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Feasibility of Treatment of the Waters of a Wadi Charged in Iron by Filters Planted of Macrophytes (*Phragmites australis*)

[1]Semadi Faten, [2]Blake Gerard, [1]Berrebbah Houria and [1]Alioua Amel
[1]Department of Biology, Faculty of the Sciences, University Badji Mokhtar, Annaba
[2]Department of Biochemistry and Biology Applied, ESIGEC-73376, Building B, Bourget of Lake-Chambéry, France

Abstract: Problem statement: The context is summarized by the presence of important Steel manufactory close to the wadi Meboudja and its effluents rejected into the wadi which contaminate the water used for irrigation by the local farmer. **Approach:** The goal is to determine the usefulness of Macrophytes (*Phragmites australis*) to filter some specific industrial effluents (Fe, Cu, Zn, Pb, Mn and Cr) present into water of wadi Meboudja. The use of Reeds (*Phragmites australis*) can be considered as a biologic and an economic solution to minimize the concentration of some industrial effluent, especially Iron which is highlighted in this article. An experimental device was built, and considered as pilot, formed of three basins plus reservoir. We use the water of Wadi to irrigate the “*Phragmites australis*” which are initially appropriated from Oubaiira Lake in a natural medium. Water and Reeds samples are selected for analyses. **Results:** Iron is found in important concentration compared to the other Elements Metal Traces (ETM). Such a variation seems to be directly related to the rate of industrial production, fluctuations of the climatic factors, and the capacities of assimilation of the plants crop. It is essentially concentrated into the roots of Reeds compared to stems and leafs. For example, in one repetition we found difference between the exit sample and the entry one in basin-1of (60-23=) 37 mg g^{-1} into roots. **Conclusion:** Plantation of Reeds (*Phragmites australis*) seems a natural solution to reduce elements metal traces, in particularly Iron, into water of wadi Meboudja. Other analysis on the garden products of local farmers should be conducted in order to quantify possible hazards on the health of consumers.

Key words: *Phragmites australis*, traces elements metallic (Fe, Cu, Zn, Pb, Cr and Min.) filters planted of reeds, phytotoxicité, feasibility of treatment, pilot, Meboudja wadi

INTRODUCTION

The Annaba region is especially submitted to an industrial pollution. The problem of pollution of this region didn't begin indeed to become troubling that from 1980, when the economic crisis pushed some industrial units to sacrifice the environmental criteria. Annaba big urban center, meeting today of serious domestic, agricultural and industrial dismissal problems to the level of the Meboudja wadi bordering to the Seybouse wadi that constitutes a representative geographical site. Known before like a place of artisanal fishing and bathing pleasure place, currently the Seybouse wadi is deserted because of the industrial pollution. It is the presence of water that generated the anarchical installation of industrial zones without worry of the preservation of the environment. Some industrial units reject in the Meboudja wadi of big quantities of mineral and organic oils, of the metallic traces elements, of the residues with sulfur, nitrogen, fluorine, of detergents, of the yeasts and other biologic pollutants. The fact that the agriculturists of the "pont-boucher" region irrigate their flora and fauna from this river, justify our contribution to the survey of the quality of the waters of this wadi.

We specify the objectives of our present survey in what follows:

- To make a synthesis of fundamental knowledge of the deterioration processes, immobilization, stabilization of Fe
- Consequences of knowledge on the possibilities of real exploitation of these treatment systems for these specific waters of sewer, with so possible an economic approach of the creation and the exploitation of this type of treatment

Corresponding Author: Semadi Faten, Department of Biology, Faculty of the Sciences, University Badji Mokhtar, Annaba

MATERIALS AND METHODS

Realization of the pilot station of purification by planted bed: An experimental station has been achieved in order to find out the retention capacities of the "ETM" present into Meboudja wadi water and to evaluate the toxic effects in this case on the plant populations "*Phragmites australis*" and its development.

Characteristics of the constituent elements of the station:

The compartment substratum (gravel): The compartment "substratum" constitutes an important element of any purifier system for understanding the filtration mechanisms and the transfer of different effluent of pollutants. The substratum is also the support of macrophytes growth that must be developed in order to do the purification in synergy with the microorganisms.

The compartment macrophytes: It is the essential biologic component of our pilot station and the support of survey of the processes of bio-accumulation of the different metallic traces elements by the plants.

As we signaled it in the objectives of the survey, the choice of the main biologic component that is *Phragmites australis* has been imposed by its presence on the site and also by the easiness of provision and the scientific results of the scientific literature.

The macrophytes belong to the grouping of the helophytes and are especially characterized by their systems of roots and very active and capable rhizomatous to resist very difficult conditions even when the aerial part of the plant is dried.

The development of new stems intervenes between the spring and the autumn (April-October).

The *Phragmites* can even support of the frost periods whose action is positive on the mud dehydration and therefore on the plug remove (frost phenomenon-thaw-retraction); Esser[1].

The reeds are capable to absorb and to concentrate important quantities of some pollutants and contribute also to the purification of waters. Their development is strong in lentils zones of the rivers.

Installation: It is about a system, hydraulic working, to dominant oblique: That means mixed (vertical horizontal). This choice of out-flow has been made because it corresponds to a system where one can let it without a hard control. Besides, our means and the pilot situation didn't permit a permanently use of pumps. One note that the means rate of distribution is of the order of 150 L h^{-1} (measured average during all the survey time) (Fig. 1 and 2).

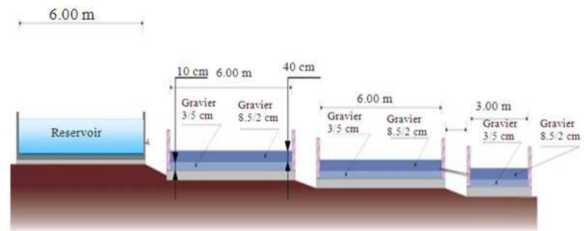

Fig. 1: Purification station plane «pont Boucher»

Fig. 2: The 3 successive basins (from upstream to downstream) after the reference basin

Plantation: We placed two layers of gravel in each of the three basins; the first layer of gravel of a 10 cm thickness, (grain size of gravel: 25/40 mm (3-5 cm)), the second layer of gravel of a 40 cm thickness and gravel had a size of 15/25 mm (0.5-2 cm).

These two layers of gravel have been chosen in order to provoke a better drainage and a good filtration of water as well as the evacuation.

The reeds come from a (healthy) clean place, without contamination, uncontaminated by the pollution of Annaba. So, the *Phragmiteses australis* has been appropriated from the Oubaïra Lake (El-Kala, near the Tunisian borders).

The *Phragmiteses australis* has been appropriated in a natural medium; every foot includes an intact rhizome and three knots consecutive at least. The plants have been chosen with the same size; the roots are cut to equal lengths, then the stems are planted by hand in gravel (substratum) for being in a good state before irrigating them. During the plantation of the reeds, the distance between a rhizome and another is of 10 cm to avoid interference between the reeds.

These basins are irrigated, rightly after the transplantation, by water coming from the well (that is at 100 m from the basins) during one week. After that, it is irrigated by water from the wadi with the help of a pump that raises the water of the wadi to send it in the main basin. This basin has a faucet, from where it distributes water on the three basins (Fig. 1). In this basin, the sedimentation rate remains weak, so it acts as reference basin.

Working: The three basins, aligned in series, receive the same quantity of water (2000l/basin) therefore the same contents in traces metallic elements, except the evaporated part in hot period.

In these three basins, waters arrive from the surface at the entry and circulate in vertical percolation (oblique), which means through the substratum (gravel). The high grain size of the substratum permits the passage of effluent in vertical sense dominantly; since waters are drained to the bottom of the basin. One can confirm therefore that it is rather about a mixed system (vertical - horizontal). Note that, once water arrives to the third basin is going to join the wadi meboudja thereafter.

The method used is of Schierup[1], Soltz[2] (modified). So, we took 1 g of plant or sediment + 75 mL of water Entertain (HNO_3 69%+HCL 37%): 49.5 mL of HCL + 24.75 mL of HNO_3; we lets the excerpt during 2 h to the ebb. We filters the solution with a porous funnel N°2, then we adjusts 100 mL of $HNO_3.10^{-2}$ N.

RESULTS

Calculation of the stay time: The stay time of the different elements metallic traces into the basins are calculated like follows:

If we note the volume of the basin: V_b = S (surface of the basin) × HS (height of the basin) = 3 m (width of the basin) × 6 m (length of the basin) × 0.8 m (height of the basin 80 cm). So:

$$V_b = 18\ m^2 \times 0.8\ m = 14.4\ m^3$$

With assumption on the emptiness: 30% of emptiness on the global gravel basin. These 30% have been verified on a reduced sample of gravel.

The useful volume of the basin becomes:

$$V_b = 14.4\ m^3 \times (1-0.3) = 14.4 \times 0.7 = 10.08\ m^3$$

Δt = 4.2 min are the necessary time that was necessary to us to recover a volume of 10 liters in order to calculate the debit (flow rate) of our basin as follows:

$$Q = 10L/4.2\ mn = 3.40\ m^3\ day^{-1}$$

The time of stay is calculated like follows:

$$T_s = \frac{V_b}{Q} = \frac{10.08}{3.40} = 2.96 \approx 3\ \text{days}$$

This theoretical calculation confirms us the following result by tracer's method: NaCl

The hydraulic conductivity measurement has been calculated as follows:

We introduced a quantity of NaCl (100 g L^{-1}) by servers on the basins and we took all half-hours the value of the conductivity while knowing that there is a homogeneous distribution of the effluent.

This tracing curve (Fig. 3) gives us the hydraulic conductivity of the saturated material (m day^{-1}). It is of order of 100 m day^{-1} in our case (gravel).

The inherent difficulties to the measures of tracing, on the site, should be taken into account.

The results of the tracing show a flattened curve, but show also that the contact time is close to the theoretical stay time nevertheless.

Dosage of iron in the water: Figure 4 shows us the variation of different metals in the water of the three basins according to different values of pH. We notice that the iron quantities are superior to the concentrations of the other metals (Cu, Zn, Pb, Cr).

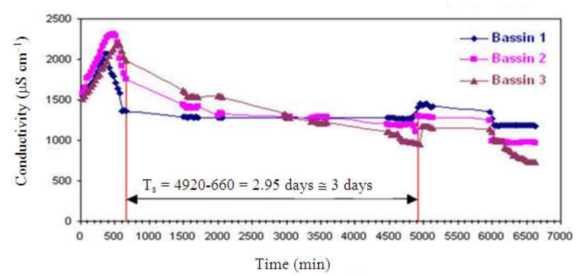

Fig. 3: Evolution of the conductivity into the three basins

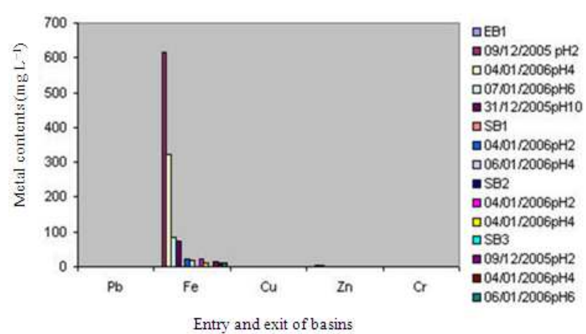

Fig. 4: Variation of different metals into the water of the three basins according to the pH

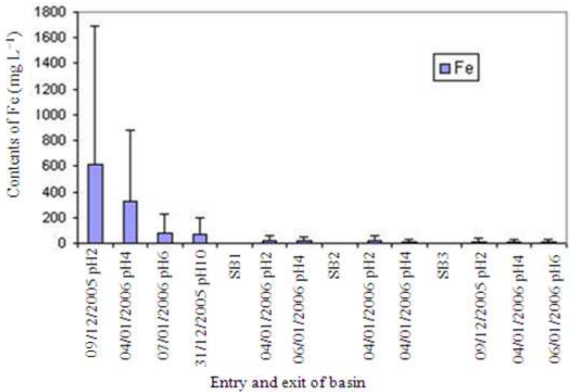

Fig. 5: Variation of the contents of iron into the water of the three basins according to the pH

The water samples have been treated by addition of acid to different pH in order to simulate the possibilities of re-dropping in different conditions of the middle of the basins, during the decomposition of the present organic matter.

We note also that more the middle is acidic more the contents made of soluble metals increase notably iron of pH 2 at the basin 1 entry. Out that, at the exit of the basins 1, 2 and 3, the contents made of iron clearly decrease and this thanks to the *Phragmiteses australis* that plays a bio-accumulate role in relation to its roots system.

The comparison of the concentration of iron between the water of the wadi and the one of the basins (Fig. 5) show that some meaningful differences exist in the time, which is related to the important and changing quantities poured by "Mital Steel" in the Meboudja wadi during our period of experimentation.

The variation in the space is also meaningful because the concentration of iron was very high at the entry of the basins compared to the exit of the basins under the effect of the precipitations, filtration and the accumulative action led by the *Phragmiteses*.

Dosage of iron at *Phragmites australis*: Figure 6, we notice a light accumulation of the contents of iron in the helophytes at the entry compared to the exit into the aerial part of the *Phragmites* (T+F: Stem + leaf), while comparing of course with the witness. With regard to the rhizome, this last didn't accumulate iron, on the other hand the roots accumulated an important contents of iron notably in the first repetition (November 2005) which vary from 300 mg g^{-1} at the entry of the basin 2-400 mg g^{-1} at the exit of the basin 2 and from 23 mg g^{-1} at the entry of the basin 1 until 60 mg g^{-1} at the exit of the first basin for the second repetition (April 2006).

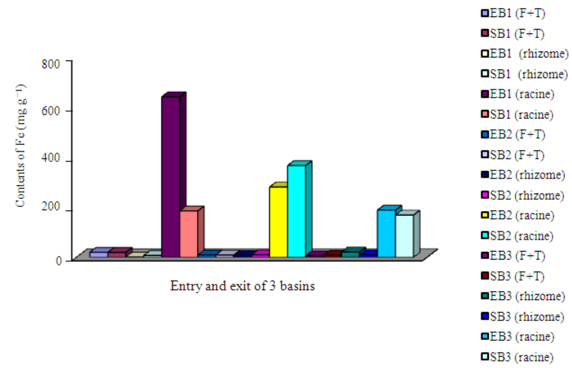

Fig. 6: Variation of the content of Fe in *Phragmites australis* into the 3 basins (entry and exit) (withdrawals of the *Phragmiteses* in November 2005)

We also note that there is a ferric accumulation reduction while passing from a basin to another and this for the two repetitions.

DISCUSSION

In scientific literature, contents of iron of exhibition don't exist in waters or soils to respect for the species *Phragmites australis*. Therefore, we compare our values of the plants to those of the witnesses.

We note that the contents of iron have the tendency to increase progressively after the stay of the *Phragmiteses* in contact with the waters of the Meboudja wadi. What explains the elevated contents found before into water of the Meboudja wadi, these contents have been trapped into the roots of the *Phragmiteses australis*. *Phragmites australis*, thanks to its roots, is going to assimilate metals and thus to make decrease their quantity in the middle. In fact, the *Phragmites* has a very active roots system and capability to resist to the elements metallic traces (EMT).

The variance analysis with two criteria for iron show that some meaningful differences exist between the entries and the exits of the basins for the different plant compartments.

One can explain these considerable contents made of iron into the roots of *Phragmites australis* by the following hypothesis:

When the temperature is raised, the plant is stimulated, that means the phenomenon of photosynthesis is activated. Of this fact, the plant clears the oxygen: A great deal of oxygen escapes in air and the small remaining quantity (of the order of 10% of the quantity produced) will leave toward the roots, because the *Phragmiteses australis* has the particularity to transport the oxygen of their aerial parts toward their underground parts, via the aerenchyme. These conditions permit the formation of oxides or hydroxides of iron (ferric plate).

These ferric plates play a double role: On one hand, the plants form some plates like means of regulation of the entry of the toxic iron in the plant, in other words these plates would be therefore an adaptation to the reducing conditions of the middle by oxidization of the roots by the aerenchymes. These plates would have rather a protective role therefore opposite the ferrous iron.

The oxides of present iron in soils and sediments possess some groupings functional OH. These last are capable to react with metals and others cations and anions[5]. It is possible that the hydroxides of iron formed into the roots of the reeds have some properties similar to those noted into the soil and the sediments. Therefore these hydroxides of iron could prevent the hold or the capture of the metals phyto-toxics.

Research on the growth of the *Typha latifolia* determined that the development of these plates on the roots of the young plants didn't increase the tolerance of metal, if it is subject to the Cu, Nor, Zn, Pb and Cd[3,4]. One notes that the presence of the plate also reduced the length of root from where the ferric plates act as being a filter for the movement of iron, Cu, Zn, Ni and Cd in the rhizomes and the shoots of *Phragmites australis*[6-8].

Fig. 7: Phenomenon of the ferric plate

Fig. 8: Leaves tried of the *Phragmiteses australis*

Alternately, the plate can act merely as physical gate. In these conditions of low pH (3, 5), the activity of hydrogen ions on the surface of the roots interfered with the movement of metals in the root, what brought it to conceal the potential effect of the ferric plate.

One can explain these considerable contents made of iron to the level of the roots of *Phragmites australis* by the following hypothesis:

When the temperature is raised, the plant is stimulated, that means the phenomenon of photosynthesis is activated. Of this fact, the plant clears the oxygen: a great deal of oxygen escapes in air and the small remaining quantity (of the order of 10% of the quantity produced) will leave toward the roots, because the *Phragmiteses australis* has the particularity to transport the oxygen of their aerial parts toward their underground parts, via the aérenchyme. These conditions permit the formation of oxides or hydroxides of iron (ferric plate).

Figure 7 shows the phenomenon of the ferric plate, at the contact of the roots of *Phragmites australis*, in our case.

The brown color corresponds to the ferric plate and the surrounds white color corresponds to the sulfate of the middle and outside of the rhizo-sphere, sulfur presents itself as black sulphides. The interactions between the oxides of iron and the bio-films can be also important; Yarrow *et al*.[9] showed that deposits of iron increased the initial rate of the bio-film which increases, on its turn, the retention of iron deposits, these results are in agreement with ours. One of the calm fundamental questions is the one because some bacteria are capable to reduce this iron chemically in presence of simple organic compounds. What is therefore the final consequence of these actions?

Hypotheses on the toxic effects of metals on the leaves of *Phragmites australis*: Figure 8 shows us the existence of stains on the leaves, this type of symptom has been observed on the reeds of our experimental pilot. Indeed, blackish necrotic "spotlights" on the leaves of the pilot's reeds appeared in October 2005 and again in April 2006. They first of all appear on the oldest leaves to reach the youngest. Their size is of the order of 5 mm of diameter and their diffuse scattering on the whole surface of the leaf. It comes with a yellowish of these leaves, 1 month about after the apparition of the necroses and of a drying up of the trilled parts.

Hypothesis on the reason of the stains observed on the leaves of *Phragmites australis*: In agriculture, it is generally observed a production loss when soil is deficient in iron but also when it is too rich of this element. It is the case of soil flooded which is too acidic that can contain a strong concentration of ferrous iron (state of oxidization II). This type of soil is toxic for the plant that is susceptible to absorb the ferrous iron.

The main symptom of the iron excess in a plant is the apparition of necroses zones on the leaves, phenomenon known as "bronzing".

Hypothesis on the lack of the phosphor at *Phragmites australis*: The presence and the growth of the macrophytes, influence the dynamics of the phosphor at the marshes. The macrophytes also provide the organic and oxidizing materials depend on the land conditions and produce bio-geo-chemically the dynamics of soil (redox: Aerobe-anaerobic), leading chemical gradients for nutritious transformations by the microbial flora[10-13]. The nutritious function and purification of the artificial swamps is also associated closely to the accumulation and to the deterioration of the organic matter, therefore it is extensively due to the microbes localized in the external layers of soils[14,15].

The phosphor can decreased in the plant because of the role of the ferric plates; these plates are caused, as we already underlined it, by the toxic iron presence in anaerobic conditions and to acidic pH.

Ahn *et al*.[16] undertook a study on the influence of the macrophytes and the phosphor on the microbial populations. Some genetic prints have been taken from the soil of microcosms while using the heterogeneity of length of chains by PCR (LH-PCR) as well as the microbial diversity of some of these soils analyzed by cloning. This last method revealed that different bacterial groups are selected by different levels of contribution in phosphor and otherwise, no meaningful effect of the macrophytes presence on the microbial populations has been detected (global $R = 0.15$, $p = 80\%$), probably because of the bad growth of the plants and the anomalies of withdrawal. The analysis in main components (PCO) and the Analysis Of Similarity (ANOSIM) some genetic prints suggested that the contribution of a big content in phosphor had a considerable impact (global $R = 0.6$, $p = 2.9\%$) on the microbial structure of the global soil, which decreasing the microbial diversity.

CONCLUSION

In a first time, this pilot with beds of reeds (with the inherent difficulties of the land) has been put in place in order to describe the possibility to study such system for a specific industrial effluent. Our research had for objectives to identify and to adjust the main biotic and no biotic parameters in order to assure optimal purification productivity.

Iron has been found in important concentration compared to the other elements metallic traces. Such variation seems to be connected directly to the rhythm of the industrial production, to the fluctuations of the climatic factors, and to the capacities of assimilation of the cultivated plants.

We consider, that the obtained results reflect the potential risks that can generate by the irrigation of cultures by the residuary waters of wadi (Meboudja).

We note the apparition of the necroses zones on the leaves of *Phragmites australis*, main symptom of iron excess and which known as" bronzing ".

Otherwise, the low values of pH of Meboudja wadi water as well as of sediments facilitated the liberation of the elements metallic traces.

We put in evidence that *Phragmites australis* developed an important roots-system in contaminated middle

One also records that the basins of *Phragmites australis* accumulate more iron in roots then other metals, and that it is within water, sediment or plant.

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