

REDUCTION OF SUSPENDED SOLIDS IN A FREE WATER SURFACE CONSTRUCTED WETLAND TREATING EUTROPHICATED WATERS

M. Martin^{1*}, N. Oliver¹, C. Hernández-Crespo¹, M.C. Regidor²

¹Instituto Ingeniería del Agua y Medio Ambiente, Universidad Politécnica de Valencia, Cno. de Vera s/n. Valencia. Spain, mmartin@hma.upv.es. ²Confederación Hidrográfica del Júcar, MMARM. Valencia. Spain.

Abstract

Water quality recovery of highly modified water bodies is one of the main objectives of Water Framework Directive (WFD). In order to achieve it, a pilot experience is being done in the Lake Albufera of Valencia (Spain), a shallow coastal lake highly eutrophicated. A surface of 0.4 km² of rice fields were transformed in a wetland ecosystem (marshes, lagoons...). Inside, three free water surface constructed wetlands (FWSCW) have been built and planted with emergent macrophytes. The feeding water flows from the Lake Albufera with high content in phytoplankton and consequently, in suspended solids. The aim is to promote the decay of phytoplankton as the sunlight was intercepted by leaves and stems, and the settling of the suspended solids. The action of bacteria on the organic matter will release the nutrients that support the growing of plants. Finally, the harvesting of macrophytes closes the cycle. After the start-up year, the results show a significantly reduction in TSS loading, with an annual mean of 39% at the FWS, but 60.9% at the best developed basins. The concentration of suspended solids has been reduced at half, but sometimes it has been higher due to the resuspension induced by the abundance of birds in spring.

Eutrophication. Shallow lakes. Constructed wetland. Suspended solids.

Introduction

The Albufera of Valencia, Natural Park, is one of the most representative natural areas in the Mediterranean coast in Spain thanks to the diversity of environments that presents, among them, the lake. It is Wetland of International Importance and Zone of Special Protection for Birds. Although in the early 60's, the lake had a good status, currently it is a hypertrophic system caused by the excessive loads of allocthonous organic matter and inorganic nutrients, mainly nitrogen and phosphorus compounds (Soria, 2006). In order to improve the water quality of the lake, according WFD, a Free Water Surface Constructed Wetland (FWS) is located in the North of the lake. The objective is to treat the own waters lake. The use of this type of treatment in eutrophication problems is not as usual as for urban wastewaters and there are only a few cases in the world (Coveney et al., 2002; Linfeng et al., 2008). Total Suspended Solids (TSS) is an important water quality parameter but it is not explicitly under consideration in WFD. In eutrophic systems it can be a complementary indicator of phytoplankton abundance. They reduce the light penetration across the water column and

consequently the plant fixation at the bottom (Wang et al., 2009). Finally, they play a crucial role in the presence of dissolved pollutants (phosphates, metals) owing to their paper in sorption processes.

Methods

The FWS is formed by three independents systems. The first system, *Group G*, consists of three basins in series, F1G, F2G, F3G, with surfaces of 0.0135, 0.0182 and 0.0172 km², respectively. The second group, *group p*, located in parallel to *Group G*, is also formed by three basins in series, f1p, f2p, f3p, with 0.0036, 0.0052, and 0.0056 km². Finally, the third system consists of a single cell (F4) of a surface equal to 0.0256 km². The average depth of the water level in each cell is 20 cm. The cells F1G, F2G, f1p and f2p were planted with cattails (*Typha* spp.), at a density of 1 stems/m², and the remaining basins were planted with a higher diversity (*Typha* spp., *Scirpus* spp. and others) but at a lower density (0.25 stems/m²). The planting period was January–February 2009. The flow from lake was gradually increased, as the basins achieve an acceptable density of plants, from 864 m³/d to 6912 m³/d. The corresponding hydraulic loading rates (HLR) were 0.02, 0.06 and 0.08 m³/m² d in spring, summer–autumn and winter, respectively. Basins F1G and f1p were harvested in November 2009. From April 6, 2009 to March 22, 2010 inputs and outputs of each cell were sampled, every two weeks. Water samples were analyzed for organic mater (COD), nitrogen (NH₄⁺-N, NO₃⁻-N, NO₂⁻-N, TN), phosphorus (PO₄³⁻-P, TP), silica (Si), total and volatile suspended solids (TSS, VSS), and phytoplankton (chlorophyll *a*). In addition, physico–chemical water parameters were measured *in situ*. The removal efficiency of TSS is calculated not over the concentration values but over loads (Mass/Time).

Results and discussion

Inputs of TSS concentrations range between 14.8 and 84.9 mg/l with a mean value of 41.3 mg/l. In Fig 1 some results of *Group G* and *group p* FWS wetlands are shown. A simple analysis of concentration values indicates that in basins F1G and F2G there is a sequential decrease of TSS, but it seems that F3G basins has a minor role. The results are fairly good, taking into account that it is the first year, with 75% of values below of 23.6 mg/l and 50% below 10 mg/l in F2G. The results in *group p* are, globally, worst, but the first small basin, f1p is slightly better than F1G. Outliers' data corresponds to May09 samples.

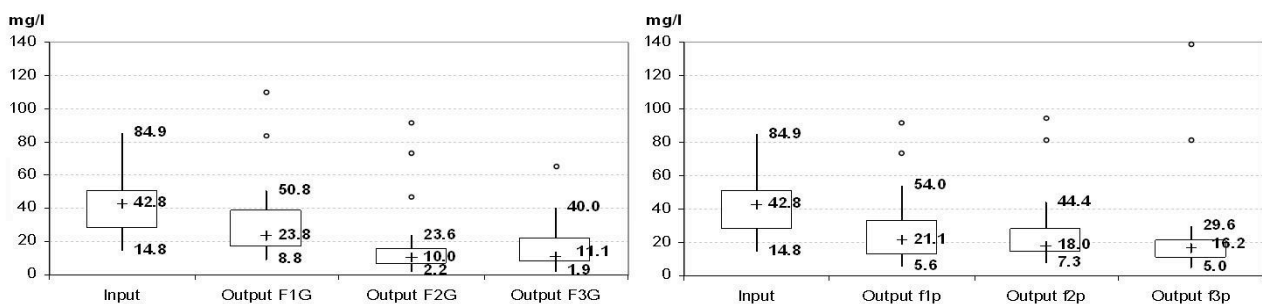


Figure 1. Box plots of TSS concentrations in Group G (left) and p (right)

Apparently the last basin, F3G, does not work properly, but it is not completely true: when concentrations in F2G are low (below 10 mg/l) it is very difficult to reduce them more, but when there are higher than 20 mg/l (for instance, when F1G was harvested) F3G basin compensates the "inactivation" of F1G. In order to see what had happened during the year, in Fig 2 is showed the removal efficiency, in the three wetlands (up) and *Group G* (down). The *Group G* achieves the best results with a 60.4% of TSS removed. *F4* basin is the worst, with only a 1.5% of net removal and *group p* is between them, with an efficiency of 43.9%. The efficiencies changes significantly during the year. There is three key points that explain this high variability: the presence of birds in May'09, the changes in hydraulic load, and the harvesting of F1G and f1p in November'09. In fact, in May'09 the wetland system exports suspended solids to the Lake Albufera. The response of the wetland to changes in HLR is shown clearly in *Group G*: when it is increased by a factor of three in July'09, the efficiency drops from 55–70% to 30% in August but it must also be said that in September–October it turns to the previous values. The increase of HLR from 0.06 m³/m² d to 0.08 in December produces, again, a decrease of efficiency from nearly 90% to 40%. In winter, the efficiency was variable, but it must be taking into account that the concentrations at the inputs were low (mean of 29.4 mg/l). The harvesting has a high impact on the efficiencies but only in the harvested basin, not over the wetland as a whole. The efficiency of *Group G*, after the harvesting of F1G in November, is similar that obtained before. In actually, is slightly higher. The explanation can be seen in Fig. 2(down): since November, in *Group G* the F2G maintains its efficiency but the F3G, with a low efficiency so far, now replaces the "inactivity" of F1G increasing its removal of TSS. In *Group G* we can see a very different efficiency, among the three basins and during the year. Apart from the question related with the harvesting of F1G, it is important to show the low initial removal in F3G due to the low plants densities and the low input of TSS. At the end of the first year, the F2G plays the major role, achieving efficiencies about 90%.

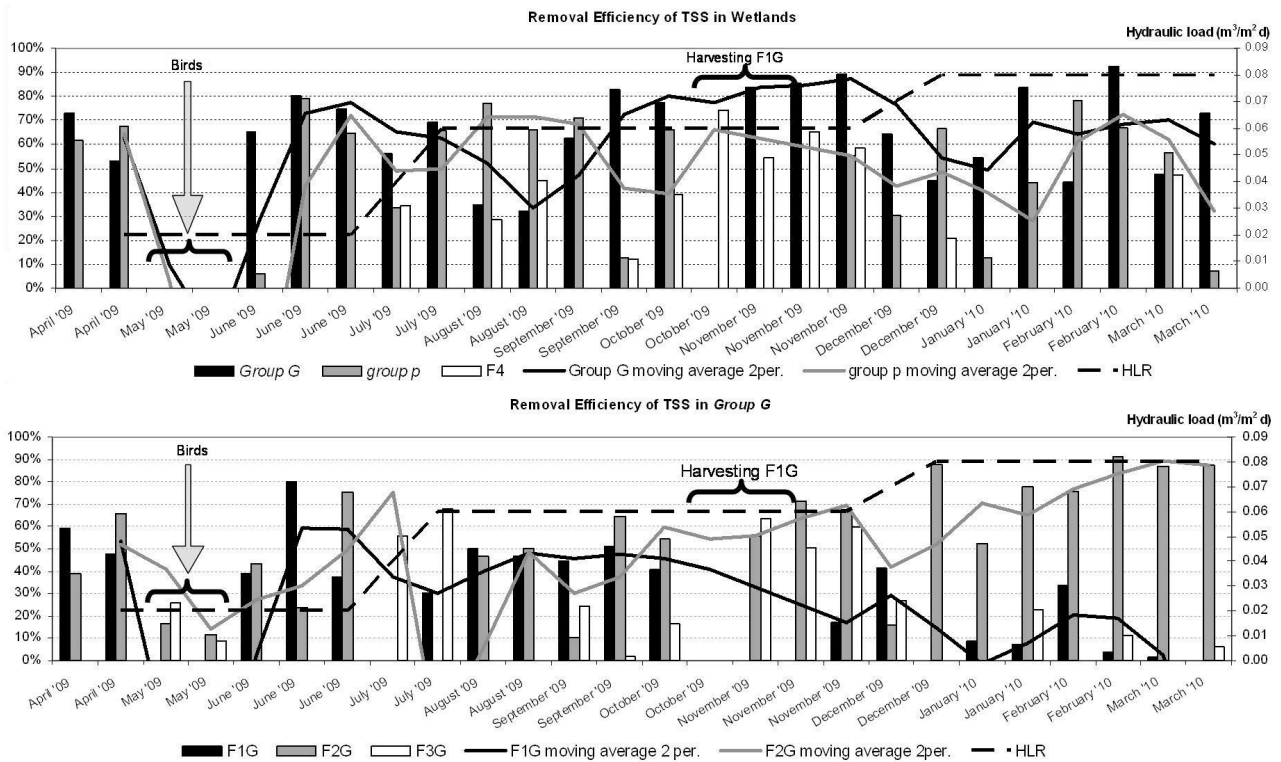


Figure 2. Removal efficiencies of TSS in Wetlands (up) and Group G (down). If bars do not appear there is a "production" of TSS.

Conclusions

A total of 0.09 km² of rice fields have been transformed in three systems of FWS in the Natural Park Albufera of Valencia. The results obtained the first year, during the start-up of the system, are very promising. Global efficiency in TSS removal is 39%, but it is very different in each system: 60.4% in *Group G*, 43.9% in *group p* but only 1.5% in F4. The daily mass of TSS eliminated from lake waters is 77.36 kg/d. The mean daily loading removed is 0.87 g/m² d but this value increases to 1.31 in *Group G* and to 2.23 in F2G, the best developed basin. The influence of wildlife is very important, and sometimes negative, but unavoidable. If every year only a basin of each group is harvested, the global efficiency is preserved.

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