PHYTO-PURIFICATION OF POLLUTED WATER BY USING POACEAE CASE OF LAKE REGHAIA

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Abstract

This work has two parts as a first part, we are interested in eliminating the heavy metals by two plants that belong to the family of Poaceae (Arundo donax and Phragmites australis). It is the treatment via planted filters. Secondly, the comparison has been made of the tolerance and accumulation by these two plants. A purification system is set up which consists of two vats: one located in height and the second in low to receive the water that flows from the first vat, in which were planted macrophytes. The results obtained, show a significant elimination of the heavy metals on the plants filter of Phragmites australis compared to Arundo donax after a stay of 30 days. The yields of eliminations are respectively 84.45% and 75.00% for Phragmites australis and Arundo donax. The results of this study also showed a significant reduction in COD, BODs, Conductivity, Phosphate and Nitrates. The greatest accumulation of heavy metals is produced in the roots followed by leaves for both plants. The calculated values of biological transfer coefficient (BTC) and bioconcentration factor (BCF) showed that Phragmites australis and Arundo donax are effectively acting as species of phytoremediation for some heavy metals.

Key words: Phyto-purification, Poaceae, Heavy metals, Reghaia lake.

Introduction

Loaded liquid wastes with heavy metals are extremely dangerous as the water enters into the composition of any entity; living or not, and, thus, constitutes a matrix that can transport these polluted objects everywhere. Also, it is clear that this industry is responsible for almost all heavy metals discharged into water. Hence, there is a need to minimize the concentration of metals in the waste water. Achieving such an objective has become possible thanks to special techniques for the elimination and recovery of these metals in water (Crine et al., 2008 and Peter et al., 2008).

To overcome the main limitations of the methods that are currently available in the decontamination strategies, researches have been, for years, directed towards the use of the plants (Ellis et al., 1994). A number of plants from humid environment have been found, more and more vigorously in different sites, contaminated with the metals indicating that these species have a certain degree of tolerance to the metals. Phragmites australis (common Reed) and Arundo donax are rhizonated plants. They belong to Poaceae family with cosmopolitan distribution (Massacci et al., 2001). The natural properties of these plants are exploited in the field of phytoremediation, which is a set of techniques allowing removing the soil, and purifying waste water by using plants (Hall et al., 2003 and Callahans et al., 2006). They usually grow in wet areas with many habitats, they can also flourish and become a dominant species. These plants can resist adverse edaphic conditions, including the presence of toxic heavy metals, such as Zn, Pb, Cu and Cd (Schierup et al., 1981). Arundo donax and Phragmites australis have useful characteristic for the on to phytoremediation of wetlands (Massacci et al., 2001). Numerous phytoremediation studies aim to increase the collection of metals by plants from polluted soils (Yang et al., 2008). The use of constructed wetland (artificial swamps) to treat waste water is a widely accepted ecological engineering approach throughout the world (Brix, 1993 & Mitsch et al., 2004, Vymazal, 2009 and Memon et al., 2017).

The objective of this study is to eliminate the heavy metals using two plants, which belong to the family of Poacées (Arundo donax and Phragmites australis). It is the treatment by means of planted filters the choice of waters of Reghaia Lake due to its pollution by industrial waste water, domestic and agricultural irrigation of effluents from the valley of Reghaia and valley of El Abiar, a comparative evaluation of tolerance and accumulation of the heavy metals, by these two plants has been realized.

Material and Methods

Description of the purification system: In the present study, we have built a standard purification filter system, the latter consisting of two vats connected to each other by a pipe, in which are implanted the young plants of macrophytes. The filter is 65 cm long and 40 cm wide, with three layers of gravel of different diameter and thickness. The lining of the floors is divided into three layers. Each tank has a top mounted at the base, in the zones the humid air was supplied through air diffusing pipes located 20 cm below the surface of the vats (Fig. 1).

Preparation of biological materials: Two species of the Poaceae family are used: Phragmites australis and Arundo donax, they are macrophytes which belong to the group of helophytes and they are particularly characterized by their very active root systems and able to withstand adverse conditions. The plant species were extracted from their initial places at a medium stage of their growth during in December 2016, and then the plants were left in the water for 15 days, until the remarkable development of the roots, then implanted in the filters. The plants were implanted in six plastic pots, three pots are planted with young stems of Phragmites australis, and the other three are planted with young...
stems of Arundo donax. The monitoring of their adaptation has been meticulously followed, first irrigated with tap water not to change the quality of the water, then they were irrigated by the water of Lake Reghaia with watering every three days.

Fig. 1. Purification system by rushes.

**Plant sampling and heavy metal analysis:** Rapid rinsing of the plants with water to remove dust, then cut it in pieces and separate the parts of the plants (roots, leaves and stems). Plant samples were put in clean plastic bags and labeled carefully with permanent marker. All the collected plant samples were placed in newspapers for the absorption of excessive water and put in oven at 105°C for 5 h. The dried plant samples were ground with a pestle and mortar so that their size was 2mm after grinding.

For the analysis of the metals, 0.5 g of sample of leaves, stems and roots were taken. 5 ml of nitric acid (65%) and 1 ml of perchloric acid (70-72%) were added (Wang et al., 2003). Digest with gently boiling on a hot plate for 10 minutes. After cooling, add 25 ml of distilled water, then filtered into a 50 ml flask and filter paper. Volume was adjusted. This extract is used for the determination of heavy metals (Pauwels et al., 1992). These steps are used for all the ashes of (leaves, stems and roots) of two tested plants. The physicochemical analyzes were carried out in the research laboratory of M'Hamed Bougara-Boumerdes University and the ONA of Djelfa, Algeria.

Monitoring physico-chemical parameters and the pollution parameters (BOD5 and COD) was carried out according to the technique of Rodier (1996). All prepared samples were analyzed for heavy metals by flame atomic absorption spectrophotometer Model ICP Perkin Elmer AA400 in Baraki ONA laboratory, Algeria.

**Determination of chlorophyll of helophytes:** The extraction of chlorophyll realized according to the method of Holm-Hansen (1965). One g leaves of plant samples cut into small pieces and ground in a mortar with 20 ml of 80% acetone and a pinch of calcium carbonate (CaCO3). The assay was realized by taking 3 ml of the solution in the spectrometer tube. The reading is done at two wavelengths 645 nm and 663 nm.

**Phytoremediation:** Phytoremediation was defined by two biological methods. The biological transfer coefficient (BTC) has been defined as the concentration of a metal accumulated in the shoot on it in the root (Khan et al., 2013). BTC = [Metal] shoot / [Metal] root.

The bio-concentration factor (BCF) was the concentration of heavy metals accumulated in plant roots divided by the concentration of the same metal obtained in their respective soil (Khan et al., 2013). BCF = [Metal] root / [Metal] soil. (Khan et al., 2013).

**Results and Discussions**

The result of ANOVA described the significance level of these parameters among treatments. The xenobiotics in the water used decrease after two purifications with the reeds.

**Physico-chemical parameter changes in lake water before and after biofiltration:** The pH values are illustrated in Fig. 2(a), a slight decrease in the pH after phytotpurification, in general the pH value of the water filtered by Phragmites australis are invariably greater than that in the water filtered by Arundo donax with mean pH value was (6.6, 7.5. respectively). The pH of 7.5 was the most ideal for successful implementation of a water phytoremediation system and optimal basin performance. (Irami et al., 2012). pH plays a very important role in the absorption and accumulation of trace elements because the more acidic the pH of the milieu, the more vegetation accumulates. Thus, according to Bryan (1979), the pH has a direct action on the availability of metal ions in the marine environment and thus on the uptake by the organisms while modifying the form of the metal and by acting on the physiology of the organisms.

Fig. 2(b) showed the variations in the conductivity of the water in the treatment vats, a very apparent reduction in the electric conductivity of water is noted with a clear predominance of Phragmites australis plant compared to Arundo donax the conductivity decreases by about 60% for the first plant and 15% for the second plant. Its reduction after passing through both vats can be explained according to Coulibaly et al., (2008), by a retention of salt in the filter the solid mass. A similar result is obtained by Finlayson & Chick (1983) for a Typha Latifolia plantation, and oppose those obtained by Coulibaly et al., (2008). This difference in results is linked to the type of plant used (Amaranthus hybridus, Corchorus oliterius).

**Phytopurification, in general the pH value of the water filtered by Phragmites australis and Arundo donax.** A significant decrease of phosphate after passing through the filters planted (Fig. 2(d)) with a clear predominance of Phragmites australis (99.81%) compared to Arundo donax (51.12%).

The results of ANOVA showed highly significant increases p<0.001 of O2 dissolved in water filtered by Phragmites australis and Arundo donax to that of the control with a yield of 93.24% and 90.32% respectively (Fig. 2 (e)). Plants can contribute to purification processes by absorbing nutrients and trace elements that allow the release of oxygen (Kadlec et al., 2000).
Fig. 2. Physico-chemical parameter changes in lake water before and after biofiltration by *Phragmites australis* and *Arundo donax* in the water of Reghaia lake.

- **pH**
  - Effet courant: \( F(2, 6) = 25.265, p = 0.0120 \)
  - Vertical bars represent confidence intervals at 0.95

- **Conductivity (ms/cm)**
  - Effet courant: \( F(2, 6) = 3487.3, p = 0.0000 \)
  - Vertical bars represent confidence intervals at 0.95

- **NO₃**
  - Effet courant: \( F(2, 6) = 63.377, p = 0.0000 \)
  - Vertical bars represent confidence intervals at 0.95

- **PO₄**
  - Effet courant: \( F(2, 6) = 4.8921, p = 0.005493 \)
  - Vertical bars represent confidence intervals at 0.95

- **O₂ dissolved**
  - Effet courant: \( F(2, 6) = 36.422, p = 0.00044 \)
  - Vertical bars represent confidence intervals at 0.95
**Variation of pollution indicators:** Fig. 3 described the results of ANOVA of Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) and Biological Oxygen Demand (BOD₅). COD and BOD₅ values were significantly decreased in the waters filtered by *Phragmites australis* and *Arundo donax* by comparison with the controls (***) P = 0.0044, 0.0005 respectively), with a yield of 67.74% and of 56.34% for COD and 72.97% and 66.34% for BOD₅ (Fig. 3(a, b)). According to Polprasert & Khatiwada, (1998) the removal of organic matter in artificial wetlands is based on a symbiotic relationship between plants and bacteria in which the bacteria use the oxygen provided by the plants during photosynthesis to degrade organic carbon. These results have been confirmed by (Garcia et al., 2005) who explain that this decrease is ensured by the good functioning of the system. The plants, through photosynthesis, thus favored the aerobic phenomena, and the structure of the filtering mass chosen made it possible to ensure the easy diffusion of the atmospheric oxygen, and consequently the dissolved oxygen in the water; which is a very important factor for good effluent purification. Indeed the significant decrease in BOD₅ and COD shows that the system is well oxygenated.

TSS values showed the a very significant reduction p<0.015 of the contents of the suspended material after purification. The difference is respectively 98.73% and 98.66% for *Phragmites australis* et *Arundo donax*. The decrease in the concentration of Total Suspended Solids in the different filtrates would be due to physical filtration that retains coarse surface materials and the finest, either by blocking between the pores, by an interception and a fixation on the grain or chemical interactions of Van Der Waals type (Chachuat, 1998).

**Variations of chlorophyll a and b:** The results of ANOVA showed a highly significant decrease p<0.001 of the chlorophyll a content in *Phragmites australis* and *Arundo donax* irrigated by lake water compared with those in the control irrigated by drinking water or the mean values of chlorophyll a and b in *Phragmites australis* irrigated by lake water was found to be 18.74 μg.g⁻¹and 11. μg.g⁻¹ respectively, with the control is 20.14 μg.g⁻¹ and 57.14 μg.g⁻¹ respectively, concerning *Arundo donax* irrigated by lake water, the chlorophyll a, b rate was 15.45 μg.g⁻¹, 15.24 μg.g⁻¹ respectively, and 24.17 μg.g⁻¹ and 37.45 μg.g⁻¹ of the control.

*Phragmites australis* appear to be more sensitive to the pollution that is due to the heavy metals present at the water level of the lake.

The decline in chlorophyll content in plants exposed to heavy metal stress is believed to be due to inhibition of important enzymes, such as –amineovulinc acid dehydratase (ALA-dehydratase) and protochlorophyllide reductase associated with chlorophyll biosynthesis, so the loss in chlorophyll content can consequently lead to disruption of photosynthetic system (Dhir et al., 2004).
Heavy metals: The results of one-factor ANOVA showed that a very significant difference with a probability of p<0.001 between the different concentrations of heavy metals before and after biofiltration stay by helophyte Phragmites australis and Arundo donax in the water of the Reghaia lake for all samples except the Cadmium (Cd).

The values for iron were strongly accumulated at the leaf level for Phragmites australis with 450 mg .g⁻¹ by dry matter (DM) and 340 mg .g⁻¹ DM for Arundo donax roots (Fig. 1). The concentration of Cu and of Zn in the leaves and of P. australis variation in the leaves from 10 mg .g⁻¹ DM to 5.1 mg .g⁻¹ DM in roots, for A.donax the accumulation of Cu was in the roots with a mean of 11.6 mg .g⁻¹ DM followed by the leaves with 11.7 mg .g⁻¹ DM. These results show that Zinc (Zn) uptake is highly important in the aerial part, especially in the Arundo donax leaves with 40 mg .g⁻¹, compared with those obtained in the Phragmites australis level. The largest fraction of Zn retained by the plant was found in the "treated" part of the limb but this element seems more mobile than copper. In contrast to the latter, there is virtually no retention of zinc in cuticular waxes resulting in a high circulation of this metal in the plant and a high migration rate (Chamel et al., 1979).From Fig. 5(f) it is found that nickel (Ni) is highly accumulated in leaves for A. donax with an amount of 2.6 mg .g⁻¹ DM and 1.7 mg .g⁻¹ DM for the roots. For example, nickel accumulation and tolerance in the genus Alyssum appear to be mainly due to increased synthesis of histidine (Kramer et al., 1996).

P. australis accumulates Lead (Pb) at stems with an average of 2.4 mg .g⁻¹ DM, however a low accumulation in roots and leaves found and varies between 1.3 and 1.49 mg .g⁻¹ of. Lead accumulation is strongly important in the aerial part of P. australis with 2.7 mg .g⁻¹ DM for stem and 2.2 mg .g⁻¹ DM for leaves, whereas accumulation at A. donax in roots and leaves with 3.6 mg .g⁻¹ DM (Fig. 5(e)). The accumulation of Cobalt (Co) (p<0.001) was highly important in the aerial part for both plants, this accumulation was localized at the Phragmites australis stems with a rate of 1.3 mg.g⁻¹ DM and at the of leaves for Arundo donax with a rate of 0.94 mg .g⁻¹ of DM (Fig. 5(f)). The Arundo donax showed the same behavior as Phragmites australis was a better accumulation of silver (Ag) in the aerial parts at the leaf level with a rate which varies between 0.27 and 0.32 mg .g⁻¹ of DM, while for the roots the accumulation ranges from 0.24 to 0.29 mg .g⁻¹ DM for both plants.

Phytoremediation of heavy metals is a profitable green technology; there are more benefits when it comes to using native plants with natural growth. (Irani et al., 2012) Phytofiltration is the use of plants to absorb or adsorb pollutants, especially metals contained in aquatic environments (Prasad, 2004). The roots of the plants will absorb, precipitate and concentrate the metals present in the water (Dushenko & Kapulnik, 2000). Mechanisms involved in biosorption include chemisorption, complementation, ion exchange, micro-prefication, surface adsorption (Gardea et al., 2004).

The presence of the filters ensures a high efficiency for the retention of the heavy metals with the following classifications Fe> Cu> Zn> and Pb minimal absorption for Ni, Co, Cd and Ag for Phragmites australis. (Fig. 6) On the other hand, for Arundo donax we found a following classification Fe> Cu> Zn> Ni>Pb> Ag and minimal absorption for Co and Cd (Fig. 7).

Phytoremediation: In this study, none of the plant species showed metal concentrations> 1000 mg .kg⁻¹ in shoots. None of them are hyper accumulators. However, the ability of these plants to tolerate and accumulate heavy metals may be useful for phytostabilization. BTC and BCF can be used to estimate a potential for phytoremediation purposes (Nazir et al., 2013).

Table 1 evaluates the BTC and BCF results of heavy metal concentration in Phragmites australis and Arundo donax. The only species with BCF, BTC greater than 1 have the potential process of remediation of metals. Considering the BCF, Phragmites australis has the characteristic of hyper accumulator for Fe, Zn, Cu, Cd, Pb, Ni and Ag, while that Arundo donax has the characteristic of hyper accumulator for Cd, Co, Ni and Ag. Some plants are able to uptake heavy metals by their roots or absorb them by their leaves and stems (Alloway et al., 1995), as Arundo donax.

Accumulative plants are characterized by an ability to efficiently transport heavy metals from the roots to the leaves, whereas in some plants the tendency to remain in the subterranean parts (roots) is greater (McGrath et al., 2002) as Phragmites australis. The phytoextraction process usually requires the translocation of heavy metals to the parts of the plants, TF values showed a significant percent of root Ni, Ag, Zn and Cu translocated to the shoot was 63%, 46.2%, 11.4% and 9.38% respectively in Phragmites australis. On the other hand Arundo donax has a better Ni accumulation (2.92) with a significant percent of translocation of Ni, Cu, Ag Zn and, Pb (60.46%, 43.63%, 40.24%, 31.94%, 17.92% respectively). Microorganisms can play a dual role in the mobilization of metals. They can affect their bioavailability by fixing the elements and releasing them by decomposing organic matter (Herman et al., 1995).
Fig. 5. Variations of heavy metals before and after biofiltration by the helophyte *Phragmites australis* and *Arundo donax* in the water of the Reghaia lake.


Wilk's Lambda =0.0000, F(8, 6)=37666, p=0.0000
Vertical bars represent confidence intervals at 0.95
- Fe mg/g Ph  Fe mg/g W Ph
- Fe mg/g Ar  Fe mg/g W Ar

Wilk's Lambda =0.0001, F(8, 6)=230.09, p=0.0000
Vertical bars represent confidence intervals at 0.95
- Zn mg/g W Ar  Zn mg/g Ar
- Zn mg/g W Ph  Zn mg/g Ph

Wilk's Lambda =0.0008, F(8, 6)=84.089, p=0.0001
Vertical bars represent confidence intervals at 0.95
- Co mg/g W Ar  Co mg/g Ar
- Co mg/g W Ph  Co mg/g Ph

Wilk's Lambda =0.0000, F(8, 6)=61.1111, p=0.0003
Vertical bars represent confidence intervals at 0.95
- Cu mg/g Ph  Cu mg/g W Ph
- Cu mg/g Ar  Cu mg/g W Ar

Wilk's Lambda =0.0000, F(8, 6)=12007, p=0.0000
Vertical bars represent confidence intervals at 0.95
- Ni mg/g W Ar  Ni mg/g Ar
- Ni mg/g W Ph  Ni mg/g Ph

Wilk's Lambda =0.0000, F(8, 6)=656.24, p=0.0000
Vertical bars represent confidence intervals at 0.95
- Ag mg/g W Ar  Ag mg/g Ar
- Ag mg/g W Ph  Ag mg/g Ph

Wilk's Lambda =0.0000, F(8, 6)=323.54, p=0.0000
Vertical bars represent confidence intervals at 0.95
- Pb mg/g W Ar  Pb mg/g Ar
- Pb mg/g W Ph  Pb mg/g Ph
Table 1. BCF and BTC of *Phragmites australis* and *Arundo donax*.

<table>
<thead>
<tr>
<th>Metals</th>
<th>Control</th>
<th><em>Phragmites australis</em></th>
<th><em>Arundo donax</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>BTC</td>
<td>8,17</td>
<td>0,54</td>
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<tr>
<td>Fe</td>
<td>BCF</td>
<td>8,87</td>
<td>37,62</td>
</tr>
<tr>
<td>Zn</td>
<td>BTC</td>
<td>2,28</td>
<td>0,99</td>
</tr>
<tr>
<td>Zn</td>
<td>BCF</td>
<td>11,4</td>
<td>31,94</td>
</tr>
<tr>
<td>Cu</td>
<td>BTC</td>
<td>2,52</td>
<td>0,825</td>
</tr>
<tr>
<td>Cu</td>
<td>BCF</td>
<td>9,83</td>
<td>43,63</td>
</tr>
<tr>
<td>Cd</td>
<td>BTC</td>
<td>2,33</td>
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<td>Cd</td>
<td>BCF</td>
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</tr>
<tr>
<td>Co</td>
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<tr>
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<td>BCF</td>
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<td>Ag</td>
<td>BCF</td>
<td>46,2</td>
<td>40,24</td>
</tr>
</tbody>
</table>

Note: BCF: Bioconcentration Factor, BTC: Biological Transfer Coefficient

**Conclusion**

*Phragmites australis* is known for their accumulating power, they can respond to pollution in a sensitive and effective way, hence the importance of their use in phytoremediation. The results of this study showed that *Arundo donax* will also have an accumulation capacity, such as *Phragmites australis*, which would reduce water pollution in the Reghaia Lake, especially those loaded with heavy metals. This study showed that *Arundo donax* has the highest ability to accumulate Fe, Zn, Cu, Cd, Pb, Ni and Ag via its roots, while *Phragmites australis* has the hyperaccumulator characteristic for Cd, Co, Ni and Ag. The results indicate that plant species differ greatly in their ability to accumulate heavy metals in roots and shoots. This hyperaccumulation is probably the cause of their high tolerance at high levels of pollution. The treatment with filters planted macrophytes seems to be an alternative effective and well enough adapted to the waters of the lake with a pollutant load variable. This study will help make a best choice for restoration of lake water; this technology is inexpensive and easy to use.

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**References**


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