

# Use of Floating Beds to Improve the Quality of Surface Water Mass

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1. Framework
2. Aim of the work
3. Methodology
4. Results and Discussion
5. Conclusions



# Use of Floating Beds to Improve the Quality of Surface Water Mass

## 1. Framework

The results of the project **QARSC** (Borrvalho& Durão, 2016) revealed the poor quality of the water of Roxo stream due the contribution of its main tributaries/ bordering activities.



Agricultural activities



Mining activity on stream basin

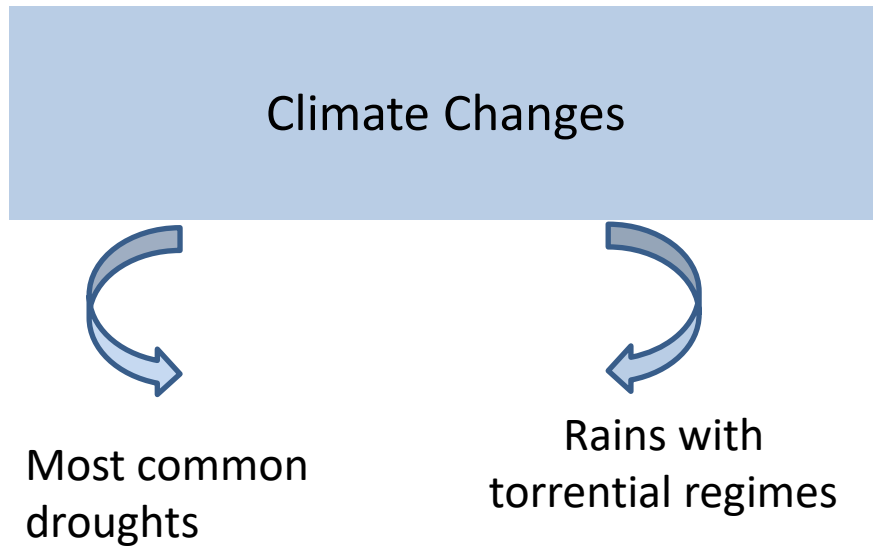


Livestock Farms

# Use of Floating Beds to Improve the Quality of Surface Water Mass

## 1. Framework

- ✓ The Roxo Stream is located in the Southeast of Portugal,
- ✓ Mediterranean Climate



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## 1. 1. Eco-Rehabilitation Measures

River rehabilitation projects (alternatively called Eco-rehabilitation) aim to remedy modified and degraded bodies of water (United Nations, 2015).

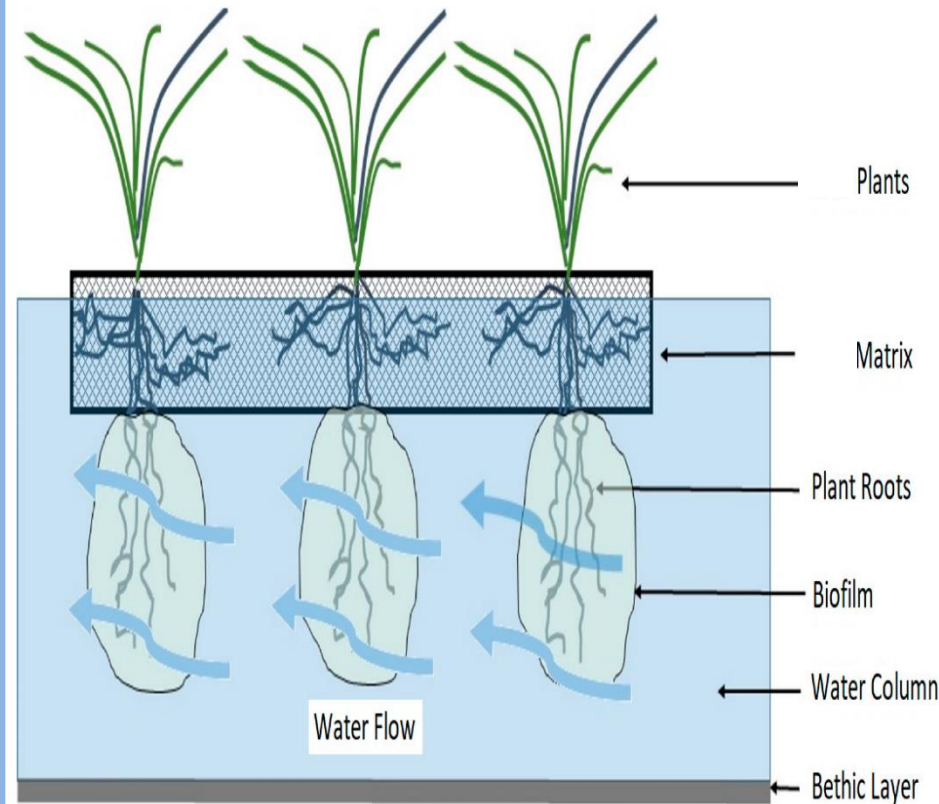
River rehabilitation and restoration cover a wide range of measures (Durão, 2013)



- Riparian galleries;
- Stability of margins;
- Wetlands and
- Floating Beds

# Use of Floating Beds to Improve the Quality of Surface Water Mass

- Floating beds (FBs) consist in a floating artificial medium (i.e., a floating matrix), to which emergent macrophytes with phytoremediation capacity are planted.
- Those are placed directly on the surface of the water and the roots of the plants are fully or partially immersed, and there should be no obstruction of their growth.



Adapted from Walker et al., 2017

Fig.1. Floating bed scheme.

## 2. Aim of the Work

To test, on a pilot scale, the floating bed technology (FB) using floating matrix with two species of macrophytes, *Phragmites australis* and *Vetiveria zizanioides*, with the purpose to improve water quality of Roxo stream, especially heavy metals (Zn, Cu, Fe and Mn), contributing to its ecological improvement and possible use for irrigation.

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## 3. Methodology

- $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ , Salinity, Cu, Fe e Mn, exceed the maximum recommended values (VMR);
- Zn above the maximum permissible value (VMA).

It is not appropriate to use in irrigation



Non-compliance with the parameter  $\text{NH}_4^+$



Poor ecological state, when evaluated only for the physicochemical parameters.

Table 1. Water physicochemical quality characterization of Roxo's stream.

| Parameters         | Units                                     | Roxo's Water Quality | Irrigation Water quality<br>Decree-Law No. 236/98<br>(Annex XVII) |         | Ecological State<br>(Water Institute, 2009) |
|--------------------|-------------------------------------------|----------------------|-------------------------------------------------------------------|---------|---------------------------------------------|
| Parameters         | Units                                     | Roxo's Water Quality | VMR                                                               | VMA     |                                             |
| pH                 | Escala de Sorensen                        | 6,2± 1,6             | 6,5-8,4                                                           | 4,5-9,0 | 6-9                                         |
| $T_w$              | °C                                        | 17 ± 2               | -                                                                 | -       | -                                           |
| Eh                 | mV                                        | 522 ± 19             | -                                                                 | -       | -                                           |
| $\text{B}^{3+}$    | mg/L                                      | 0,2 ± 0,1            | 0,3                                                               | 3,75    | -                                           |
| EC                 | $\mu\text{S}/\text{cm } 20^\circ\text{C}$ | 1 813 ± 117          | -                                                                 | -       | -                                           |
| DO                 | mg/L                                      | 7 ± 1                | -                                                                 | -       | ≥5                                          |
| DQO                | mg/L $\text{O}_2$                         | 23± 3                | -                                                                 | -       | -                                           |
| $\text{CBO}_5$     | mg/L $\text{O}_2$                         | 4 ± 0,0              | -                                                                 | -       | ≤6                                          |
| $\text{PO}_4^{3-}$ | mg/L                                      | 0,007 ± 0,001        | -                                                                 | -       | -                                           |
| $P_{\text{total}}$ | mg/L                                      | 0,01± 0,01           | -                                                                 | -       | ≤0,13                                       |
| Nkj                | mg/L                                      | 4 ± 1                | -                                                                 | -       | -                                           |
| $\text{NH}_4^+$    | mg/L                                      | 2 ± 1                | -                                                                 | -       | ≤1                                          |
| $\text{NO}_3^-$    | mg/L                                      | 7 ± 1                | 50                                                                | -       | ≤25                                         |
| $\text{SO}_4^{2-}$ | mg/L                                      | 826 ± 31             | 575                                                               | -       | -                                           |
| F                  | mg/L                                      | 1,0 ± 0,0            | 1,0                                                               | 15,0    | -                                           |
| Cl                 | mg/L                                      | 700 ± 21             | 70                                                                | -       | -                                           |
| TSS                | mg/L                                      | 19 ± 1               | 60                                                                | -       | -                                           |
| TDS                | mg/L                                      | 1 238 ± 232          | -                                                                 | -       | -                                           |
| Zn                 | mg/L                                      | 13,0 ± 2,1           | 2,0                                                               | 10,0    | -                                           |
| Fe                 | mg/L                                      | 7,7 ± 0,8            | 5,0                                                               | -       | -                                           |
| Cu                 | mg/L                                      | 3,3 ± 0,7            | 0,20                                                              | 5,0     | -                                           |
| Mn                 | mg/L                                      | 7,3 ± 1,2            | 0,20                                                              | 10      | -                                           |
| SAR                | -                                         | 2 ± 1                | 8                                                                 | -       | -                                           |

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## *Phragmites australis*

Grass of cosmopolitan nature, has been widely studied, especially for the reduction of environmental contamination (Köbbing et al., 2013).

### Main features of the plant :

- ❖ Moderate salinity tolerance (Canais-Seco, Peres, & Bentes, 2008);
- ❖ Resistance to pH between 2 and 8 (Canais-Seco, Peres, & Bentes, 2008);
- ❖ Resistance to temperatures between 6.6°C and 26.6°C (Canais-Seco, Peres, & Bentes, 2008);
- ❖ High metal removal (Srivastava et al., 2014);
- ❖ Removes organochlorinated pesticides (Guo et al., 2014) and
- ❖ It is considered as an invasive macrophyte (Uddin & Robinson, 2018).



Adaptated from Remesh et al., 2018

Fig.2. Picture of *Phragmites australis*.

## *Vetiveria zizanioides*

### Main plant features (Brix., 2003; Almeida., 2017):

- ❖ Large and deep root system;
- ❖ Can support a wide pH range (3,3 a 9,5);
- ❖ Resists high saturation levels of Al, Mn and heavy metals;
- ❖ Has high efficiency to removing nutrients such as nitrogen and phosphorus;
- ❖ Tolerates air temperatures between -20°C e 60°C;
- ❖ Effective in herbicide retention ;
- ❖ Tolerates sodic, saline and alkaline soils and
- ❖ Although it is not native of Portugal, it is not considered an invasive specie according to the Decree-Law n.º 92/2019.



Fig.3. Picture of *Vetiveria zizanioides*.

# Use of Floating Beds to Improve the Quality of Surface Water Mass

## 3.1. Pilot Instalation

- Floating Bed 1 (FB1)- Floating Matrix with *Phragmites australis* and Roxo's stream water (800L);
- Floating Bed 2 (FB2)- Floating Matrix with *Vetivertia zizanioides* and Roxo's stream water (800L).

## 3.2. Experimental Procedure

- Batch trials, with monthly affluent renewal from January to June 2019 (location: coordinates GPS: 37.944685-8.153876).
- Monthly monitoring the physicochemical quality of water of the beds (Affluents and Effluents 1 and 2) and monitoring the plants (growth, biomass production and metals accumulation Fe, Zn, Cu e Mn).

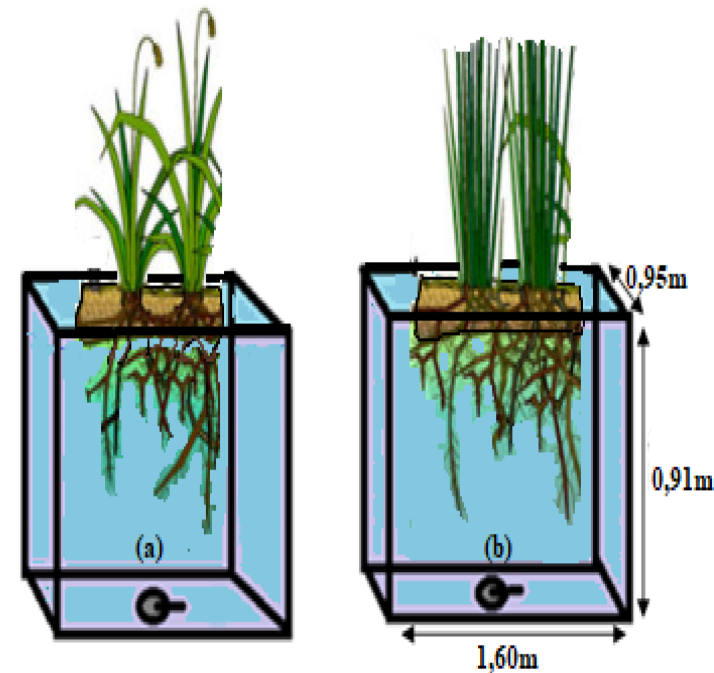


Fig.4.Scheme of the pilot instalation: (a) Floating Bed 1 (FB1) and (b) Floating Bed 2 (FB2).

## 4. Results and discussion

### Average metal removal efficiency

#### Mn

- 16% - Effluent 1 (FB1) - *Phragmites australis* can remove high concentrations of Mn (Srivastava et al., 2014).
- 14% - Effluents 2 (FB2)
- All values, although below the VMA, are still far from the VMR.

#### Zn

- 17% - Effluents 1 (FB1) - Values below the VMA (February, March and June).
- 25% - Effluents 2 (FB2) - The VMA was only exceeded in April.

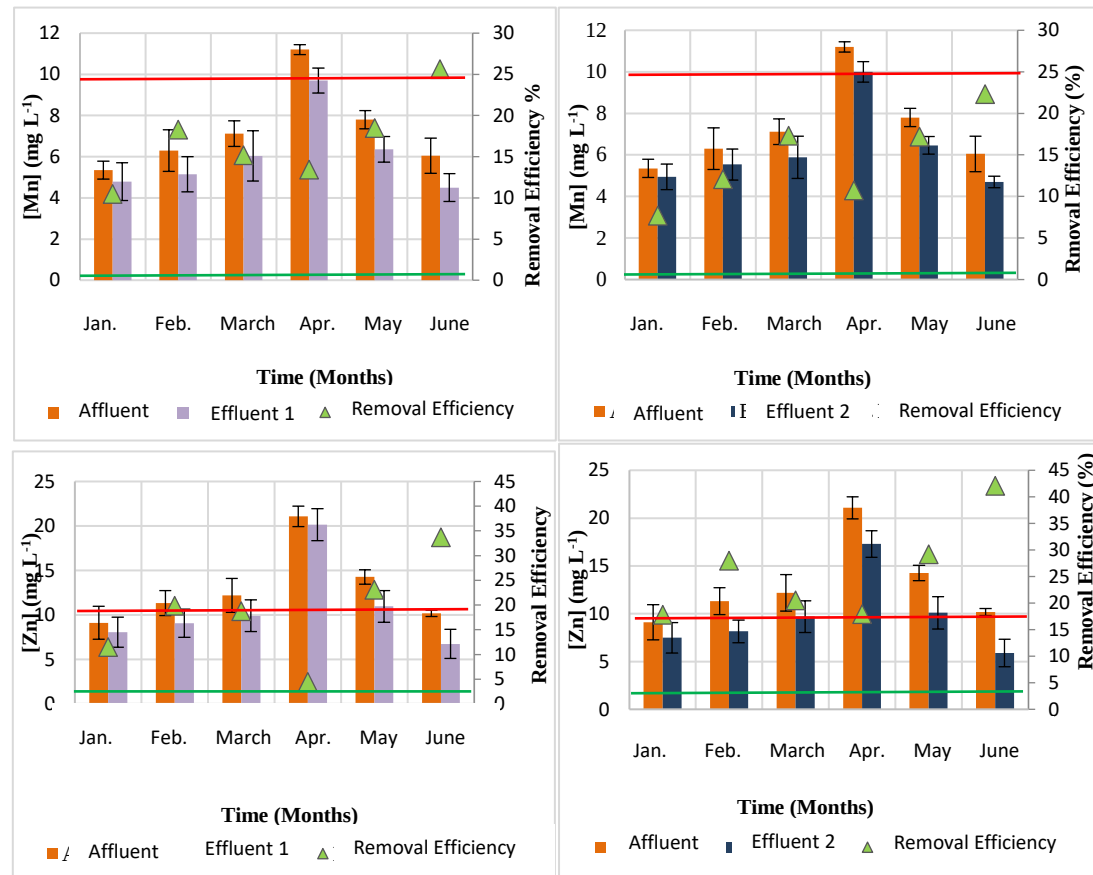


Fig 5. Evolution of manganese (Mn) and zinc (Zn) contents in affluents, effluents 1 and effluents 2, and their removal efficiency during the monitoring period (Average  $\pm$  D.P.: n=3).

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## Average metal removal efficiency

### Cu

- 6% - Effluents 1 (FB1)
- 15% - Effluents 2 (FB2)

All values were lower than the VMA, except in April, in both effluents.

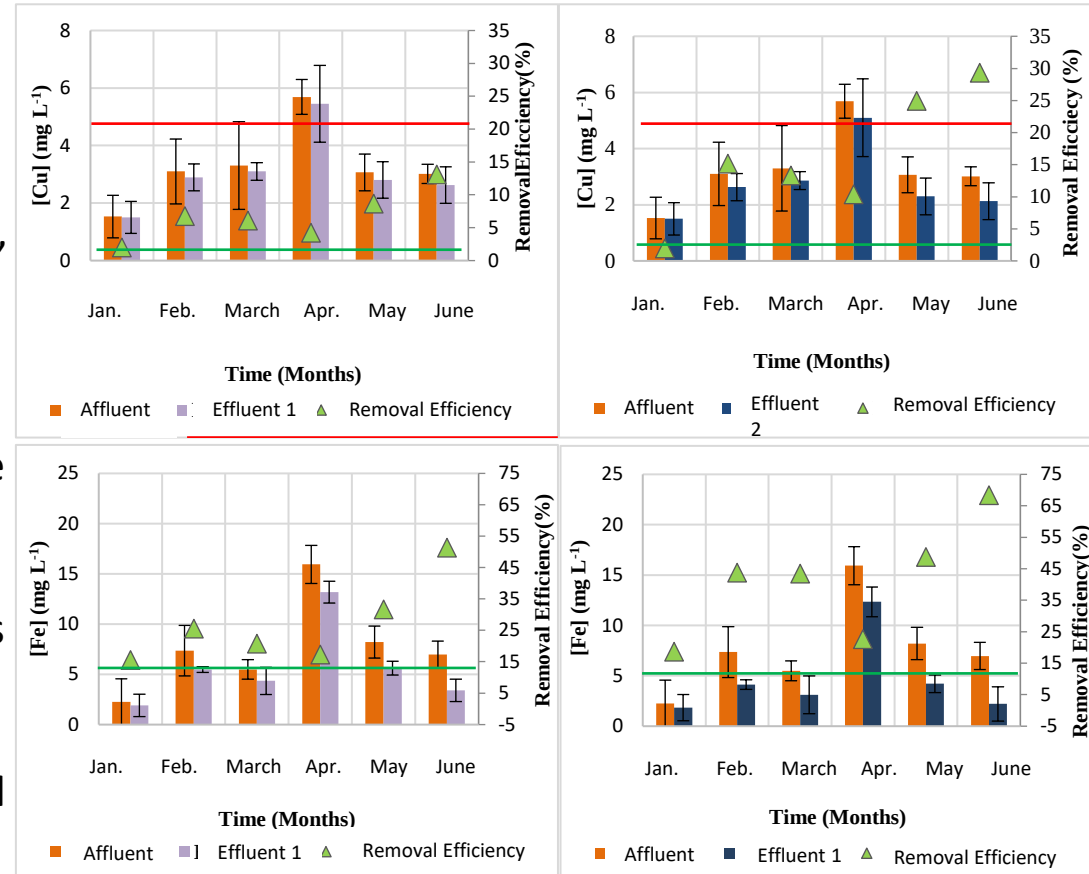


Fig 6. Evolution of cooper (Cu) and iron (Fe) metal contents in tributaries, effluents 1 and effluents 2, and their removal efficiency during the monitoring period (Average  $\pm$  D.P.:n=3).

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## Phytoremediation by macrophytes

- The concentration of metals was higher in the roots than in the aerial part (Bonanno, 2011; Suelee et al., 2017).
- The accumulation order in *Phragmites australis* was  $Fe > Zn > Mn > Cu$  for root biomass and  $Fe > Mn > Zn > Cu$  for leaf biomass.
- The accumulation order in *Vetiveria zizanioides* was  $Fe > Zn > Cu > Mn$  for root biomass and  $Fe > Zn > Mn > Cu$  for leaf biomass.

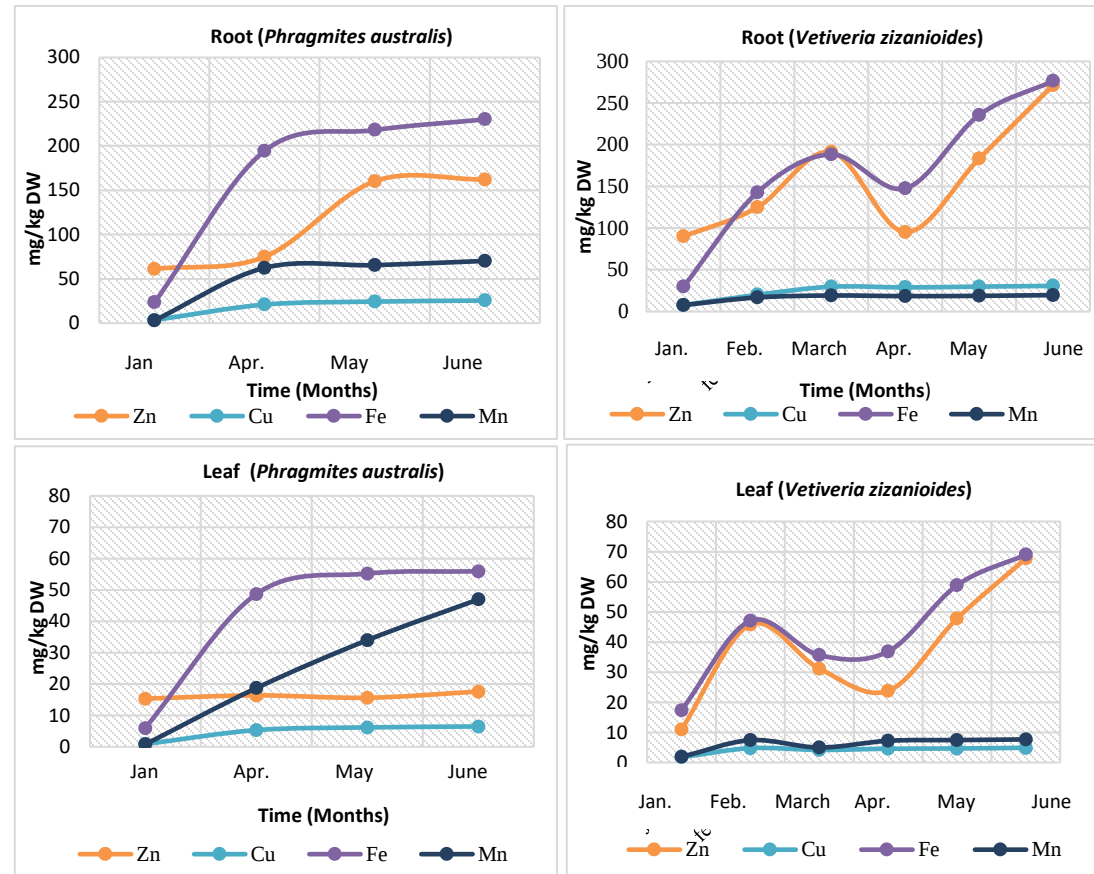


Fig. 7 Accumulation of Zn, Cu, Fe and Mn in the root and foliar zone of *Vetiveria Zizanioides* and *Phragmites australis*.

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## Bioconcentration Factor (BCF) and Translocation Factor (TF)

*Phragmites australis*

$BCF > 1$

$TF < 1$

Suitable for  
phytoremediation by  
rhizofiltration.

**BCF** -Bioconcentration Factor - Ability of plants to accumulate metals in relation to the concentration of the medium.

**TF**-Translocation Factor - Ability of the plant to extract metals from the root to the aerial part.

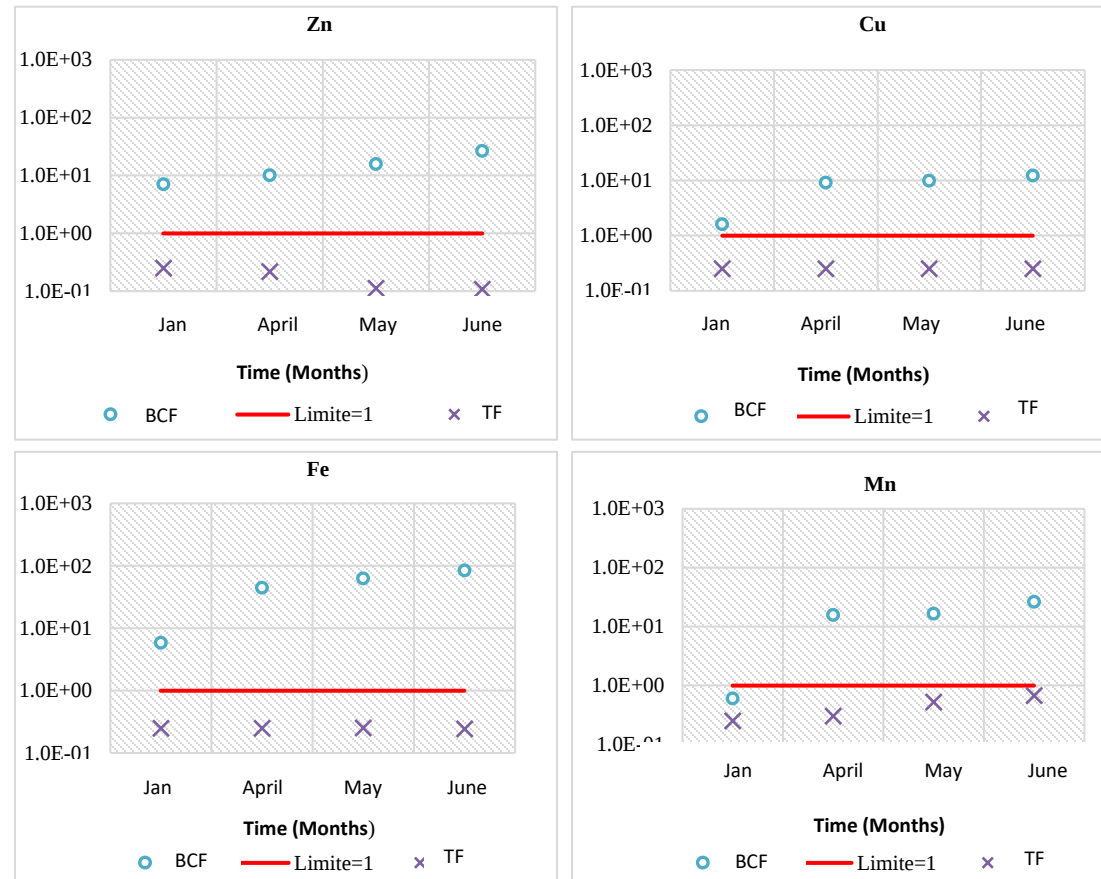


Fig.8. Evolution of Bioconcentration Factor (BCF) (o) and Translocation Factor (TF) (x) in *Phragmites australis* for the following elements: Zn, Cu, Fe and Mn.

# Use of Floating Beds to Improve the Quality of Surface Water Mass

## Bioconcentration Factor(BCF) and Translocation Factor (TF)

*Vetiveria zizanioides*

$BCF > 1$

$TF < 1$

Suitable for  
phytoremediation by  
rhizofiltration.

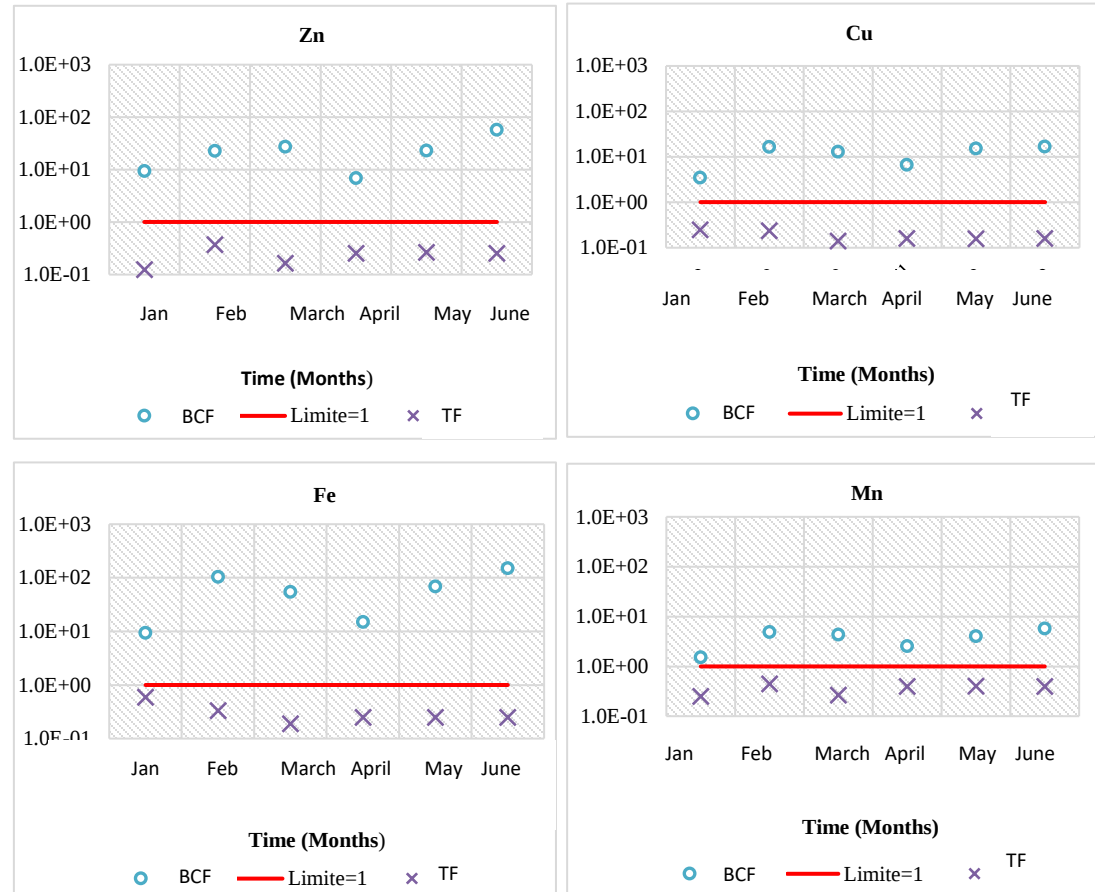
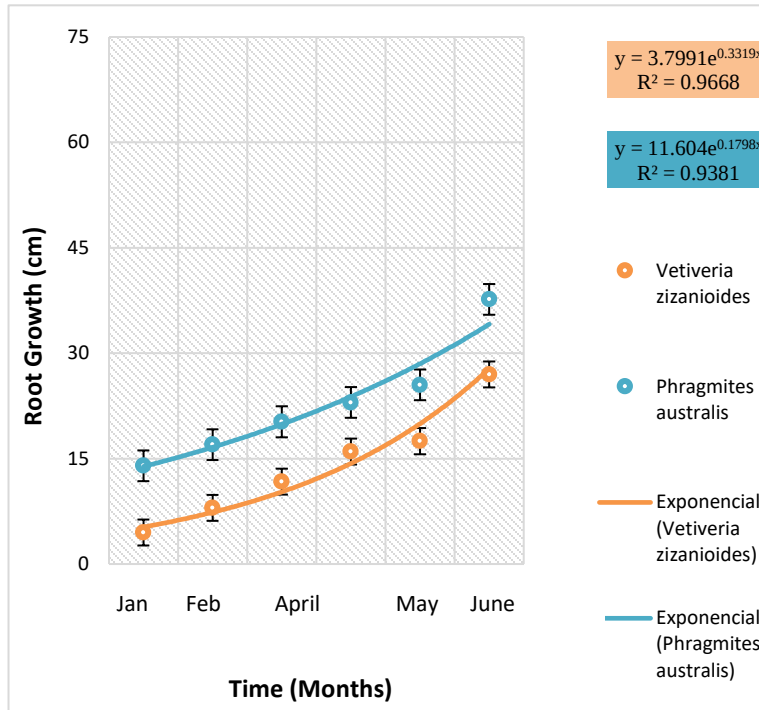


Fig.9. Evolution of Bioconcentration Factor (BCF) (o) and Translocation Factor (TF) (x) in *Vetiveria zizanioides* for the following elements: Zn, Cu, Fe and Mn.

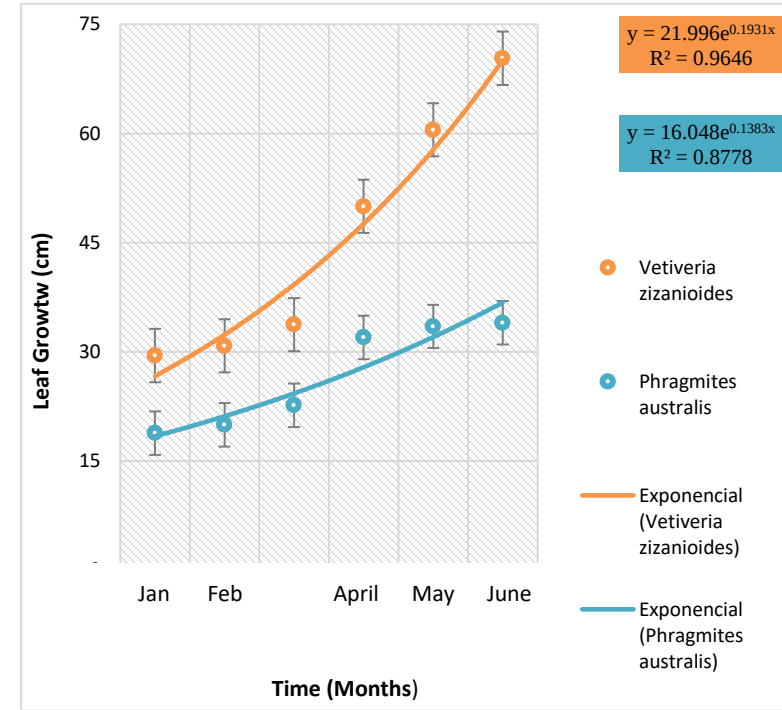
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## Biomass growth and production rate



### *Phragmites australis*

Root growth rate was  $4.1 \pm 0.2$  cm/month and  
Leaf growth rate was  $2.5 \pm 0.0$  cm/month.



### *Vetiveria zizanioides*

Root growth rate was  $3.8 \pm 0.1$  cm/month and  
Leaf growth rate was  $7.1 \pm 0.3$  cm/month.

# Use of Floating Beds to Improve the Quality of Surface Water Mass

## Biomass growth and production rate

| Macrophytes                                         |           |           |                                                      |           |           |
|-----------------------------------------------------|-----------|-----------|------------------------------------------------------|-----------|-----------|
| <i>Phragmites australis</i> (g m <sup>-2</sup> DW ) |           |           | <i>Vetiveria zizanioides</i> (g m <sup>-2</sup> DW ) |           |           |
| Shoot                                               | Leaf      | Total     | Shoot                                                | Leaf      | Total     |
| 515±74                                              | 2 728±396 | 3 243±470 | 1 041±248                                            | 3 858±454 | 4 859±702 |

Total biomass production was low in both plants. *Vetiveria zizanioides* obtained higher values.

Inhibition of biomass growth and production in both macrophytes can be explained by:

- i) Low temperatures recorded on the first months of monitoring,
- ii) Appearance of algae that have settled on the roots zones preventing the growth of roots and leaves;
- iii) Low nutrient content and
- iv) High metal contents of the medium.

## 7. Conclusions

The water physicochemical characterization of Roxo stream revealed, among others, high levels of metals (Fe, Zn, Mn, Cu), sulfates, chlorides and low nutrient levels, so is not appropriate to use in irrigation;

The effluents water quality under study showed improvements for the monitoring period of 6 months, mainly in the removal of heavy metals, sulfates and chlorides:

-FB 2 (*Vetiveria zizanioides*), Fe=40%; Zn=25%; Cu=15%; Mn=14%,  $\text{SO}_4^{2-}$  =18% e  $\text{Cl}^-$  = 11%.

- FB1 (*Phragmites australis*), Fe=27%; Zn=17%; Mn=16%; Cu=6%,  $\text{SO}_4^{2-}$  =10% e  $\text{Cl}^-$  =5%.

The growth of the macrophytes showed survival capacity in this type of medium, with low nutrients content, without occurrence of severe damage on its external and anatomical morphology, although with some inhibition of growth.

The phytoremediation mechanism used by both macrophytes seems to be rhizofiltration.

Although there was a decrease in almost all of the physicochemical parameters analyzed, it has not yet been possible to conclude about the efficacy of this type of treatment when placed on a real scale.

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## Bibliography

- Almeida, A. A. M. (2017). Fitorremediação: uma tecnologia sustentável para remoção de compostos de azoto em águas residuais. Lição apresentada no âmbito das Provas Publicas de Avaliação de Competências Pedagógicas e Tecno-Científicas na área da disciplinar de tecnologia do ambiente, Instituto Politécnico de Beja, 1-187. Obtido a 21 de maio de 2019.
- Borralho, T., Durão, A. (2016). Qualidade da Água da Albufeira do Roxo na Dinâmica dos Solos e Culturas Agrícolas (QARSC). Associação de Regantes do Roxo, Instituto Politécnico de Beja, Universidade de Évora. pp. 25-45.
- Brix, H. (2003). Plants used in constructed wetlands and their functions. 1 St. International Seminar on the Use of Aquatic Macrophytes for Wastewater Treatment in Constructed Wetlands, 68(December), 30. <https://doi.org/10.1016/j.ejphar.2014.05.01.3>
- Canais-Seco, T., Peres, J. A., & Bentes, I. (2008). Avaliação De Leitões De Macrófitas No Tratamento De Águas Residuais Domésticas Em Portugal: Sistemas De Fluxo Sub-Superficial Horizontal. 9º Congresso Da Água, 14.
- Decreto-Lei n.º 236/98. (1998). Ministério do Ambiente, 1 de Agosto de 1998. Diário Da República I Série A, Nº 178, 3676–3722.
- Durão, A. C. R. (2013). Estratégias para a melhoria da qualidade da água na Bacia Hidrográfica do Rio Ardila. Tese elaborada na Universidade de Évora, para a obtenção do grau de doutor em Ciências da Engenharia do Território e Ambiente, Évora. Obtido em 19 de março de 2019.
- Guo, Wei, Zhang, H., & Huo, S. (2014). Organochlorine pesticides in aquatic hydrophyte tissues and surrounding sediments in Baiyangdian wetland, China. *Ecological Engineering*, 67, 150–155. <https://doi.org/10.1016/j.ecoleng.2014.03.047>
- Instituto da Água. (2009). Critérios para a classificação do estado das massas de água superficiais. *Ministério Do Ambiente, Ordenamento Do Território e Do Desenvolvimento Regional*.
- Köbbing, J., Thevs, N., & Zerbe, S. (2013). The utilisation of reed (*Phragmites australis*): a review. *Mires and Peat*, 13(01), 1–14.
- Srivastava, J., Kalra, S. J. S., & Naraian, R. (2014). Environmental perspectives of *Phragmites australis* (Cav.) Trin. Ex. Steudel. *Applied Water Science*, 4(3), 193–202. <https://doi.org/10.1007/s13201-013-0142>

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- Suelee, A. L., Hasan, S. N. M. S., Kusin, F. M., Yusuff, F. M., & Ibrahim, Z. Z. (2017). Phytoremediation Potential of Vetiver Grass (*Vetiveria zizanioides*) for Treatment of Metal-Contaminated Water. *Water, Air, and Soil Pollution*, 228(4), 1–15. <https://doi.org/10.1007/s11270-017-3349-x>
- United, N. (2015). International Initiative on Water Quality. International Hydrological Programme.
- Uddin, M. N., & Robinson, R. W. (2018). Can nutrient enrichment influence the invasion of *Phragmites australis*? *Science of the Total Environment*, 613–614, 1449–1459. <https://doi.org/10.1016/j.scitotenv.2017.06.131>
- Walker, C., Tondera, K., & Lucke, T. (2017). Stormwater treatment evaluation of a Constructed Floating Wetland after two years operation in an urban catchment. *Sustainability (Switzerland)*, 9(10), 1–10. <https://doi.org/10.3390/su9101687>
- Bonanno, G. (2011). Trace element accumulation and distribution in the organs of *Phragmites australis* (common reed) and biomonitoring applications. *Ecotoxicology and Environmental Safety*, 74(4), 1057–1064. <https://doi.org/10.1016/j.ecoenv.2011.01.018>
- Panja, S., Sarkar, D., & Datta, R. (2018). Vetiver grass (*Chrysopogon zizanioides*) is capable of removing insensitive high explosives from munition industry wastewater. *Chemosphere*, 209, 920–927. <https://doi.org/10.1016/j.chemosphere.2018.06.155>

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Thank you for your attention!!!!

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