# The Use of Macrophytes as Biosorbents in Radioactive Liquid Waste Treatment – 18039

Eduardo Ferreira *, Ludmila Vieira *, Rafael Vicente de Pádua Ferreira *, Júlio Takehiro Marumo *
* Nuclear & Energy Research Institute

## ABSTRACT

An important stage of the management of radioactive liquid waste is the chemical treatment. In the last few years, biosorption has attracted attention as one alternative method to remove radionuclides in liquid LL/ILW due to its efficiency and low costs. There are many biomasses that can be applied for this purpose, as agricultural residues and Macrophytes. This study aims at studying Macrophytes (*Pistia Stratiotes*, *Limnobium Laevigatum*, *Lemna sp* and *Azolla sp*) ability to absorb uranium in liquid solutions. The biosorption capacity of uranium by the Macrophytes was experimentally determined. The experiments determine the metal uptake after the solution was in contact with each biosorbents by inductively coupled plasma optical emission spectrometry (ICP-OES). The results show that these materials are potentially applicable in the treatment of liquid radioactive waste.

## INTRODUCTION

Chemical treatment of radioactive liquid waste is an important stage of its management and aims at reducing its volume, modifying its chemical properties and separating long-lived radionuclides. The most used techniques currently used in the nuclear industry to treat these wastes are incineration and evaporation. However, these processes are expensive and unfeasible for the low volume of radioactive liquid waste. Consequently, alternative processes have to be studied to treat these solutions.

In the last decades, biosorption has been studied as an alternative to removing radionuclides in liquid LL/ILW, since this process has low cost, do not require high technology and have a wide range of materials to be used [1]. Many studies reported the biosorption ability of different biomasses to remove radionuclides from solutions, such as banana peels [2], coconut fiber [3], *Padina sp*. algae [4] and *Catenellarepens*, red algae [5]. A good biosorbents has some characteristics, as efficient and rapid sorption/desorption of the metal, high selectivity, reusability and easy separation from solutions [6].

Macrophytes have all of these characteristics. They are aquatics species that have been demonstrated as a material with a capacity of adsorbing heavy metals in effluents [7] and the potential to remove radionuclides from liquid LL/ILW.

This work aims at evaluating the uranium biosorption capacity of some Macrophytes that have been used to treat industrial effluents containing heavy metals. The biosorption capacity was evaluated by experiments performed to determine the metal uptake in four different Macrophytes: *Pistia Stratiotes*, *Limnobium Laevigatum*, *Lemna sp*, and *Azolla sp*.

## MATERIALS AND METHODS

The Macrophytes used in this work were prepared by washing (with distilled water), drying (for 24h at 60ºC) and sterilizing (by UV radiation for 30 minutes) to avoid the rapid deterioration. After the preparation, the material was ground and sieved and particles with a size between 0.297 and 0.125mm were used for the biosorption experiments.

To assess the time required for the equilibrium, the biomass (0.2 g) was added to a Uranium solution (10 mL and concentration of 150 mg/L of Uranium), prepared in the laboratory, with pH of 4.0. The samples were stirred, at a constant temperature of 21ºC in the incubator Orbital Shaker BT 400 with speed of 130 rpm, until achieving the equilibrium. The time of contact was of 5, 30, 60, 120 and 240 minutes and the experiments were performed in triplicate. The solutions were then filtered to separate the biomass and the Uranium concentration determined by atomic emission spectrometry with inductively coupled plasma (ICP-OES). The incubator and ICP-OES equipment are shown in Figure 1.

Subsequently, the biosorption capacity as a function of Uranium concentration was evaluated. For this purpose, solutions with varying concentration from 75 to 20,000 mg/L of Uranium, were prepared and mixed with the biomass (10 mL of solution and 0.2 g of biomass) for a predetermined period of time (the ones obtained in the first experiments). The experiments were performed in triplicate. After the contact with the biomass, the solutions were then filtered and the Uranium concentration determined by atomic emission spectrometry with inductively coupled plasma (ICP-OES).

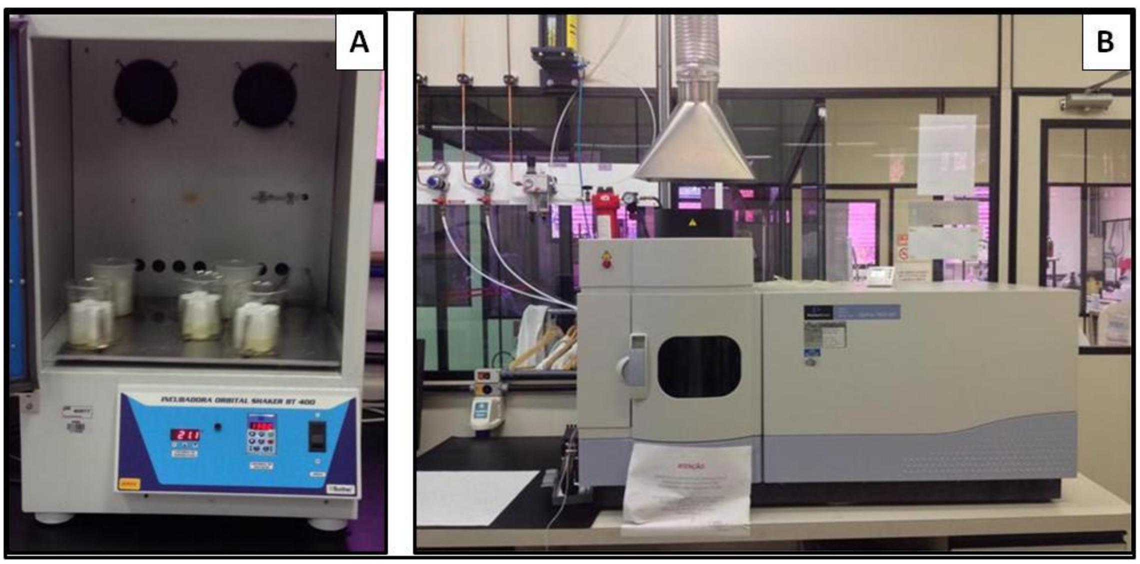


Fig. 1. – A) Incubator Orbital Shaker, B) ICP-OES Perkin Elmer.

The biosorption capacity of Uranium was determined by the following equation:

$$q = \left(\frac{C_i - C_f}{m}\right)V$$

Where:
q = (mg/L) is the biosorption capacity;
Ci = (mg/L) is the initial concentration of Uranium in the solution;
Cf = (mg/L) is the Uranium concentration in the solution in equilibrium;
V = (L) is the total volume of the solution; and
m = (g) is the mass of the biosorbents material.

## RESULTS AND DISCUSSION

The results of biosorption as a function of time are shown in Figure 2.

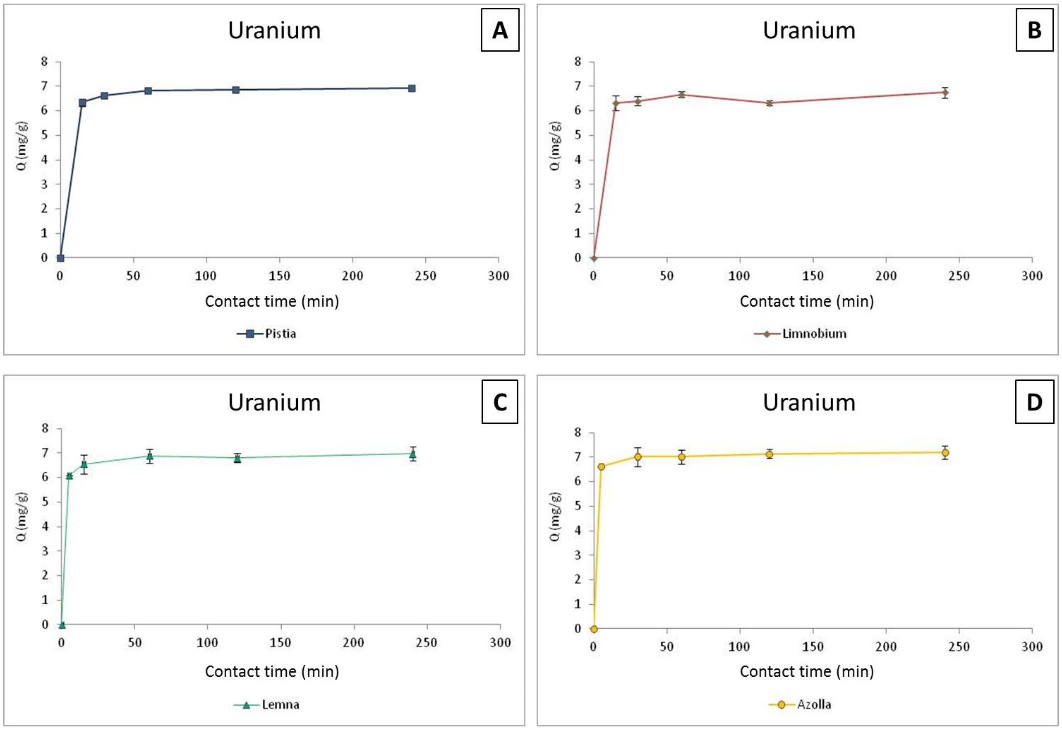


Fig. 2. Biosorption of Uranium by the Macrophytes a) *Pistia Stratiotes*, b) *Limnobium Laevigatum*, c) *Lemna sp*, and d) *Azolla sp*.

These results show that the uranium concentration in the biomass increase until achieving the equilibrium, where the adsorptions sites were completed filled. This behavior was expected since uranium accumulates in the biomass at the adsorption sites until dynamic equilibrium occurs, with the interaction between the ions where the desorption rate approaches the biosorption rate [8].

The equilibrium time was 60 minutes from *Pistia Stratiotes*, *Limnobium Laevigatum*, and *Lemna sp* and of 30 minutes for *Azolla sp*. These times of equilibrium were used in the next experiments to calculate the biosorption capacity of each biomass. The results are presented in TABLE I.

TABLE I. Biosorption Capacity of each Biomass

| **Biomass** | **Uranium biosorption capacity** | |
|---|---|---|
| | **(mg/g)*** | **(mmol/g)*** |
| *Pistia Stratiotes* | 6,80 ± 0,06 | (287 ± 2,52) x$10^{-7}$ |
| *Limnobium Laevigatum* | 6,70 ± 0,11 | (280 ± 4,62) x$10^{-7}$ |
| *Lemna sp* | 162,10 ± 1,8 | (681 ± 7,80) x$10^{-6}$ |
| *Azolla sp* | 161,80 ± 2,0 | (680 ± 8,40) x$10^{-6}$ |
| * x ± s (mean ± standard deviation) | | |

The highest value for biosorption capacity was found in the experiments with *Lemna sp* and *Azolla sp*. For these two biomasses, the sorption capacity did not achieve it maximum, although was used solutions with elevated concentrations of uranium, until 20,000 ppm. From the results obtained until now, the *Azolla sp* is the most effective biomass in the biosorption process because it requires a shorter time to remove uranium.

## CONCLUSIONS

The Macrophytes evaluated at this work showed efficient biosorption capacity, especially the *Lemna sp* and *Azolla sp* biomasses. The period for total removal of uranium of the solution was between 30 and 60 minutes. This study shows us that the Macrophytes are potentially applicable in the treatment of liquid radioactive waste.

The study of isotherms and biosorption kinetics will be done in order to improve the understanding of the biosorption process of each Macrophyte, using the results obtained in the experimental work. Moreover, a suggestion for further work includes evaluating the behavior of the Macrophytes in solutions with higher concentrations of uranium and in solutions with more than one radionuclide, since the metals compete among them to be adsorbed in the biomass sites. Lastly, the immobilization of the biomass in a monolithic matrix has to be evaluated, as it is a requisite for deposition of radioactive waste in a final repository.

## REFERENCES

1. VOLESKY, B. “Sorption and Biosorption,” Montreal, Canada (2003).
2. BONIOLO, M. R.”Biossorção de Urânio nas Cascas de Banana.” São Paulo, Brazil. (2008).
3. FERREIRA, R. V. P.; FERREIRA, E. G. A.; VIEIRA, L. C.; SILVA, E. A.; MARUMO, J. T. “Biosorption of uranium in radioactive liquid organic waste by coconut fiber,” *Inter. Nucl. Atla. Conf*., (2013).
4. M. H. KHANI. Uranium biosorption by Padina sp. algae biomass: kinetics and thermodynamics, *Environ Sci Pollut Res* 18:1593–1605. (2011).
5. S. V. BHAT., J.S. MELO., B.B. CHAUGULE ., S.F. D’SOUZA. ” Biosorption characteristics of uranium(VI) from aqueous medium onto Catenellarepens, a red alga.”*J Hazard Mater*; v 158. p. 628–635. (2008).
6. VOLESKY, B. Biosorbents for Metal Recovery. *Tib technology*, v.5. p.96-101. 1987.
7. KHOSRAVI M., RAKHSHAEE R., GANJI M. T. Pre-treatment processes of Azollafiliculoidesto remove Pb(II), Cd(II), Ni(II) and Zn(II) from aqueous solution in the batch and fixed-bed reactors. *J Hazard Mater*; B 127.p. 228–237, (2005).
8. FOO, K. Y.; HAMEED, B. H. Insights into the modeling of adsorption isotherm systems. *Chem. Eng. J*.v. 156, p. 2-10, (2010).