Percolation – Treatment – Arid climate.

Epuration des effluents de tannerie par phytoremédiation et infiltration-percolation en climat aride

Résumé. Le but spécifique de ce travail est d'évaluer la capacité potentielle de *Phragmites australis* à éliminer le chrome des eaux usées de tannerie diluées (50%) par rapport au sol nu en climat aride. La dilution est réalisée en utilisant de l'eau de puits. Parallèlement, on illustre le traitement des effluents de tannerie bruts par infiltration-percolation. Les résultats indiquent que, sur les 13 mois d'expérimentation, le chrome total est éliminé à 99% dans les deux parcelles, ce qui permet de produire de l'eau épurée et limpide. A partir des données sur la distribution du chrome total dans les différentes strates de la roselière artificielle, on met en évidence une accumulation totale de Cr égale à 80% dans les strates superficielles des deux systèmes. En plus, les résultats montrent que le chrome pourrait migrer vers des couches plus profondes du sol. Au bout de 13 mois, le sol affiche une teneur élevée en chrome : 94% et 98% pour les systèmes avec ou sans lit de *phragmites*, respectivement. Toutefois, 5% de Cr est accumulé dans *Phragmites australis*. Egalement, les résultats indiquent que *Phragmites australis* accumule 1690 mg/kg de matière sèche de chrome dans les racines. L'étude du traitement des eaux usées de tannerie brutes par infiltration-percolation confirme que sur sept mois d'expérience, le taux moyen d'élimination pour le chrome total s'élève à 98%. Le traitement des effluents de tannerie en utilisant la phragmite associée à l'infiltration-percolation représente une approche propre sur le plan écologique et une alternative économiquement viable par rapport aux approches purement chimiques pour les effluents de tannerie.

Mots-clés. *Tannerie – Chrome – Phragmites australis – Infiltration – Percolation – Traitement – Climat aride.*

I – Introduction

The term phytoremediation (phyto = plant and remediation = correct evil) is relatively new, coined in 1991. Basic information for what is now called phytoremediation comes from a variety of research areas including constructed wetlands, oil spills, and agricultural plant accumulation of heavy metals (Mulligan *et al.,* 2001; EPA, 2000 ; Lutts *et al.,* 2004). Phytoremediation applications can be classified based on the mechanisms involved. Such mechanisms include extraction of contaminants from soil or groundwater; concentration of contaminants in plant tissue; degradation of contaminants by various biotic or abiotic processes; volatilization or transpiration of volatile contaminants from plants to the air; immobilization of contaminants in the root zone; hydraulic control of contaminated groundwater and control of runoff, erosion, and infiltration by vegetative covers (Ralinda and Miller, 1996 ; Schwartz *et al.,* 1999 ; EPA, 2000).

The leather tannery industry is well known for having a severe negative impact on the environment. In this industry animal hides are transformed into leather in a succession of various complex stages, consuming high quantities of water and using large amounts of such chemicals as lime, sodium chloride and chromium salts. The most dangerous problem of the pollution generated by the tannery industries in Marrakech is the discharge of heavy metal into the environment, mainly the chromium (≈40 tons/year) which is able to disturb the biological breakdown of the effluents (Scandiaconsult International, 1999). Tannery wastewater flows directly into the receiving medium without any preliminary treatment.

The objective of this study is to investigate the potential of a helophytic plant *Phragmites australis* (Cav.) Trin ex Steudel to remove chromium from concentrated tannery effluent in comparison to unplanted soil, under arid climate conditions on the one hand. On the other hand, to study the treatment of raw tannery effluent by infiltration percolation system.

II – Methods

The experiment was conducted from August 2002 to August 2003. Six plots were filled to 15 cm in depth and 60 cm with respectively gravel and soil. Three plots were planted with young shoots of *Phragmites australis* (36 stems/m^2) taken from local and natural reed stand. Three unplanted plots served for checking (figure 1).

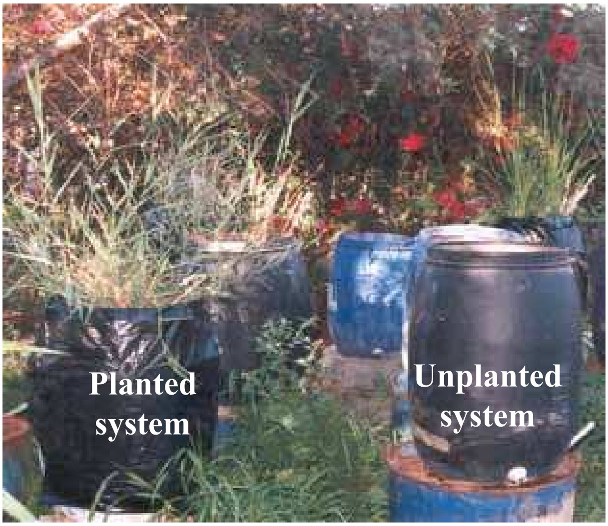

Figure 1. Experimental setup.

The soil (88% sand) used for the study is coming from the Tensift river (Marrakech). Wastewater used originates from an industrial tannery in the Marrakech region. The experimental plots were alimented by tannery wastewater, 3 times a week (10 litres per day). The water flowed vertically through substratum. The measure of the hydrogen potential (pH) is determined with a pH-meter type ORION. Electrical conductivity (EC) is measured using a standard conductimeter Tacussel (AFNOR, 1983). The total chromium is measured by spectrophotometer of atomic absorption (RODIER, 1984).

1. Physico-chemical characteristics of soil

The analysis in table 1 shows that the substrate used is rich in organic matter. Its electrical conductivity is high. It is an alkaline basic soil (table 1).

Table 1. Physico-chemical characteristics of soil.

Parameters	Contents
pH	8.63
% O.M	4.7
Cl (mg/g)	71
Zn (mg/kg)	12.11
Pb (mg/kg)	1.2
Cr (mg/kg)	0.6

2. Physico-chemical characteristics of the influent

Table 2 summarizes the mean characteristics of tannery effluent. This latter has an acid pH due to the utilization of H_2SO_4 in the operation of preparation for tanning. The effluent has a very high electrical conductivity (EC), reflecting the wealth in salts of these waters and the high concentration of chloride (20.6±4.3 g/l). This chloride concentration largely exceeds the maximum limits recommended by WHO (1989) guidelines (700 mg/l).

Table 2. Physico-chemical characteristics of the influent (number of samples: 20).

pH	3.08±1.16
EC (ms/cm)	118±50
BOD_5 (mg/l)	45±2.45
COD (mg/l)	2500±13
Cl^- (g/l)	20,6±1.3
Cr (mg/l)	1230.5±123.2

The tanning wastewater contained an important amount of total chromium (1230.5 mg/l) exceeding by far the maximum limit recommended by WHO (1989) guidelines (2 mg/l).

III – Results and discussion

1. Treatment of tannery effluent by phytoremediation

-Temporal changes in total chromium at the inlet and outlet of the two systems

Figure (2) represents the temporal evolution of the total chromium concentration at the inflow and outflow of (PP) and (NPP) systems. The total chromium concentration at the inflow varies from 534 mg/l to 1000 mg/l with an average concentration of 780±196 mg/l.

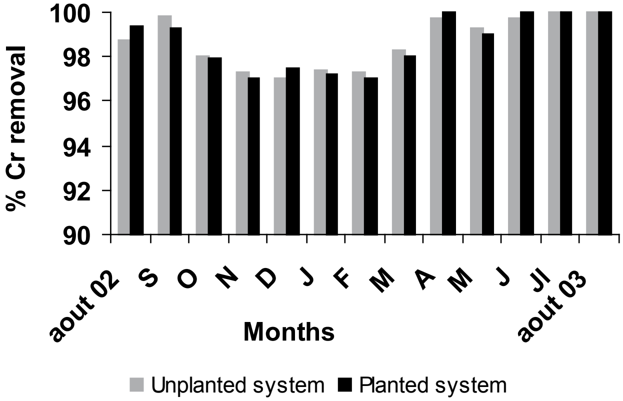

Figure 2. Total chromium percent removal of the planted and unplanted systems.

At the outflow, the total Cr concentration varies from 2.2 mg/l to 3 mg/l with an average concentration of 2±0.5 mg/l for (PP) system and from 2.5 mg/l to 4 mg/l with an average value of 2.4±1.3 mg/l for (NPP) system.

The total chromium contents at the outflow of the two systems are lower than the maximum limit recommended by WHO guidelines (2mg/l). The total chromium undergoes an overall removal of 99 % for the two plots, which provides limpid purified water (Tiglyene *et al.*, 2005). In the systems of treatment by macrophytes, several processes are responsible for the elimination of chromium. They include a mixture of physicochemical, biological and microbiological reactions with an aerobic and anaerobic procedure for wetland sites (Eger, 1994).

-Total chromium in different soil horizons of the planted system

The analytical results revealed that there is a significant total Cr 80% accumulation in the surface horizon (0-5 cm) for planted (figure 3a) and unplanted systems (figure 3b) (Tiglyene *et al.,* 2008a). Results also show that Cr could migrate also towards deeper levels of the soil. Moreover, several authors have reported these results (Legret *et al.,* 1988 ; Selim *et al.,* 1989 ; Kafka and Kuras, 1994).

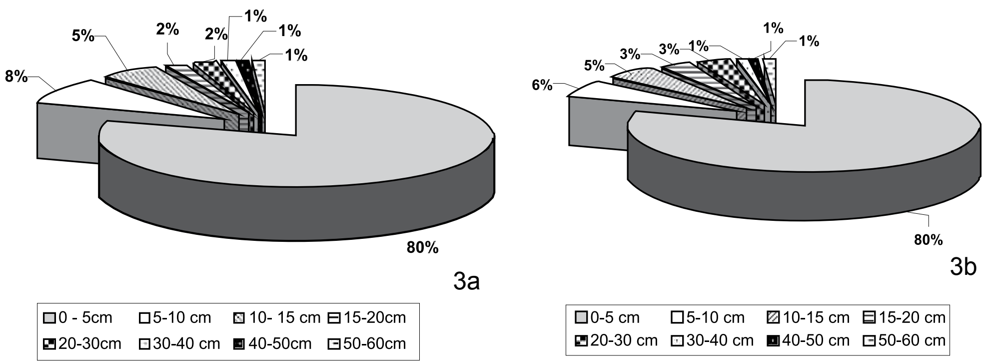

Figure 3. Total chromium percent in different soil horizons of the planted and unplanted system

-Total chromium content in Phragmites australis

Table (3) summarizes that all parts of *Phragmites australis* contain chromium. Indeed, the Cr content presents a statistically significant difference ($p<0.01$) between leaves and roots of the plant. This result was to be expected because of the close contact between the root surface and the sediment-water interface. On the other hand, *Phragmites australis* released from the root exudates, which can involve to complex the chromium. Indeed, many authors confirmed this observation (Aldrich *et al.,* 2003; Howe *et al.,* 2003).

Table 3. Total chromium content in Phragmites australis

	Leaves	Rhizomes	Roots
[Cr] g/Kg(dry weight)	0.25±0.5	0.35±1.5	6±0.5

-Mass balance of Cr for the planted system

Furthermore, after 13 months of experiment, the soil accumulates high content of chromium (94%) and 5% of Cr accumulated in *Phragmites australis.* The presence of plant ensures a sufficient porosity for the percolation of water for treatment, which makes it possible to treat a more important volume of wastewater and to reduce the required surface area by treated capita.

2. Treatment of tannery effluent by infiltration percolation

Figure 4 represents the temporal evolution of the total chromium concentration at the inflow and outflow of system. The total chromium concentration at the inflow varies from 1009 mg/l to 1345 mg/l with an average concentration of 1230.5±123.2 mg/l. At the outflow, the total chromium concentration varies from 3.4 mg/l to 5 mg/l with an average concentration of 3±0.5 mg/l.

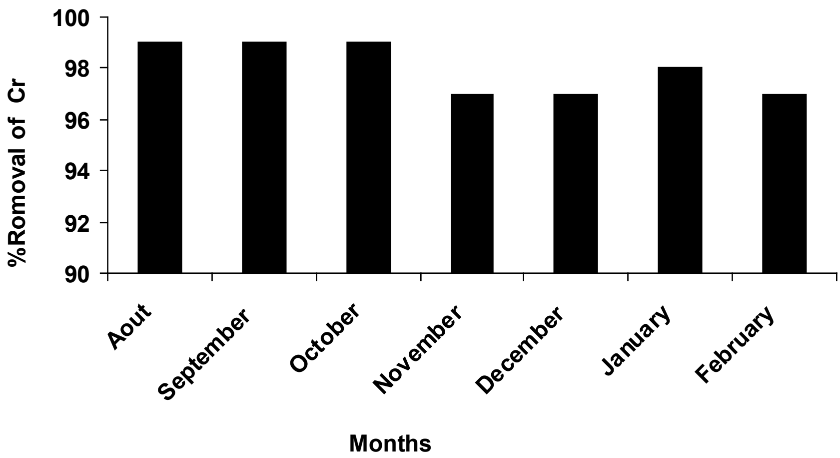

Figure 4. Temporal changes in total chromium at the inlet and outlet of the system.

The total chromium contents at the outflow of the two systems are lower than the maximum limit recommended by WHO guidelines (2 mg/l). The total chromium undergoes an overall removal of 98% for the pilot, which provides limpid purified water (Tiglyene *et al.*, 2008b). In the system of treatment by infiltration-percolation, chromium was retained by immobilization on the level of the soil via mechanisms such as adsorption on the level of the sites of exchange, fixing to the organic matter, incorporation in the structure of the ground and by precipitation in the form of insoluble compounds (Comber and Gardner, 2003).

IV – Conclusions

The objective of this study was, on the one hand, to evaluate the potentialities of a helophytic plant, *Phragmites australis,* to purify the diluted tannery wastewater (50%), and to compare them to those of an unplanted soil, under arid climate conditions; on the other hand, to study the treatment of raw tannery effluent by infiltration percolation system.

The results indicated that the total chromium undergoes an overall removal of about 99% for the two plots, which provide purified water. The results indicated that there was a significant accumulation of total Cr reaching 80% in the surface strata for the planted system. *Phragmites australis* accumulated significantly high amount of Cr in the roots.

After 13 months of experiment, the soil accumulates high content of chromium, 94% and 5% of Cr accumulated in *Phragmites australis.* Furthermore, the presence of plant ensures a porosity sufficient for the percolation of water in the treatment. Over seven months of experiment, the study of the treatment of raw tannery wastewater by infiltration percolation system showed that the mean elimination rate for total chromium was 98%.

This work shows clearly that the treatment of tannery effluent by reed bed combined with infiltration percolation system could be the depuration system alternative for raw tannery wastewater in comparison to the purely chemical approaches for the treatment of tannery effluents.

References

Aldrich M.V., Gardea-Torresdey, J.L., Peralta-Videa J.R. and Parsons J.G., 2003. Uptake and reduction of Cr(VI) to Cr(III) by mesquite (*Prospis* spp.): chromate-plant interaction in hydroponics and solid media studied using XAS, *Environ. Sci. Technol.* **37** (2003), pp. 1859–1864

AFNOR, 1983. *Recueil de normes Françaises : eau, méthodes d'essai,* 2ème ed, Paris.

Comber S. and Gardner M., 2003. Chromium redox in natural waters. *J Environ Monit.,*5:410-413.

Eger P., 1994. Wetland treatment for trace metal removal from mine drainage: the importance of aerobic and anaerobic processes. *Wat. Sci. Tech.,* 29(4), 249-256.

EPA (Environmental Protection Agency), 1996. Method 3060A: Alkaline digestion for hexavalent chromium. Soil Screening Guidance: technical background document. 9355.4-17A. DC: Office of Emergency and Remedial Response. Washington. EPA/600/8-91/011B.

Howe J.A., Loeppert R.H. Derose V.J., Hunter D.B. and Bertsch P.M., 2003. Localisation and speciation of chromium in subterranean clover using XRF, XANES, and EPR spectroscopy. *Environ. Sci. Technol.,* 37(18), 4091-7.

K**afka Z. and Kuras M., 1994.** Analysis of heavy metals in soils contaminated from different sources. *Fresenius Environ. Bull.,* 3:407-412.

Legret M., Divet L. and Juste C., 1988. Movement and speciation of heavy metals in a soil amended with sewage sludge containing large amount of Cd and Ni. *Wat. Res.,* 22(8):953-959.

Lutts S., Lefèvre I., Delpéré C., Kivits S., Dechamps C., Robledo A. and Correal E., 2004. Heavy metal accumulation by the halophyte species Mediterranean saltbush. *J. Environ. Qual.,* 33:178-181.

Mulligan C.N., Yong R.N. and Gibbs B.F., 2001. Remediation technologies for metal-contaminated soils and groundwater: an evaluation. *Engineering Geology,* 60:193-207.

Ralinda R. and Miller P.G., 1996. Phytoremediation. Ground-Water Remediation Technologies Analysis Center, TO-96-03, *Pittsburgh PA,* 1-26.

Rodier J., 1984. L'analyse de l'eau : eaux naturelles, eaux résiduaires, eau de mer, 7ème ed : Dunod. Bordas. Paris. Sludge process. J. *Water Poll. Control. Fed*., 53:1323-1332.

Scandiaconsult International, 1999. Etude de la réduction des rejets industriels sur la qualité des eaux des bassins d'Oum Er Bia et de Tensift, Maroc. *Rapport du Ministère du Commerce de l'Industrie et de l'Artisanat, Division de la protection de l'Environnement,* 18 p.

Schwartz C., Morel J.L., Saumier S., Whiting S.N. and Baker A.J.M., 1999. Root development of thezinc-hyperaccumulator plant *Thlaspi caerulescens* as affected by metal origin, content and localization in soil. *Plant and Soil,* 208:103-115.

Selim H.M., Amacher M.C. and Iskandar I.K., 1989. Modelling the transport of chromium (VI) in soil columns. *Soil. Sci. Soc.,* 53:996-1004.

Tiglyene S., Mandi L. and Jaouad A., 2005. Enlèvement du chrome par infiltration verticale sur lits de *Phragmites australis* (Cav.) Steudel. Revue Sciences de l'Eau, 18(2):117-198.

Tiglyene S., Jaouad A. and Mandi L., 2008a. Mobilité et spéciation du chrome dans un système à *Phragmites australis* de traitement des eaux usées de tannerie. *Revue Sciences de l'Eau*. 21(1):1-16.

Tiglyene S., Jaouad A. and Mandi L., 2008b. Traitement du rejet du tannage par infiltration percolation : Elimination et spéciation du chrome dans le sol. *Revue Environmental Technology,* 29(6) :1-12.

WHO, 1989. L'utilisation des eaux usées en agriculture et aquaculture : Recommandations à visées sanitaires. Rapport. Technique, 788, 82.