Semana de Engenharia 2010
*Guimarães, 11 a 15 de Outubro*

# EUTROPHICATION-THREATENED AQUATIC ECOSYSTEMS: SEDIMENT BIOGEOCHEMICAL PROCESSES TOWARDS NUTRIENTS CONTROL

Gilberto Martins, Daniel Ribeiro, António Brito, Regina Nogueira
IBB – Institute for Biotechnology and Bioengineering, Centre of Biological Engineering, University of Minho
E-mail: gilberto.martins@deb.uminho.pt

**KEYWORDS**
Eutrophication, sediments, biogeochemical processes.

## INTRODUCTION AND OBJECTIVES

Eutrophication is the most common reason for the need of lake management and results mainly from anthropogenic activities occurring in their watersheds (Martins et al., 2008; Conley et al., 2009). Although microbial denitrification can permanently remove nitrogen (N) from a lake there is no equivalent process that can remove phosphorus (P) (McCarthy et al. 2007). Consequently, P tends to accumulate in lake sediments leading to an excess of P in the water column and the concomitant proliferation of planktonic algae (Ribeiro et al., 2008). Several methods, ranging from artificial destratification, hypolimnetic aeration, dredging, flocculation, and sediment capping using passive or active capping agents, have been developed to reduce P release from sediments (Hickey and Gibbs, 2009). In Azores, despite the considerable effort made to describe the phytoplankton growing on the water column, the lack of information regarding the microbial processes both in the water column and sediments is still high. In that regard, the present work aims to assess the sediment reference conditions of Azorean lakes (Verde, Azul, Furnas and Fogo) in order to incorporate sediment issues and knowledge into management strategies enhancing the efficacy of the remediation activities that should be taken to achieve the good ecological status until 2015.

## METHODOLOGY

Sediment samples were collected and the geochemical profiles (organic matter (OM), total N, total P, total Fe) as well as P distribution in sediments were determined. Besides, dominant members of the sediment bacterial community were identified using denaturing gradient gel electrophoresis. Subsequent, the abundance and the activity of bacteria involved in nutrient (N and P) and Fe cycling in sediments were determined by quantitative PCR and by activity tests respectively. Finally, a mathematical model for lake Verde water quality was developed in order to support the decision making processes in aquatic restoration programmes.

## RESULTS AND DISCUSSION

Biogeochemical profiles (Figure 1) showed that total P concentration in the uppermost layer of sediments seemed to be correlated with the total P concentration in the water column, and the low TN:TP ratios in upper sediment layers suggested internal nutrient cycling of P. The thermal stratification and the consequent anoxia verified in lake Verde, with the high amounts of P (mainly bound to metals ~142 μg P/g and incorporated into biomass and detritus ~108 μg P/g) in uppermost layer of sediments suggested a higher contribution of internal load of P in lake Verde than in the other lakes. For lake Azul, the geochemical profiles were quite homogeneus for all determined parameters, while in lake Furnas total Fe profile presented an peak below the oxic layer. The high amount of Fe in lake Furnas sediments might suggest a higher capacity for P retention in sediments (~47 % of total P in lake Furnas sediments was bonded to metals).

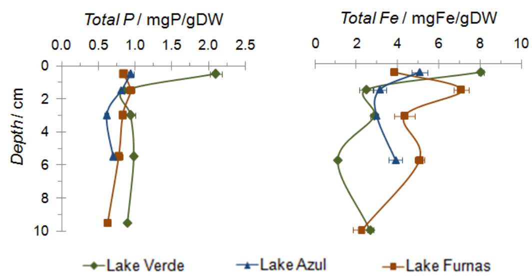


Figure 1: Vertical profiles of total P and total Fe in sediments from Azorean lakes.

Although dominant members of the sediment bacterial community in lakes Verde, Azul and Furnas were similar (mostly affiliated to phylum *Proteobacteria*, group *Bacteroidetes*/*Chlorobi* and phylum *Chloroflexi*.), the *Cyanobacteria* phylum was solely detected in sediments from lake Verde and lake Furnas that presented the highest amounts of N and P both in the water column and sediments. The combination of quantitative PCR (Figure 2) and activity tests (Figure 3) suggested that bacteria performing ammonium oxidation (aerobic and anaerobic), nitrite oxidation, heterothrophic nitrate reduction, iron reduction and biological P storage/release were present and active in sediments from lakes Verde, Azul, Furnas and Fogo. Anaerobic ammonium oxidation bacteria (4.3 % to 13.7 %) were the most abundant in sediments, followed by nitrifiers (ammonium- and nitrite-oxidizing bacteria) (0.9 % to 13.3 %), denitrifying bacteria (0.5 to 8.6 %), iron-reducing bacteria (0.1 % to 1.4 %), and phosphate-accumulating organisms (less than 0.3 %).

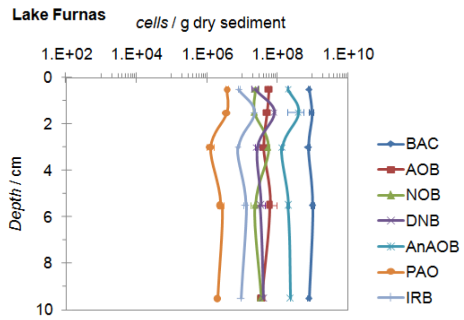


Figure 2: Sediment bacterial profiles in volcanic lake Furnas.

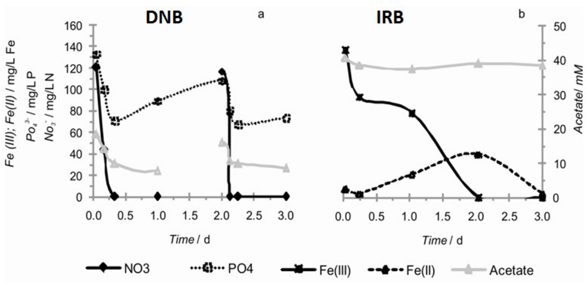


Figure 3: Activity assays of DNB and IRB in sediments.

The present work also suggested that biological P storage/release by denitrifying bacteria in sediments might as well contribute to the release of P from sediments (Figure 3).

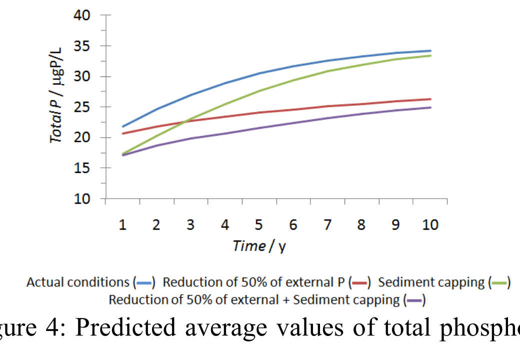


Figure 4: Predicted average values of total phosphorus concentration in Lake Verde.

The calibrated mathematical model proved to support the decision making processes in aquatic restoration programs. Prospective scenarios showed that external measures are not enough to improve water quality in lake Verde (an average concentration of total P of 26 µg/L and phytoplankton biomass of 1.4 mg/L could be reached in a 10 years horizon) and that an integrated approach (external and internal measures) need to be designed.

## CONCLUSIONS

In conclusion, the present work suggested that sediment bacteria were active and performed diverse roles on carbon, nutrients and iron cycling. The variability of sediment geochemical profiles as well as the structure and activity of sediment bacterial community indicates that individual lake sediment characterization and site-specific assessments of the efficacy of remediation approaches are required. In this regard, the designing of re-qualification strategies towards the good ecological status prescribed by the Water Framework Directive should include, in addition to the classical procedure, an evaluation of the contribution of biological processes in sediments to the eutrophication problem.

## REFERENCES

Conley, D.J., Paerl, H.W., Howarth, R.W., Boesch, D.F., Seitzinger, S.P., Havens, K.E., Lancelot, C., Likens, G.E., (2009). Controlling Eutrophication: Nitrogen and Phosphorus. Science, 323, 1014-1015.

Hickey, C.W. and Gibbs, M.M., (2009). Lake sediment phosphorus release management-Decision support and risk assessment Framework. New Zeal J Mar Freshwat Res, 43, 819–856.

McCarthy, M.J., Gardner, W.S., Lavrentyev, P.J., Moats, K.M., Joehem, F.J., Klarer, D.M. (2007). Effects of hydrological flow regime on sediment-water interface and water column nitrogen dynamics in a Great Lakes coastal wetland (Old Woman Creek, Lake Erie). J Great Lake Res, 33, 219–231.

Martins, G., Peixoto, L., Ribeiro, D.C., Parpot, P., Brito, A.G., Nogueira, R., (2010). Towards Benthic Microbial Fuel Cell implementation in Volcanic Eutrophic lakes: bacterial electrochemical activity assessment in Lake Furnas (Azores) – Portugal. Bioelectrochemistry, 78, 67-71.

Martins, G., Ribeiro, D.C., Pacheco, D., Cruz, J.V., Cunha, R., Gonçalves, V., Nogueira, R., Brito, A.G., (2008) Prospective scenarios for water quality and ecological status in Lake Sete Cidades (Portugal): the integration of mathematical modelling in decision processes. Applied Geochemistry, 23, 2171-2181.

Ribeiro, D.C., Martins, G., Nogueira, R., Cruz, J.V., Brito, A.G., (2008). Phosphorus fractionation in volcanic lake sediments (Azores - Portugal), Chemosphere 70, 1256–1263.

## ACKNOWLEDGMENTS

The authors are indebted and grateful to the Regional Department of Water Resources and Land Planning (Azores) to Virgílio Cruz and Paulo Antunes (Geosciences Department, University of Azores), to Barth Smets and Akihiko Terada (Department of Environmental Engineering, Technical University of Denmark), to Paul Bodelier (Netherlands Institute of Ecology, NIOO-KNAW) and to Isabel Henriques (Department of Biology, University of Aveiro). The authors also acknowledge the Grant SFRH/BD/25639/2005 from the Foundation for Science and Technology/M.C.T.(Portugal) awarded to Gilberto Martins.