There is mounting evidence that the condition of inland water bodies in many regions of the world is worsening. With the rapid economic growth taking place, the challenges faced by professionals dealing with the management of lakes and reservoirs is increasing. The specter of climate change poses further serious uncertainties to the management strategies which have been designed for historical conditions. Our understanding of the physical, chemical, and microbiological processes controlling water quality in lakes and reservoirs, though, has improved considerably during the last decades, and the new scientific knowledge is very useful in designing strategies to improve water quality in lakes and reservoirs. The second IWA Symposium on Lake and Reservoir Management: Sustainable Strategies to Enhance Water Quality will be convened at Granada, Spain from June 13-17, 2011. Global experts on Lake and Reservoir Management will gather in Granada to discuss approaches to Sustainable Water Quality Management, to expand networking possibilities and discuss new collaborations. The Symposium is hosted by the University of Granada, funded in 1531, and one of the leading research centers in Southern Spain, in collaboration with the IWA Specialist Group on Lake and Reservoir Management. Six keynote speakers, international experts in lake and reservoir management, will address topics such as impact of climate change on water quality, management of large scale reservoir systems in China or Brasil, nutrient sequestration in lakes, etc. Chief water managers will report on the challenges faced by their Agencies when dealing with water quality problems in Spanish reservoirs.

Local Organizing Committee

- Francisco Rueda (Univ. Granada), Chair
- Ernesto Hontoria (Univ. Granada)
- Juan Lucena (Univ. de Málaga)
- Joan Armengol Bachero (Univ. Barcelona)
- Javier Paredes (Univ. Politécnica de Valencia, UPV)
- Inmaculada de Vicente (Univ. Granada)
- Rafael Marcé (ICRA-Girona)
- Enrique Moreno-Ostos (Univ. Málaga)
- EMASESA
- Fernando Delgado (Univ. Granada)
- Elena Sánchez (Univ. Granada)
  With the collaboration of María Teresa Hontoria

International Scientific Committee

- Joan Armengol Bachero (Grupo FLUMEN, Univ. Barcelona)
- Justin Brookes (University of Adelaide, Australia)
- Michael Burch (Australian Water Quality Centre, Australia)
- Francisco Cubillo (Chair of IWA Specialist Group on Efficient Operation and Management of Urban Water Systems)
- Carmelo Escot (EMASESA)
- Tsair-Fuh Lin (National Cheng Kung University, Taiwan)
- John Little (Virginia Tech, USA) (Chair of IWA Specialist Group on Lake & Reservoir Management)
- Francisco Rueda (University of Granada, Spain)
- Alfred Wüest (EAWAG, Switzerland)
PROGRAM

Monday, June 13

Workshop on Lake and Reservoir Oxygenation

08.30 – 13:30. Topics covered by Mark Mobley, Jim Ruane, Paul Gantzer, John Little, and Enrique Dacal (Air Liquide)

Workshop on Algal Control

15.00 – 19:00 – Topics covered by Michael Burch

Tuesday, June 14

Registration and opening ceremony

08:30 – 10:00 – Registration
10:00 – 10:30 – Opening Ceremony
- Authorities of the University of Granada
- Dirección General del Agua, Ministerio de Medio Ambiente
- Consejería de Medio Ambiente. Junta de Andalucía.
10:30 – 11:00 – Coffee

Session I – Management of Lakes and Reservoirs (Chair: Francisco Rueda)

11:00 – 11:40 – Keynote scientific speech I 'Managing Lakes in a Highly Regulated but Uncertain World' (Prof. Glen George)

11:40 – 13:00 – Full oral presentations (4)
- Trends in water quality, trophic conditions, and management of Římov reservoir, the Czech Republic. Hejzlar J., Borovec J., Jan J., Kopáček J.
- Management of Lake Eppalock (SE Australia) from nearly dry to full and spilling - challenges and lessons learned – A. Graesser, B. Huider and S. Lamb
- Water quality in reservoirs under a changing climate: Potential risks and management opportunities - Rafael Marcé and Joan Amengol

13:00 – 13:30 – Short-orals + posters (4)
- Short-term environmental effects of drawdown in San Esteban reservoir (Galicia, Spain). Jordi Cirera-Boix and Francisco Rodríguez-Basanta
- Role of hydrological and physical-chemical variables on larval dynamics in Ribarroja reservoir: implication for recruitment, colonization and control of Zebra Mussel (Dreissena polymorpha) in aquatic infrastructures. – Navarro, E.; Palau, A.
- Decadal ecological changes in a deep subalpine lake: Lake Iseo, Italy. B. Leoni, P. Huang, L. Garibaldi, C.L. Marti and J. Imberger

13:30 – 15:30 – Lunch
Session II – Modelling & monitoring for water quality management (Chair: Rafael Marcé)

15:30 – 16:10 – Keynote scientific speech II ‘Advective processes in a canyon-shaped Mediterranean reservoir: ecological basis for drinking water supply management’ (Prof. Joan Armengol)

16:10 – 17:30 – Full oral presentations (4)

- An Integrated Operational Water Quality Management System for Singapore’s Inter-connected Reservoirs. - Tan Kok Meng & Eikaas Hans
- Benthic-pelagic coupling between zebra mussels and algae in western Lake Erie: Relative impacts of stratification, vertical mixing and grazing rate. Leon Boegman

17:30 – 18:00 – Short-oral + posters (4)

- Analysis and management of water masses by means of terrestrial video-image techniques: ZEUS-FLUEM project - Molina, Rafael; Hernandez, José María; Mascarell, Aina
- The Rappbode Reservoir Observatory: Monitoring nutrients and organic carbon across a whole ecosystem – K. Friese, B. Kuehn, M. Cebula, B. Boehrer, P. Herzsprung, J. Tittel, K. Rinke
- Cyanobacteria monitoring for model development – M. Ndong, D. Bird, M. Prévost and S. Dorner
- Sustainable Water Management on Regional Level via Unmanned Aerial System-based Aerial Teledetection (UAS) - Irene Eslava Lecumberri

18:00 – 18:30 – Coffee / Poster


20.00 – Visit to ‘Hospital Real’ & Reception
Wednesday, June 15

Session III – Modelling water quality (Chair, Alfred Wüst)

08.30 – 09.10 – Keynote scientific speech III ‘Climate-Driven Management Challenges for Lakes and Reservoirs in the 21st Century’ (Prof. Geoffrey Schladow)

09:10 – 10:30 – Full oral presentations (4)
- Modelling the impacts of bushfires on reservoir water quality: Upper Yarra Reservoir Case Study - Shane Haydon, Rianda Mills, Pat Lane, Gary Sherida and Hugh Smith
- Water quality management DSS for Marina Reservoir in Singapore: a eutrophication test case. A. Goebloed, H. S. Elkaas, and D. Schwanenberg
- Using a Quarry Reservoir for Raw Water Storage in Atlanta, Georgia V. Singleton, B. Jacob, M. Feeney & J. Little.

10:30 – 11:00 – Short-orals + posters (4)
- Application of hydrodynamic modelling for predicting the fate of inflows in Lake Tegel, Berlin. S. Schimmelpfennig
- Hydrodynamic model study of a shallow stratified lake (L. Pusiano, Italy) for water quality improvement planning – R. González-López, H. Ramírez-León, A. Capodaglio, F. Salerno, D. Copett
- Should intermittency of small-scale turbulence be taken into account for large scale biochemical modelling in lakes? Bonhomme C., Cuypers Y., Saad M., Violiier E., Lopez F., Vinçon-Leite B, Tassin B.

11:00 – 11:30 – Coffee / Poster

Session IV – Oxygen Balance (Chair, Leon Boegman)

11.30 – 12:50 – Full oral presentations (4)
- The large scale signature of bubble plume oxygenation systems - F. J. Rueda, Singleton, J. Little, and G. Lawrence
- Application of the technology of water-lifting and aeration (TWLA) for improving water quality in a deep canyon-reservoir: A case study from northern China. Ting-Lin Huang, Yue Ma, Hai-Bing Cong. ***
- Deep-water oxygen consumption in lakes - Alfred Wüst, Lee D Bryant, Andreas Matzinger, Martin Schmid, Beat Müller

12:50 – 13:20 – Short-orals + posters (3)
- Influence of the BBL thickness variability on diffusive-induced dissolved-oxygen fluxes in porous water-sediment interfaces – E. Sánchez-Badorrey
- Sensitivity analysis of models for the design of hypolimnetic aerators - Tinglin Huang, Xin Sun, Wushou Zhang ***
• One-dimensional evaluation of greenhouse gases emissions in a south-Brazilian reservoir
  Mannich, M.; Fernandes, C.V.S; Bleninger, T.; Mine, M.R.M. (Brazil)

13:20 – 15:30 – Lunch

Session V – Oxygen and other gases (Chair, Michael Burch)

15:30 – 16:10 – Keynote scientific speech IV ‘Comparative study on dynamics of
cyanobacterial bloom and fate of cyanotoxins in lake Taihu, Dianchi and Chao in China’
(Prof. Lirong Song)

16:10 – 17:30 – Full oral presentations (4)

• Using the source as the solution: oxygenation effects on Mn cycling and water quality. Bryant,
  Lee D., Heileen Hsu-Kim, Paul A. Gantzer, and John C. Little.
• Oxygen Diffusers to Enhance Water Quality and Fish Habitat in Natural Lakes, Water Supply
  Reservoirs and Hydropower Reservoirs - Mobley and others.
• Operating a Hypolimnetic Oxygenation System to Control Iron and Manganese in Water Supply
  Reservoirs. Paul Gantzer.
• Methane emissions from two reservoirs in a steep, sub-tropical rainforest catchment. Bradford
  Sherman and Phillip Ford

17:30 – 18:00 – Short-orals + posters (3)

• Mixing of an interflo‡ into the ambient water of Lake Iseo - Hogg C, Pilotti M, Imberger J, &
  Huppert HE.
• Impact of hydraulic management on reservoir residence time - H.Ó. Andradóttir, F.J. Rueda & R.
  Marcé
• Seasonal variations in the concentration and distribution of estrogens and pharmaceuticals in
  drinking water sources and rivers in the Luan River Basin (China). Jianghong Shi, Jinling Cao,
  Qingcai Chen & Zhifeng Yang.

18:00 – 18:30 – Coffee / Poster

18:30 – 19:10 – Invited seminar II ‘Programmes of water quality monitoring and emerging tools
for the management of the reservoirs of the Jucar Hydrographical Demarcation’. Authorities of
Confederación del Júcar, Water Management Agency in charge of water resources management
in the basin of Jucar river, Spain)

21.00 – Nocturnal visit to Alhambra (NEED TO SIGN IN)
Thursday, June 16

Session VI – Algae (Chair, Luis Cruz Pizarro)

08.30 – 09.10 – Keynote scientific speech VI - Application of the functional group concept to reservoir phytoplankton (Prof. Judit Padisak)

09:10 – 10:30 – Full oral presentations (4)
- A new device of destroying a thermo-cline and its effect of controlling algal boom in a reservoir in Japan - Kenichi Fukuda, Toshio Yamatogi, Kenji Okubo, Saburo Matsui
- High-frequency monitoring and modelling of cyanobacteria dynamics in urban lakes: Application of new approaches in Lake Enghien (France) and Lake Pampulha (Brazil). T. Silva, and others

10:30 – 11:00 – Short-orals + posters (4)
- Toward linking algal boom vulnerability with the hydropower plant operation in Rapel Reservoir – G. Ibarra & A. de la Fuente
- Development of on-line and in-situ continual quantification of algae and cyanobacteria. Eliska Marsalkova, Blahoslav Maršálek, Lenka Sejnohova, Stepan Žezulka
- Effects of essential oils and aqueous extracts of several plant species on the growth of Anabaena Cylindrica (Cyanophyta) and Chlorella Vulgaris (Chlorophyta). L. Monteiro, A. M. Geraldes, S. Barros & C. Fernandes

11:00 – 11:30 – Coffee / Poster

Session VII - Algae and Restoration (Chair, Tsair-Fuh Lin)

11.30 – 12:50 – Full oral presentations (4)
- Reservoir Management Plans for cyanobacterial blooms - a case study. Dr Thorsten D. Mosisch.
- A case study: restoration measures to control cyanobacteria in a drinking water reservoir. Castro-Castellon, AT., Hawkes, M., Yallop, M. Hayes, P.
- Microcystis-targeted restoration strategies - Maršálek B., Eliska Marsalkova, Lenka Sejnohova, Holba M., Miroslav Ploteny, Roman Sladek & Jiri Palcik
- Freshwater Lake Restoration in China: History and Prospective. Boqiang Qin **

12:50 – 13:20 – Short-orals + posters (4)
- Cyanobacterial bloom dynamics - some lessons from the Nineties. Bradford Sherman, Phil Ford, and Ian Webster.
- Evaluation of cascade effect of reservoirs on water quality and relationship with biological community composition - Saldaña-Fabela P and others. ***
- Manganese sources and cycling in a tropical eutrophic water supply reservoir, Paso Bonito Reservoir, Cuba - C. Betancourt, F. Jorge, R. Suárez, M. Beutel & S. Gebremariam
- Sedimentary phosphorous in a cascade of 5 reservoirs (Lozoya River, Central Spain). Pilar López, Rafael Marcé, Iñaqui Urrutia, Mari Carmen Gordo y Joan Armengol.

13:20 – 15:30 – Lunch
Session VIII – Restoration and sediments (Chair, Inmaculada de Vicente)

15:30 – 16:10 – Keynote scientific speech VIII ‘Lake restoration by nutrient loading reduction and in-lake measures’ (Prof. Erik Jeppesen)

16:10 – 17:30 – Full oral presentations (4)

- The Effects of Nitrate on Nutrient Cycling at the Sediment-Water Interface of a Thermally Stratified Water Supply Reservoir. F. Cubas, J. T. Novak, A. N. Godrej, and T. J. Grizzard
- Characterization of bottom sediments in lakes using hydro-acoustics and comparison with laboratory measurements. Michael A. Anderson
- Improvement of eutrophication in the Ancient Canal by active zeolite barriers capping. Jinlan Xu, Junchen Kang, Tinglin Huang, Sen Wang ***
- European experiences in lake restoration and cyanobacterial control through in situ phosphorus binding with Phoslock®, a lanthanum enriched bentonite. Patrick Van Goethem

17:30 – 18:00 – Short-orals + posters (5)

- Use of the HSPF Nutrient Algorithm PQUAL: Calibration, Verification and Sensitivity Analysis for the Upper Broad Run Watershed, Virginia - Yingmei Liu, Adil N. Godrej, Thomas J. Grizzard
- Application of iron sulphate on the reservoir inflow as the control measure for external phosphorus and cyanobacterial load - Maršálek B., Jancula Daniel, Eliska Marsalkova, Lenka Sejnohova, Holba M., Miroslav Ploteny, Roman Sladek, Jiri Palcik
- Field Test of Reservoir Management Practice Pollutant Removal Efficiencies in Southern China - Ru Zhang, Wenbin Zhou, Richard Field, Anthony Tafuri, S. L. Yu **

18:00 – 18:30 – Coffee / Poster

18:30 – 19:10 – Invited seminar III (President of Confederación del Guadalquivir, Water Management Agency in charge of water resources management in the basin of Guadalquivir river, Spain) – Closing ceremony

21.00 – Gala dinner

Friday, June 17

08:00 – 20:00 Technical Trip – organized by EMASESA to visit the Seville Water Supply System

Or

Touristic Tour in Granada
Poster presentations

Session 1

1.- From the ocean to the reservoir: the influence of the Gulf Stream position on the phytoplankton community in El Gergal reservoir (SW Spain). E. Moreno-Ostos, and others
2.- Current situation of Cyanobacterial abundance in Spanish reservoirs, with emphasis on differences related to basin bedrock categories. Caridad de Hoyos & others.
3.- Hydrological sustainable management of anthropized wetlands in Mediterranean climate: a case study of northern Algeria. Martín-Rosales & others.

Session 3

6.- Physical modelling of lake Lagarfljót, Iceland - Morgane Priet-Mahéo1, Hrund Ó. Andradóttir1 and Francisco J. Rueda2.
7.- An analysis of multi-reservoir operation using multi-objective optimization algorithms. Gerald A. Corzo P, Jie Wen, Oscar Hernandez Murcia, CongJiao Zhang, HongLi.
8.- Characterization and biogeochemical modelling of a water reservoir that receive acid mine drainage in the Odiel basin, SW of Spain. Torres & Ayora.
9.- Simulation of the growth and movement of Microcystis colonies with a size distribution by particle trajectory modelling Yu-ching Chien and Shian-chee Wu.
10.- Circulation and mixing at the confluence of two rivers entering a meandering reservoir. C. Ramón, J. Dolz, J. Armengol and F. Rueda.

Session 4

11.- Developing a Coupled Bubble-Plume/Reservoir Model for Carvins Cove Reservoir Mallory Barkdull, Vickie Singleton, Kevin Bierlein, Francisco Rueda, and John Little.

Session 5

12.- River inflow mixing in stratified Mediterranean reservoirs - Alicia Cortés, Fco Rueda, W.E. Fleenor and others.
13.- The radiological characteristics of sediments from several reservoirs in Granada. Piñero García F. and others.
15.- On the water thermal response to the passage of cold fronts over a tropical hydroelectric reservoir, Enner Alcantara.

Session 6

16.- The effects of selective withdrawal on the succession of phytoplankton communities in reservoirs, Rigosi, A., Rueda, F.
17.- Modelling the longitudinal distribution of phytoplankton in a periodically forced reservoir. Javier Vidal, Anna Rigosi, Andrea Hoyer & Francisco Rueda.
19.- Dominant bacterio-plankton phytypes in geographically distant Portuguese water bodies under a severe summer drought scenario de Figueiredo D.R., Pereira M.J. & Correia A.

21.- Spatial bacterioplankton diversity at Vela Lake (Central Western Portugal) during cyanobacterial blooms and under severe drought conditions. de Figueiredo D.R., Castro B.B., Pereira M.J. & Correia A.

22.- Phytoplankton community dynamics in a recent reservoir, La Breña II (Córdoba, Spain) – C. Hidalgo-Lara, M.J. Fernández-Rodríguez, P. Peñalver, D. León & J. Toja.

Session 8


25.- Six years of experiences with the application of polyaluminiumchloride for cyanobacterial blooms treatment and lake restoration - Blahoslav Marsalek, Daniel Jančula, Eliska Marsalkova, Darina Vinklárková.

26.- Microbial food web bio-manipulation: a low cost tool for control of eutrophication in Mediterranean reservoirs. Dorado-García, I.; Medina-Sánchez, J.M.; Carrillo, P.


28.- Modelling of collapse of aggregated minute soil particles from forest basins due to temperature change Goro Mouri, Seirou Shinoda and Taikan Oki.


30.- Restoration of north german shallow lake using lanthanum modified bentonite. S. Yasseri.
Managing Lakes in a Highly Regulated but Uncertain World (KEYNOTE SPEECH)

D.G. George
University College, London, and University of Aberystwyth, UK

Contact email: glen@abercuch.wanadoo.co.uk

Abstract

Those charged with the management of lakes are now facing the twin challenges of more rigorous environmental regulation and the uncertainties associated with the projected change in the climate. In Europe, the objectives set by the Water Framework Directive (WFD) require Member States to maintain or enhance the ecological status of all the aquatic habitats in their territories by 2015. At present, the associated remedial measures are focused on the management of the surrounding catchment but future programmes will have to pay more attention to the perturbing effects of the climate. In this review, I discuss some of the techniques that can be used to quantify the relative effects of ‘local’ changes in the catchment and ‘regional’ changes in the weather on the dynamics of lakes. Regional Climate Models (RCM’s) provide the best available means of predicting the large-scale effects of changes in the climate but cannot resolve the small-scale events that have such an important effect on the seasonal dynamics of lakes. Here, I describe how the outputs from these RCM’s can be combined with the results from a stochastic ‘weather generator’ (WG) to produce more realistic assessments of the changes expected in future decades. The WG described here uses time-series of meteorological measurements to derive a set of parameters that can be used to produce multiple-sequences of the daily weather. These sequences were then used to drive a range of lake and catchment models and explore the potential impact of some extreme weather events. The review includes some examples of the way in which short-term (week-to-week) changes in the weather influence the physical, chemical and biological characteristics of lakes. These examples are taken from some recent studies of the climatic effects noted in two Welsh lakes (Llyn Padarn and Llyn Peris). In Llyn Padarn, a combination of an unusually mild spring and a wet summer resulted in an unexpectedly prolonged bloom of the cyanobacterium Anabaena flos aquae. In Llyn Tegid, the high-resolution measurements acquired by an automatic monitoring station revealed that the flux of nutrients into the lake was periodically enhanced by the transfer of sediment from the surrounding catchment and the entrainment from the deep water. The review concludes by discussing some of the way in which meso-scale changes in the circulation of the atmosphere can either increase or reduce the severity of the water quality problems experienced at a particular location. For example, periods where the synoptic situation is dominated by high pressure give rise to more stable stratification and an increased risk of prolonged cyanobacterial blooms. In recent years, summers in the UK have been unusually cool and wet so such blooms have tended to appear at the end rather than the beginning of the summer. The main factor responsible for these atypical summers was the position of the fast-flowing, high altitude current of air known as the Atlantic Jet Stream. When the Jet Stream returns to its more usual ‘northerly’ position, summers in the UK will become warmer and drier and there will be a corresponding change in the periodicity of the cyanobacteria.
Trends in water quality, trophic conditions, and management of Římov reservoir, the Czech Republic (Full Oral Presentation)

Hejzlar J., Borovec J., Jan J., Kopáček J.

Biology Centre AS CR, Institute of Hydrobiology, Na Sadkach 7, 370 05 Ceske Budejovice, Czech Republic

Contact email: hejzlar@hbu.cas.cz

The drinking water supply Římov Reservoir is a dimictic, canyon-type, and eutrophic water body (volume, 34 hm3; area, 2,1 km2; max/mean depth, 43/16 m; mean water residence time, 91 d) that underwent many changes since its first filling in 1979. For example, hydrological conditions of the water pool were modified by changed operation rules to increase flood control efficiency in the end of 1990s, external nutrient loads (P, N) continuously decreased during the whole period, and concentrations of dissolved organic matter (DOM) in the reservoir inflow started to increase dramatically in the middle of 1990s. The study aimed to elucidate causes of water quality problems in this reservoir and show methods employed for their alleviation. An analysis of the inflow and in-reservoir P concentrations via empirical P retention models showed that the development of trophic conditions corresponded to a long-term stable reservoir ability for P retention and that no increase in the internal P load from sediments occurred. This result was supported also by a study of sediment accumulation rates in the reservoir and characterizations of sediment composition by P fractionation techniques. Nevertheless, it seems that further reductions of external P loads, especially during the vegetation period, is inevitable for the desired reduction of trophic level and restriction of anoxic conditions in the hypolimnion that cause water quality problems due to increased Mn concentrations etc. Problems with water quality deterioration in the reservoir by DOM inputs during high runoff events from the catchment in the vegetation season were analysed by the modelling of reservoir hydrodynamics and water quality with the CE-QUAL-W2 model. Based on results of scenario modelling, optimum outflow depth rules were designed and applied to shortcut DOM-loaded inflow water masses through the metalimnion, hence preserving clean water in the upper hypolimnion for the waterworks’ withdrawal during the stratification period.
Management of Lake Eppalock (SE Australia) from nearly dry to full and spilling - challenges and lessons learned (Full Oral Presentation)

Dr Anne Graesser, Ms Bianca Huider and Mr Stephen Lamb
Goulburn Murray Rural Water Authority, Victoria, Australia

Contact email: anneg@g-mwater.com.au

ABSTRACT

Lake Eppalock is a 300 GL storage in the southern part of the Murray Darling Basin, Australia. It is used as a popular recreational venue, a source of drinking water for various regional centres and supplies irrigation water to farmers. Eppalock is a relatively modern storage built in the early 1960s. The multi-level offtake tower has to be manually operated to take water from various depths. The storage is located in the foothills of the Campaspe river catchment. Historically, its catchment was mainly livestock farming with some forestry and gold mining. Now more of the catchment is urbanised with “tree-changers” taking over smaller farms on the fringes of urban centres and developing hobby farms or lifestyle blocks, as well as more intensive agricultural developments such as vineyards and olive groves. These changes have significantly affected land management practices. Under normal circumstances, the water authority has obligations to release water from the storage to support the downstream aquatic environment. This storage has experienced periods of stratification that resulted in deoxygenated water being released downstream as well as significant blooms of toxic cyanobacteria (Anabaena circinalis and Microcystis aeruginosa) and elevated levels of dissolved manganese in the storage hypolimnion. From time to time, these conditions have threatened the usage of the stored water supplies. The water authority is working with regional agencies to improve storage and catchment conditions such as improving adjoining land management practices and onsite domestic wastewater management, and restoring riparian buffers along streams and rivers. Catchment models have been developed to prioritise subcatchments for the water quality improvement. Over the past decade, when the Murray Darling basin has experienced the worst drought since rainfall was recorded in Australia, water levels have gradually declined with lowest levels around 1% storage capacity recorded in 2009. During the drought, recreational fish stocks, water based recreation, drinking water and irrigation water supplies were threatened in the storage as well as the downstream environmental values. Since 1998, cyanobacteria levels have been routinely monitored and dissolved oxygen concentrations, water temperature and electrical conductivity have been monitored throughout the water column since 2005 in response to the drying conditions. This information has enabled the water authority to balance the risks associated with maximising water availability with releasing poor quality water downstream into the river system to maintain environmental values during the drought period. This presentation will demonstrate how improved monitoring of key water quality parameters has continued to benefit our operational management of the storage and river system during the more recent flood conditions.
ABSTRACT

The importance of water resources stored in reservoirs on a global scale is not matched with a sound knowledge of the possible impacts of climate change on reservoir water quality. This is especially relevant in the Mediterranean regions, where most countries rely on reservoirs to fulfill their water supply needs, and virtually all climate models predict increasing water shortage in the next 20 years. In this talk, we show a close coupling between streamflow entering reservoirs and its hypolimnetic oxygen content for a wide range of systems. In brief, high streamflow maintains anoxia at comparatively low levels. Therefore, we can expect a reduction in water quality following future reductions in runoff. To illustrate these effects, we analyzed a 44 year data set of oxygen measurements from Sau Reservoir in Spain to detect possible effects of climate variability on the extent of deep-water anoxia. In addition, we show that a trend of decreasing streamflow, related to climate change, has increased the risk of anoxia in the reservoir during the last decade. From these results, we propose a framework for climate change impact studies on reservoir water quality using streamflow and labile organic matter as master drivers. Finally, we identify the research required to improve our understanding of how reservoirs will behave in a changing climate, and give some guidelines on how to manage Mediterranean reservoirs under future “scarcity” conditions.
Best Management Practices in Reservoirs. Revision of environmental techniques and applied research in a guide for managers

Ana García Bautista (1), Francisco Javier Sánchez Martínez (2), Rafael Minaya González (1), and Mariano Cebrián del Moral (1)

(1) Infraestructura y Ecología S.L.
(2) Ministerio de Medio Ambiente y Medio Rural y Marino.

Contact email: mcebian@infraeco.es

ABSTRACT

Dams and reservoirs provide our societies with benefits, but they also represent negative impacts for the natural environment they completely change. Nowadays, reservoir management is conditioned by the necessity of preserving the aquatic ecosystems health and social use; in Europe, there is also the imperative set by the Water Framework Directive of achieving the Good Ecological Status for all water bodies in year 2015, including reservoirs and rivers downstream dams. This communication will present a revision of environmental techniques and applied research in a guide for managers in Spain, which will be published soon: The Guide for Best Management Practices in Reservoirs. This document is about the state of the art in matching the demands on regulated water resources with environment protection. Very briefly, the aims of this Guide are: (1) To identify major environmental issues in reservoirs; (2) To propose an evaluation system to know if the reservoir management is integrating the adequate environmental criteria; (3) To present the most illustrative previous experiences in Spain and abroad; (4) To describe possible measures and to classify them depending on the environmental element they concern (fish or other fauna, riparian vegetation, physic and chemical water quality…); and; (5) To be a reference for reservoir managers on practices and measures with an environmental aim, to help the assessment process and decide which of them are feasible and desirable in each case.
Short-term environmental effects of drawdown in San Esteban reservoir (Galicia, Spain)

Jordi Cirera Boix (1) y Francisco Rodríguez Basanta (2)

(1) United Research Services España, S.L. (URS). C/Urgell nº143, 4ª. 08036, Barcelona (Spain)
(2) Iberdrola Generación, S.A. Generación Sil. C/Circunvalación nº17. 32350, A Rúa (Spain)

Contact email: jordi_cirera@urscorp.com

ABSTRACT

The environmental effects of San Esteban reservoir drawdown were studied. This reservoir, which is located in the river Sil (NW Spain), has a total volume of 213 hm³ and a maximum water depth of 105 m. The drawdown was conducted during spring 2010 in order to build a new outlet for the hydroelectric power plant. The water level was lowered 31 m and the reservoir remained within 30.8% of total volume until October 2010. In normal conditions, the reservoir has a very stable water level, and during the last 49 years has remained within 85% of its total volume, consequently large amounts of sediments have deposited in the transition zone.

The main environmental effects of the drawdown and the maintenance of a low water level were: 1) a reduction of physical habitats for fish and 2) the alteration of water quality by the mobilization of sediments, increasing turbidity and affecting the patterns of water stratification in the reservoir. The environmental adequacy of the operation, which took 30 days, consisted in controlling the speed of the drawdown and the river inflow. With a drawdown rate of 3.5 cm/h and a river inflow rate of 112 m³/s, sediments were gradually mobilized, producing little effect on water quality and preventing damage to fishes.
Role of hydrological and physical-chemical variables larval dynamics in Ribarroja Reservoir: implication for recruitment, colonization and control of Zebra Mussel (Dreissena polymorpha) in aquatic infrastructures.

Navarro, E.1; Palau, T.2
1. CSIC - Instituto Pirenaico de Ecología; Av. Montañana 1005; Zaragoza 50059; España

Contact email: enrique.navarro@ipe.csic.es, antonio.palau@endesa.es

ABSTRACT

During the summer of 2001, Zebra mussels (Dreissena polymorpha) were found in the coupled reservoir system composed by Mequinenza, Riba-Roja and Flix (Ebro River, Northeast Spain). Two years later, mussels successfully settled, reaching densities of 4000 adults m-2. Since then, an extensive and intensive monitoring program has been implemented in those reservoirs. This work presents a summary of this monitoring, focusing on how Riba-Roja hydrological conditions and other environmental variables (as temperature) might be controlling both the larval dynamics of zebra mussel and its settling success or failure. Larvae density and water column physical-chemical characteristics were assessed in different points of the reservoir, upon a monthly or biweekly sampling. Physical-chemical profiling was used also to characterize water flow in the reservoir through year. Because the short residence time (between 2 and 15 days), Riba-roja water characteristics and summer stratification depend more on the quality and temperature of water inputs than in its biological activity. These inputs come from the previous reservoir (Mequinenza) and a tributary (Segre-Cinca). The most favourable conditions (oxygen, temperature) for zebra mussel gamete fecundation prevailed from April to June. Indeed, the maximum density of larvae is usually detected in June near the dam. During these months it was found a positive relationship between water residence time and the maximum density of larvae. It was also noticed that intensive water drawn during this period (due to intensive rain events), provoked an acute and sudden reduction on larval densities through reservoir. These two evidences may lead to the implementation of measures aiming at reducing the settling of new mussels in aquatic infrastructures.
Decadal Ecological Changes In A Deep Subalpine Lake: Lake Iseo, Italy

Barbara Leoni¹, Peisheng Huang², Letizia Garibaldi¹, Clelia Luisa Marti² and Jorg Imberger²
¹ Dipartimento di Scienze dell’Ambiente e del Territorio, Università degli Studi di Milano-Bicocca, Italy
² Centre for Water Research, The University of Western Australia

Contact email: barbara.leoni@unimib.it

ABSTRACT

During the last 35 years Lake Iseo, located in the Lombardy region of Northern Italy, experienced a significant increase in phosphorus content in the water column, and a tendency for warmer water. The trophic status changed strongly during the last century with a 7-fold increase in total phosphorus concentrations from 1960s to the late 1990s. The increase in water temperature in Lake Iseo is analogous to the warming recorded in other subalpine deep lakes. The aim of this work is to use a long term physical, chemical, and biological field data combined with the three-dimensional coupled hydrodynamic-ecological model ELCOM-CAEDYM to identify and interpret the effects of anthropogenic nutrient alterations and climatic fluctuations on the evolution of the trophic state, on stability of water column, on the development of phytoplankton communities and on the resulting deterioration of hypolimnetic waters in the deep Lake Iseo.
SESSION 2
Abstract

The water quality management of the reservoir of Sau has been based on three approaches: 1) To reduce the point sources pollution from the watershed, 2) To improve the “in situ” biological processes in the reservoir, which reduces the amount of organic matter and nutrients across the reservoir, and 3) To increase the thermal stability of the water column allowing the selection of the best water quality that outflows the reservoirs.

In this presentation we will emphasize on the chemical and biological processes that takes place inside the reservoir. From the plunge point to the dam the hydrodynamics of the superficial water of Sau follows a piston model. The inflow of the river Ter, a polluted river with high concentrations of nutrients and organic matter allows the formation of a clear gradient in the composition of the water across the reservoir. The coupling of hydrodynamics and river exports explains the formation of a heterotrophic-autotrophic gradient that supports a structured set of microbial, phytoplankton and zooplankton communities organized as a spatially segregated food web. As a result of these processes, and mainly because the biological activity, Sau works as a highly efficient system that transform the polluted water inflow and improves the water quality at the outflow.
A synthesis of physically-based water quality model and multi-agent-based model for spatial pattern dynamics of aquatic plants (Full Oral Presentation)

Hong Li (1) & Arthur E. Mynett (2)
(1) International Water Association, 2595AA, The Hague, Netherlands hong.li@iwahq.org
(2) UNESCO-IHE Institute for Water Education, P.O. Box 3015, 2601DA Delft, Netherlands
Delft University of Technology, Faculty CiTG, P.O. Box 5048, 2600 GA Delft, Netherlands

Contact email: hong.li@iwahq.org

ABSTRACT
Aquatic ecosystems are sensitive to rapid economic development, urbanization, population growth, and effects of climate change. The UN Millennium Development Goals and the EU Water Framework Directive are putting emphasis on ensuring environmental sustainability through improved water resources management. Research on assessing potential impacts and optimising effects of measures to aquatic ecosystem is essential. Spatial pattern dynamics is one important aspect used to reflect the consequences of internal and external pressures on aquatic ecosystems, and supplies basic information to help understand the behaviour of these systems as a whole. Therefore, research on spatial pattern dynamics is important for the sustainable management of aquatic ecosystems. However, aquatic ecosystems are among the most complex due to the highly nonlinearity, randomness, as well as interactive multi-processes in multi-scales. Besides, highly limited understanding and very limited measurement data make the modelling of such kind of systems a very challenging task, which needs to combine domain knowledge, available data and other models. The present study demonstrates the capabilities of integrating biotic and abiotic processes in environmental systems modelling with a case study carried out in Lake Veluwe, the Netherlands. Abiotic processes like hydrodynamic flow and transport phenomena are often formulated based on physical principles like conservation of mass, momentum and energy. These processes are quite well represented mathematically by second order partial differential equations that can then be solved numerically in a variety of ways. However, in aquatic ecosystem modelling, biological/ecological processes play an important role and these processes are not always understood at adequate level of detail to be captured in terms of conservation principles. Still, biotic processes may also be represented by mathematical equations, be it of a different class like coupled ordinary differential equations for population dynamics modelling or data-driven approaches like neuro-fuzzy computing for processes that are not yet well understood. In this paper a particular modelling approach for biotic processes is explored for representing spatial pattern dynamics of aquatic ecosystems, viz. Multi-Agent Systems (MAS). The concept of Multi-Agent Systems (MAS) in modelling spatial population dynamics of aquatic plant growth is explored in this research due to the capability of MAS in utilizing various information and data, reflecting both the interactions among different entities and entity’s own properties. Expert biological knowledge, GIS maps and environmental conditions are used as input information and data in the development of submerged plant spatial dynamics model. Several different aspects are included: plant agents, environmental backgrounds, and animal influences. A synthesis approach of multi-process, nonlinear feedback systems into a unified modelling framework was developed. This synthesis approach included both continuous processes, conventionally modelled by differential equations (by using Delft3D software package), and discrete processes modelled here by a Multi-Agent System approach. Although the feedback from aquatic plant dynamics to the flow pattern was not included yet in this synthesis approach, the results in this research show that integration of different types of models holds the potential of representing the combined features of nonlinearity, randomness and complexity of aquatic ecosystems. Moreover, the synthesis approach developed here enhanced the conventional differential equation based modelling that was already available.
An Integrated Operational Water Quality Management System for Singapore's Inter-connected Reservoirs (Full Oral Presentation)

Tan Kok Meng & Eikaas Hans
Waterways Health and Limnology Unit
Catchment Waterways Department
Public Utilities Board

Contact email: TAN_Kok_Meng@pub.gov.sg

ABSTRACT

An Operational Management System (OMS) embedded with a fully functional hydrodynamic and water quality modelling framework has been developed to help manage the water quality in the reservoirs in Singapore. In essence, this OMS provides the temporal and spatial information on meteorological observations, 1D and 3D surface water movements through a network of canals, rivers and reservoirs and finally the observed and modelled water quality of the receiving waterbodies. The OMS incorporates, visualises and integrates numerous data-feeds from various sources of online field observations as well as historical stored data. The field observations include precipitation, solar radiation, wind, cloud cover for meteorological parameters, the water levels and discharges at various locations of the inflow tributaries and water quality profiles from online profiler stations in the reservoirs. The modelling framework comprises of the hydrological and hydrodynamic models, the 3D hydrodynamics and the 1D and 3D water quality models. The models use the meteorological forcing data and the discharges at the in and out flows of the reservoirs as inputs to compute the water quality. The OMS then visualises the results as timeseries charts or as spatial water quality maps for hotspots and important locations such as the water intake structures. The OMS is a server-client based system whereby the models reside on a central server system that users access remotely from within the organisation. An added feature incorporated into the OMS is the use of rainfall forecast results from NCEP Global Forecast System and from a local rainfall forecasting project with a research institution to make prediction of the likely water quantity and quality that the operator could expect in the immediate future. On a daily basis, all these information are displayed logically with respect to the water cycle on multi-screens with each showing the essential information that refreshes at regular intervals. Alert via email or text messages are also configurable in the system.
Effect of Series of In-stream Reservoir Constructions in the Nakdong River, Korea (Full Oral Presentation)

D. Seo*, M. Kim*, S. Bae*
* Dept. of Environmental Engineering, Chungnam National University, 220 Gung-dong Yuseong-gu, Daejeon 305-764, S. Korea

Contact email: seodi@cnu.ac.kr

ABSTRACT

Series of in-stream reservoirs construction plan is being implemented in the Nakdong River, Korea as a part of 4 great river restoration projects to mitigate effects from flood and drought and to improve environmental conditions of the river. Serial use of 3 Dimensional hydrodynamic model, EFDC and water quality model, WASP are used in combination to predict flow and water quality of the river after the construction. While estuarine dam has been in operation in the Nakdong River since 1987, this project will strengthen this dam and build 8 additional instream structures in the 334 km long section of the river. For modeling the river was divided total of 3036 segments including 1500 horizontal and 2 vertical grids. Flow and waste load data were collected from Korean governmental data base management systems and the model was calibrated using data collected for the river by Korean government for data set of 2007. In general, due to reservoir constructions in the river, annual average BOD5 concentrations became lower due to increased detention time while annual average TN and TP concentration were found to be about the same. However, Chl-a concentrations in the river significantly increased almost everywhere except near to estuarine dam area where Chl-a concentrations became lower after the construction. It seems overall decrease of light availability due to increased depth of the estuarine dam area is responsible for this results.

Keywords: Water Quality Model WASP, 3-D Hydrodynamic Model EFDC, The Nakdong River, 4 Great River Restoration Project, Korea, Estuarine Dam
Benthic-pelagic coupling between zebra mussels and algae in western Lake Erie: Relative impacts of stratification, vertical mixing and grazing rate (Full Oral Presentation)

Leon Boegman
Environmental Fluid Dynamics Laboratory, Department of Civil Engineering, Queen's University, Kingston, Ontario K7L 3N6, Canada

Contact email: Leon.Boegman@civil.queensu.ca

ABSTRACT

Zebra mussels (Dreissena polymorpha) are an invasive species that have been implicated in the reduction of algae stocks in the near-shore environment of western Lake Erie. To determine their basin-wide effects, we applied a two-dimensional hydrodynamic and water-quality model for 1994. The model accurately reproduced lake-wide hydrodynamics and water quality. When modeled as true benthic organisms (resting on the bottom), the dreissenids grazed 53% of the western basin May through September net algal growth. This grazing resulted in a ~0.1 mg/L reduction in the pelagic algae concentration relative to the case without dreissenids. In comparison, dreissenids grazed 77% western basin net algal growth when the lake was modeled as a fully mixed water column. We found that the biomass grazed was governed by a balance between the timescales of vertical wind-induced mixing and benthic grazing. During calm conditions, weak diurnal stratification (~1°C between surface and bottom waters) was sufficient to suppress vertical mixing, when the mean daily wind speed 4 m above the lake surface ($U_4$) was ~6 m/s. These conditions allowed a concentration boundary layer ~1 m thick to form, accounting for the reduced grazing effect relative to the fully mixed case. Entrainment of the concentration boundary layer occurred for $U_4 > 6$ m/s (associated with the lake’s characteristic 10-d storm cycle) facilitating algae supply to the benthos. We formulated the mean daily biomass grazed in terms of the dreissenid areal pumping rate ($\alpha$) and $U_4$ and found that because typically $U_4$ is <6 m/s, the western basin is weakly stratified thermally and a concentration boundary layer forms when $U_4 < 3 \alpha$ or $\alpha > 2$ m$^2$/m$^2$/d. The dynamics of both wind-mixing and thermal stratification must, therefore, be considered in mixing models applied to shallow weakly stratified lake basins.
Analysis and management of water masses by means of terrestrial video-image techniques: ZEUS-FLUEM project

Molina, Rafael ¹; Hernandez, José María ²; Mascarell, Aina ²

¹ Laboratory of Ports, Cátedra Pablo Bueno. Universidad Politécnica de Madrid.
² TECNOMA, TYPSA Group.

Contact email: rmolina@caminos.upm.es

ABSTRACT

The quality of water bodies, specifically the diagnosis and study of trophic status of them, requires the monitoring of multiple parameters. Within the framework of environmental monitoring and exploitation of reservoirs, these parameters are usually analyzed by *in situ* instrumental techniques or in laboratory. In this sense, the analysis of satellite and aerial images has enabled to support the evaluation of multiple processes related to eutrophication, providing information from a broader territorial perspective. Nowadays, terrestrial video-image is an economical and versatile alternative tool, as it offers a better spatial and temporal resolution.

The team of the Laboratory of Ports of the Universidad Politécnica de Madrid works since 2004 in video-image monitoring techniques. The result of this work was the project of video-image analysis called ZEUS (Zenithal-Unattended-System) In 2009, it was signed a collaboration agreement with the company TECNOMA, from which ZEUS- FLUEM was born, in order to adapt its abilities to the monitoring of rivers and reservoirs.

The project's objective is to design an automatic system for reservoirs monitoring in real time, using hyperspectral analysis and video-image techniques. The system aims to determine the temporal and spatial variation of chlorophyll levels, the early prediction of "blooms", the classification of algal groups, as well as the detection of floating particles which may be associated with the presence of surface pollutants. This tool also includes parallel applications for the management of public waters (control of the intrusion and navigation, detection of floating particles), for the support to the exploitation (filling height, control of overflow channels, support for the auscultation of the dam) and environmental management (vegetation, birds) from the shore of the reservoir.

Keywords: chlorophyll, spectral signature, monitoring of reservoirs, video-image, spectral analysis of images.
The Rappbode Reservoir Observatory: Monitoring nutrients and organic carbon across a whole ecosystem

Kurt Friese, Burkhard Kuehn, Malgorzata Cebula, Bertram Boehrer, Peter Herzsprung, Jörg Tittel, Karsten Rinke
UFZ - Helmholtz Centre for Environmental Research, Department Lake Research, Brueckstr. 3a, D-39114 Magdeburg, Germany,

Contact e-mail: kurt.friese@ufz.de

ABSTRACT

Climate change is one of the most essential and pressing challenges for water managers in the actual decade. An increase in concentration of dissolved organic carbon (DOC) in surface waters is observed on the northern hemisphere for over 15 years (Monteith et al. 2007). Also in Germany, an increase of DOC concentration is registered in several reservoirs. Some authors argue that this increase in DOC might be a result of increasing global average temperature. To identify the sources and pathways of the organic carbon fluxes an extensive observatory was installed in the Rappbode reservoir system, the largest drinking water reservoir in Germany, located in the eastern Harz Mountains. Automatic probes for continuous registration of DOC, nitrate (NO$_3^-$), electric conductivity (EC), and temperature (T) were deployed in the inflow rivers of the pre-dams, overflow points to the main dam and at the outlet of the main dam. In addition, four automatic water samplers were placed at the four inflows. Three automatic probes complement the data acquisition with vertical profiles of T, EC, pH, and dissolved oxygen (DO) at the deepest points of both pre-dams and the main-reservoir. Finally, a meteorological buoy collects data of wind direction and speed, air temperature, amount of precipitation, and global radiation on the main reservoir. First results from a study at the Muldenberg reservoir (Ore Mountains, Saxony) showed a high positive correlation of DOC concentration and amount of precipitation or discharge, respectively. For the sediment quality monitoring a step wise approach will be performed. A single sediment coring program is combined with bi-monthly pore water analyses and monthly sediment trap collection. In a later step the potential sediment source units will be characterized and classified. It is assumed that the sediment will act as an important carrier for the organic carbon balance of the system (source and sink, respectively depending on the environmental conditions).
Cyanobacteria monitoring for model development

Mouhamed Ndong¹, David Bird², Michèle Prévost¹ and Sarah Dorner¹

1 École Polytechnique de Montréal, 2 Université du Québec à Montréal
mouhamed.ndong@polymtl.ca

ABSTRACT

Many lakes are affected by cyanobacteria and cyanobacterial toxins which can present a health risk for exposed communities and can reduce economic activities related to the water body. Tools are needed to improve cyanobacteria bloom prediction in order to plan treatment responses and mitigation strategies. The environmental factors leading to cyanobacterial blooms at Missisquoi Bay in Lake Champlain in southern Quebec were studied. Missisquoi Bay situated in the northern region of transborder Lake Champlain, is a eutrophic water body with recurring cyanobacterial blooms, and is used as a drinking water source. In situ probes were installed in the bay from 2007-2010 to follow bloom-related variables, including phycocyanin fluorescence, chlorophyll a, pH, temperature, dissolved oxygen and turbidity. Multiple regression analysis for data from 2007 to 2009 demonstrated that turbidity and daily variation of pH and dissolved oxygen, and atmospheric humidity were the best predictors of cyanobacteria biomass (respectively $R^2 = 0.58$, $R^2 = 0.49$, $R^2 = 0.40$, all $p < 0.05$). The unexplained variance was strongly related to changes of the weather conditions. A time-series analysis was performed to determine the effects of weather conditions on cyanobacteria proliferation in Missisquoi Bay. Weather conditions such as temperature, precipitation, wind speed and direction, relative humidity were considered in the analysis. For 2008 and 2009, the weather conditions demonstrated significant covariance with the accumulation of cyanobacteria, although the relationship was not strong. A similar trend was not observed for 2007 in which cyanobacterial biomass was extremely low. On a seasonal scale, winds effects from the south were dominant during 2008 and 2009 but not in 2007, suggesting that year-to-year variations might be related to lake mixing dynamics. But more importantly, on a daily scale, there was clear evidence of downwind buildup of toxic biomass. Thus, weather conditions, and particularly wind direction, might usefully be incorporated into monitoring tools for early warning systems for cyanobacteria proliferation in lakes and reservoirs. A hydrodynamic model of cyanobacteria buildup and toxin production is being developed that will model the effect of weather conditions on the occurrence of cyanobacterial blooms and toxin production in Missisquoi Bay.
AG_UAS PROJECT: “Sustainable Water Management on Regional Level via Unmanned Aerial System-based Aerial Teledetection (UAS)”

Irene Eslava Lecumberri
Navarra Industry Association. S. Cosme y S. Damián s/n 31191 Cordovilla (Navarra) Spain

Contact email: ieslava@ain.es

Abstract

AG_UAS is a Life project engaged in sustainable water management on a regional level via Unmanned Aerial System-based Aerial Teledetection (UAS). Its objective is to show the technical-economic feasibility of a new Aerial Teledetection methodology, to improve global water management and contribute to its sustainable use. It is one of the Spanish projects approved by the European Union in the LIFE 2009 call, with 3-year execution time, as from 01/10/2010. Propose to provide solutions to the problems that exist with respect to the use of water in: resource utilisation (efficiency of hydraulic infrastructures, irrigation optimisation, etc.), safety of mine exploitation storage facilities, resource protection (dumping, thermal pollution, etc.), efficient control of the water status and Water resource inventory. To do this, a technology that already exists (UAS- VTOL) will be developed that will offer us spatial information.

The main innovation brought by AG_UAS is that it makes it possible to use teledetection from aerial means via a UAS solution, which can overcome the cost and operational capacity limitations and problems of present-day teledetection solutions (satellite and aircraft). Specific objectives are:

• To test two new and innovative aerial teledetection systems by designing and constructing two prototypes, one based on a high resolution infrared camera and another on a multispectral camera. Both will use an unmanned helicopter as an aerial platform.
• To demonstrate the technical feasibility of the method by executing environmental missions.
• To demonstrate the economic feasibility of the method (assessing the operation costs of the environmental missions)
• To promote a Dissemination Plan on a national and European level of the Project and of its results to support the EU environmental policy.
• To develop a procedures manual to effectively apply the new methodology on sustainable water management, supporting the development and application of Directives 2000/60/EC and 2006/21/EC.

What is its aim? To develop UAS-VTOL technology in order to demonstrate the technical-economic feasibility of the methodology in the following environmental missions: detect leaks and filtrations in linear hydraulic transport (canals) and accumulation (dams) infrastructures, detect leaks and filtrations in extractive industry waste storage reservoirs, identify crop irrigation needs, detect dumping and emissions in surface water, detect thermal pollution in water masses, watch over the chemical and ecological status of surface water, detect the existence of ground water. The missions will be executed within a demonstration plan that will include 142 demonstration flights, which will be carried out on surface water masses, irrigated land and infrastructures of the Foral Community of Navarra, seeking the most representative points of these infrastructures.

The Ebro river drainage basin covers more than 85,000 km², in this territory we have identified about 1100 wetlands among which only 109 lakes and 56 reservoirs are listed as “body of surface water” following Water Framework Directive (WFD) criteria. The application of the European WFD in the field of the reservoirs has supposed some important challenges for the River Ebro Water Authority (Confederación Hidrográfica del Ebro- CHE), starting with the establishment of the methodology to evaluate the status of the reservoirs and ending with the way to achieve the objectives of the directive. To meet the obligations set in the WFD for the reservoirs, the River Ebro Water Authority has built up the Reservoir Monitoring Network, integrated by 56 reservoirs and 3 artificial bodies of surface water. These water bodies have been classified into 7 typologies and their status has been diagnosed following the methodology included in the WFD and its incorporation to the Spanish law, the Hydrological Planning Instruction (ORDEN ARM/2656/2008, de 10 de septiembre, por la que se aprueba la instrucción de planificación hidrológica-IPH). When a water body does not achieve the good status (objective of the WFD for heavily modified water bodies as the reservoirs) the CHE designs a program of measures to improve its status. Besides this, the CHE has set out some works with the aim of improving the knowledge about the reservoir ecosystem. Among them we have developed an “Experimental methodology” to evaluate the reservoir status, in contrast with the “Official methodology” compiled in the IPH, in which we propose to use other biological elements from the WFD such as invertebrate fauna. We are also carrying out investigations about fish populations in the Ebro basin reservoirs with acoustic technologies and studies regarding reservoir issues, such as episodes of contamination or spread of invasive species, like zebra mussel. This information collected by the different working areas of the CHE is the basis for the development of strategies and measures programs for preserving, protecting and improving the status of the Ebro reservoirs and the ecosystem connected to them.
Climate-Driven Management Challenges for Lakes and Reservoirs in the 21st Century
(KEYNOTE SPEECH)

S. Geoffrey Schladow
Tahoe Environmental Research Center
University of California, Davis

Contact email: gschladow@ucdavis.edu

Abstract

By now it should come as little surprise to scientists and engineers that climate, as we have known it, will be different in the future than it has been in the past. Though the details of the likely changes are still uncertain with respect to magnitude, timing and spatial distribution, two factors seem to show constancy across the predictions for much of the globe. First, the net downward heat flux will increase (warmer air temperatures are just one of the consequences of this). Second, extremes in both meteorology and climate are to be expected. Both of these factors go to the very essence of lake and reservoir management, the first primarily impacting issues of water quality and the second impacting issues of water quantity, although there are very strong linkages between the two. Much can be learned at this stage by the examination of existing long term data records and through the prudent use of numerical models. Using examples from lakes and reservoirs around the world, a range of management challenges will be discussed.
Modelling the Impacts of Bushfires on Reservoir Water Quality: Upper Yarra Reservoir Case Study (Full Oral Presentation)

Shane Haydon1, Rianda Mills2, Pat Lane3, Gary Sheridan3, Hugh Smith3

1: Melbourne Water Corporation, Victoria 3001, Australia, corresponding author
2: Hydronumerics, Victoria 3053, Australia
3: Department of Forest and Ecosystem Science, University of Melbourne, Victoria 3010, Australia

Contact email: shane.haydon@melbournewater.com.au

ABSTRACT

South-eastern Australia is one of the most fire prone regions of the world, and reservoir water quality can be severely impacted by bushfires. Bushfires can increase the occurrence of debris flows, as fire essentially removes stabilising vegetation increasing slope instability. Even relatively small rainfall events can then initiate large debris flows, and these debris flows can inject many tonnes of sediment into a reservoir rapidly. Melbourne Water has been loosely coupling the outputs of a bushfire research program and a hydrodynamic research program to attempt to predict the impacts of bushfires on reservoir water quality. Upper Yarra Reservoir is a critical reservoir in the Melbourne water supply system. A model examining the impacts of bushfire instigated debris flows on this reservoir's water quality has been devised. A debris flow model is used to predict a range of possible debris flows following a fire, this data is then used as an input to a hydrodynamic model which is used to determine reservoir behaviour. The hydrodynamic model predicts suspended solids throughout the reservoir based on three possible sediment loads into the reservoir from three different high risk locations around the reservoir. Three different debris flow temperatures and two seasons of the year are used to simulate the possible inflow situations. The model shows that depending on the location of the fire, the impacts can be long lasting and quite severe from a drinking water quality perspective.
Water Quality Modeling Used to Understand and Provide Decision Support for Operating Hydropower Reservoirs (Full Oral Presentation)

Richard J. (Jim) Ruane, President, Reservoir Environmental Management, Inc. 900-5 Vine Street, Chattanooga, TN 37403 USA jimruane@comcast.net (423) 265-5820

Gary E. Hauser, PE, Loginetics, Inc., 6009 Mont Richer Avenue, Knoxville, TN 37918 USA gehauser@loginetics.com

Daniel F. McGinnis, PhD, McGinnis Environmental Research and Consulting, Inc, 805 Oglesby Court, Virginia Beach, VA 23464 USA dfmcginnis@yahoo.com
Paul J. Wolff, PhD, Wolffware Ltd, PO Box 554, Norris, TN 37828 USA pjwolff@bellsouth.net
Mark Mobley, PE, Vice President, Mobley Engineering, Inc. PO Box 600 Norris, TN 37828 USA mark@mobleyengineering.com

Andy F. Sawyer, Reservoir Environmental Management, Inc. 900-5 Vine Street, Chattanooga, TN 37403 USA andysawyer@comcast.net

ABSTRACT

Water quality models provide valuable insights and solutions for cost-effectively operating hydropower reservoirs. Various uses of reservoirs have significantly increased in the past few decades, and modeling has contributed to enhancing these uses through better understanding and more cost-effective management solutions. This paper would provide examples of solutions developed using models and information on the models that have proven most useful. The examples cover a wide range of reservoir locations and sizes as well as issues that have been addressed. The models applied include reservoir ecosystem models; river water quality, ecosystem, and fish bioenergetics models; and aeration system models for several aeration methods and combinations of methods. The issues addressed include revising reservoir pool level rule curves, linking nutrient levels to algal growths and dissolved oxygen levels, in-lake aeration systems, striped bass habitat, anoxic products, turbine aeration systems, tailrace aeration systems, temperature control methods for hydropower releases from reservoirs, optimizing hydropower unit operations as well as whole hydropower operations for aeration and electric generation, and development of water quality standards for dissolved oxygen and chlorophyll a. Actual applications of the models to specific hydropower and reservoirs would be presented. [Note: the amount of information provided would depend on the time allotted for the presentation.]
We discuss the possible configuration of an operational Decision Support System for Marina Reservoir in Singapore. The systems objective is to optimize for water quality control. For this test case, the focus will be on minimizing and mitigate eutrophication. Two different model based configurations will be analysed and compared. Firstly, a fully coupled 1D-3D water quality model of the system that can accurately represent the water quality state of the real system. The control strategy is based on the model results of the coupled model only. Secondly, we use a 0D eutrophication model of the water system that is fast enough to be used in an optimization algorithm for water quality. The resulting control strategy is then verified using the coupled model. A historical test period to verify the optimized 0D eutrophication algorithm is then selected over which the feasibility of both methods is analysed. The test period is selected from the model results of the coupled 1D-3D model.
ABSTRACT

The City of Atlanta plans to convert a recently acquired urban quarry into Bellwood Quarry Reservoir, which will be used as an off-stream supplemental water supply. CE-QUAL-W2, Version 3.5 was used to perform 5-year water quality simulations of the reservoir. Nine different inflow/outflow scenarios were evaluated with respect to thermal stratification, dissolved oxygen, algae, and iron (Fe) and manganese (Mn). If the reservoir is operated in a no flow-through mode with occasional pump exercising, then Scenario 1.1 (bottom inflow/bottom outflow exercising) is recommended. If the reservoir is operated in a continuous flow-through mode, then Scenario 6 (mid-depth inflow/bottom outflow) is recommended. Bottom flows will help to hydraulically flush the hypolimnion. Substantial accumulation of dissolved Fe and Mn in the reservoir is primarily prevented by two mechanisms: 1) the relatively high flushing rate for the flow-through scenarios, which brings in good quality river water, and 2) the relatively deep mean depth and low sediment surface area to volume ratio. Oxygen recharge during the predicted annual overturn is essential to maintain good water quality.
ABSTRACT

The riverine Lake Tegel is one of the most important drinking water resources of Berlin, Germany. The composition of its water is affected by two inflows with different loads of pollutants. The first is the River Havel, which undergoes a serious loading of nutrients due to the agriculture in Berlin's surroundings. The second is connected to an upstream wastewater treatment plant, which contaminates the lake with trace pollutants remaining in the treated wastewater (e.g., pharmaceuticals). In addition, a certain part of the first inflow is pumped to the second inflow through an artificial pipeline, undergoing treatment to reduce the phosphorus content. The complex bathymetry of the lake and large number of islands requires applying a hydrodynamic circulation model with a high spatial resolution and dynamic wind forcing. The Princeton Ocean Model (POM) was applied to estimate the influence of (i) the wind and (ii) the river discharge on currents and mass transport in Lake Tegel. For model validation, the simulation results were compared with a one-year long dataset of electric conductivity, considered as a conservative tracer to distinguish between the water provided by each inflow. The river water enters the lake not as a plunging underflow but as a buoyant surface inflow horizontally mixed by wind that allowed application of the 2-D version of the model. Model scenarios with varying inflow rates and typical wind situations are calculated to develop a strategy for the pipeline operation and water treatment, depending on which contaminant (phosphorus or wastewater pollutants) is determined to threaten the lake.
Hydrodynamic model study of a shallow stratified lake (L. Pusiano, Italy) for water quality improvement planning

Ricardo González-López (1), Hermilo Ramírez-León(1), Andrea Capodaglio(2), Franco Salerno(3), Diego Copetti(3)

(1) Instituto Mexicano del Petroleo, Eje Central Lazaro Cardenas Norte 152, San Bartolo Atepehuacan, Gustavo A. Madero, 07730, Distrito Federal
(2) Università degli Studi di Pavia, Facoltà di Ingegneria, Via Ferrata 1 27100 Pavia, Italy
(3) Istituto di Ricerca Sulle Acque-Consiglio Nazionale delle Ricerche (IRSA-CNR), Via Del Mulino 19. Località Occhiate I-20861Brugherio (MB)

Contact e-mail: capo@unipv.it

ABSTRACT

Lake Pusiano is a shallow stratified lake in Northern Italy, slowly recovering from severe eutrophicaton problems. Actions have been planned and in part implemented to achieve water quality improvement in this water body. A thorough understanding of the lake’s hydrodynamic behavior is however necessary to determine internal mixing and diffusion of nutrients and pollutants and fully exploit the benefits of any further intervention. This work is based on the application of a general hydrodynamic model developed at the Mexican Petroleum Institute, to reproduce the behavior of currents in Lake Pusiano. The model is based on the shallow-water equations, including perturbation for the velocity components and for turbulence due to vegetated zones. This correction is calculated by means of the determination of a shear stress, which is a function of the vegetation density and their characteristic dimensions. Bottom stress is calculated for two different zones, the vegetated zones and the non-vegetated zones. The model was designed for the calculation of multiple layers in the vertical direction, being capable to represent the behavior of the vertical velocity profile when submerged vegetation exists. A data set collected by the Istituto di Ricerca Sulle Acque (IRSA) was used as the input of the model, which includes daily inflows and hourly wind data. The paper illustrates the results obtained by the simulations and discusses their impact on the ongoing water quality remediation effort.
Performance of an ecosystem dynamic model to simulate the biomass dynamics of cyanobacteria, using integrated data acquired by an autonomous multi-sensorial device.

Monteoliva, A.P. 1, Castanedo, S2., Gómez, A.G.2, Monná, A1, J.A. Monteoliva1 & C.M. Linares2

1Ecohydros, S.L. PG. de Cros, Ed.5-nº8. 39600- Maliaño, Spain.
2Environmental Hydraulics Institute. IH Cantabria, Universidad de Cantabria. Avda. de los Castros s/n. 39005- Santander, Spain

Contact e-mail: apmonteoliva@ecohydros.com

ABSTRACT

La Cuerda del Pozo reservoir (Soria, Spain) collects the waters of the Duero River near its source and is a key element of the drinking water supply to some regional cities; its catchment is scarcely anthropized, with low human population and well forested. In spite of this, the reservoir is eutrophicated and suffers from potentially toxic cyanobacteria blooms (involving Anabaena sp., among others) during the late summer and early autumn. A remote autonomous multisensorial device has been deployed to monitor cyanobacteria biomass, besides a large set of physical, chemical, meteorological and solar radiation variables, along a growing cycle. This remote infrastructure has provided high temporal resolution data, which has been advocated as a must to monitor cyanobacteria dynamics, due to their fast dynamics compared to other microalgae. These data have been used to evaluate the performance of an ecosystem dynamic model (CAEDYM, Computational Aquatic Ecosystem Dynamics Model) in simulating the plankton dynamics. The agreement of modeled and real data has been acceptable in broad time scales (week to month resolution), but poorer in the shorter times (day to week interval). The work explores the possible causes of the lack of adjustment and evidences the need of adopting different modeling strategies for predicting the cyanobacteria biomass in the short (pulses and blooms) and long time (seasonal to interannual evolution).
Should intermittency of small-scale turbulence be taken into account for large scale biochemical modelling in lakes?

Bonhomme C.¹, Cuypers Y. ¹, Saad M.¹, Viollier E. ², Lopez F. ², Vinçon-Leite B¹, Tassin B¹.
(1) LEESU, Laboratoire Eau Environnement et Systèmes Urbains, Ecole des Ponts ParisTech, 6 et 8 avenue, Blaise Pascal, Cité Descartes, Champs sur Marne 77455 Marne la Vallée Cedex 2
(2) LGE, Laboratoire de Géochimie des eaux, IPG, Bât. Lamarck - 6e étage - case courrier 7052 - 35 rue Hélène Brion - 75205 PARIS CEDEX 13

Contact email: celineb@leesu.enpc.fr

ABSTRACT

Lake Pavin presents the particular feature to be meromictic: the bottom compartment of the lake exhibits a very low mixing rate with the rest of the water body. Using temperature and conductivity microstructure measurements from years 2006 and 2007, vertical dispersion coefficients (Kz) are calculated in the water column of Lake Pavin (Auvergne, France). Microstructure measurements confirm the overall shape of Kz distribution in the water column in comparison with Kz calculated from mean stratification state for the purpose of previous modelling works. Nevertheless, this study highlights the strong variability of “measured” vertical dispersion coefficient (Kz) in Lake Pavin. In fact, dissipation rates are highly intermittent in time and space and calculation of vertical dispersion coefficient can vary from 1 to 2 orders of magnitude depending on the calculation method. This study compares Kz and dissipation values from different calculation methods. At last, this study addresses the question of the impact of this variability on large-scale 1D water quality modelling by testing intermittency scenarios of Kz with biochemical water quality model AQUASIM. The importance of intermittency in the transport of solutes is highlighted.

Key words: lake, vertical dispersion coefficient, intermittency, microstructure, 1D water quality model
SESSION 4
Large scale signature of bubble-plume oxygenation systems (Full Oral Presentation)

F. J. Rueda(1), V. Singleton(2), J. Little(2), and G. Lawrence(3)

(1) Department of Civil Engineering & Institute for Water Research, University of Granada. Spain.
(2) Department of Civil & Environmental Engineering, Virginia Tech, USA
(3) Department of Civil & Environmental Engineering, University of British Columbia, Canada

Contact email: fjrueda@ugr.es

ABSTRACT

Bubble-plume diffusers are increasingly used to replenish hypolimnetic dissolved oxygen (DO) while preserving stratification. While bubble plumes are successful at adding oxygen, they also introduce energy which drives basin-scale transport and mixing processes. Plume-induced mixing, for example, changes the thermal structure of the reservoir, which, in turn, influences the plume performance. Here, we account for this complex plume-reservoir interaction by coupling a circular bubble-plume model with a three-dimensional hydrodynamic model. The coupled model is applied to several case studies and scenarios of increasing complexity which include: a synthetic rectangular basin, Spring Hollow Reservoir (Virginia), and Amisk Lake (Canada). In Amisk Lake, it is used to assess the relative role of bubble-induced circulation in driving inter-basin exchange, which has two basins separated by a narrow and shallow channel. Model simulations accurately reproduced field observations. We argue that inter-basin exchange is predominantly driven, not by bubble-induced circulation, but rather by internal-wave pumping. We examine the conditions under which the operation of bubble plumes will drive inter-basin exchange of oxygen.
A Comprehensive Evaluation of the Impacts of Hypolimnetic Oxygenation on Fish Habitat and Water Quality in Twin Lake, Washington (Full Oral Presentation)

Marc Beutela, Barry Mooreb, Stephen Denta, Paul Gantzer and Ed Shallenbergerd

aWashington State University, Department of Civil and Environmental Engineering
bWashington State University, Department of Natural Resource Sciences
cGantzer Water Resources Engineering, LLC
dConfederated Tribes of the Colville Indian Reservation

Contact email: mbeutel@wsu.edu

ABSTRACT

North and South Twin Lakes are moderately deep (Zmean ~10 m; Zmax ~ 15 m), meso-eutrophic, dimictic lakes located on the Confederated Tribes of the Colville Indian Reservation in eastern Washington State. Both lakes exhibit seasonal hypolimnetic anoxia during summer thermal stratification and winter ice-over. In the summer, trout are squeezed into a thin layer of water a few meters thick below warm surface waters but above anoxic bottom waters. To improve habitat for cold water trout, a hypolimnetic oxygenation system was installed in North Twin Lake in 2008. The system included a 22.7-m³ on-shore liquid oxygen storage tank and a 760-m-long submerged line diffuser. Total system capacity was around 4,300 kg of oxygen per day, and the system is operated from around May through October. This presentation presents the results of a two-year comprehensive water quality and fish habitat monitoring program. Oxygenation substantially improved fish habitat for stocked trout. The volume of suitable habitat (> 5 mg/L dissolved oxygen and < 20 °C) in late summer increased six fold after oxygenation. For the first time ever, trout were captured below the thermocline during the summertime. Carryover, the survival trout from year to year, also increased dramatically. Effects of oxygenation on water quality were more ambiguous. Preliminary analysis suggests that some repression of internal phosphorus loading was achieved after oxygenation; however, levels of total nitrogen, iron and manganese appear to not have been affected. One very unique result was the nearly complete inhibition of methylmercury accumulation in bottom waters after oxygenation. While oxygenation maintained dissolved oxygen levels in hypolimnetic water column sufficient to support fish habitat, it appears that oxygenation did not oxidize the sediment-water interface. This is possibly due to the combined effects of high sediment oxygen demand, the relatively flat morphology of this natural lake, and enhanced mixing in bottom waters due to diffuser operation.
Application of the technology of water-lifting and aeration (TWLA) for improving water quality in a deep canyon-reservoir: A case study from northern China (Full Oral Presentation)

Ting-Lin Huang a, Yue Ma a, Hai-Bing Cong a,b

a. School of Environmental and Municipal Engineering, Xi’an University of Architecture & Technology, 13 Yanta Road, Xi’an, 710055 Shaanxi Province, China
b. College of Environmental Science and Engineering, Yangzhou University, 88 South University Avenue, Yangzhou, 225009 Jiangsu Province, China

Contact email: huangtinglin@xauat.edu.cn

ABSTRACT

The technology of water-lifting and aeration (TWLA), which is a newly developed in-situ water restoration strategy based on artificial mixing and oxygenation, can be widely applied in water destratification, aeration, algal inhibition and endogenous pollution control. Jin-pen reservoir, the drinking water source in Xi’an city of China, with a total storage capacity of 200,000,000 cubic meters and a maximum depth of 100 meters, have been undergoing increasing water pollution and eutrophication in the past few years, such as the elevated nutrients levels, frequent algae blooms, etc. The internal pollution induced by the seasonal oxygen shortage at the bottom of reservoir is considered to be the dominant cause for its water degradation. Besides, the stable thermal stratification formed in the reservoir also aggravates the situation. To solve this problem, the Water-lifting Aerator system was installed in Jin-pen reservoir in the summer of 2010 and its improving effect on water quality was investigated experimentally and analytically. The results show that the seasonal anaerobic state at the bottom of the reservoir has been effectively inhibited, and the endogenous load as well as algae biomass has been sharply reduced. During this period, the dissolved oxygen concentration of bottom water has been maintained above 2mg/L and the concentrations of total-phosphorus, ammonia-nitrogen, CODMn and chlorophyll-a in the outlet water have been respectively reduced by 43.9%, 68.1%, 21.2% and 53.4% compared to the same period of 2008, however, the present cost of water improvement considering depreciation is only 0.004 Yuan RMB /m^3, which indicates that the water pollution control by TWLA under such deep-water and stratified conditions is effective and economical.

Keywords:
Water-lifting Aerator Stratification Mixing and oxygenation Algal control Endogenous pollution
Deep-water oxygen consumption in lakes (Full Oral Presentation)

Alfred Wüest1,2, Lee D Bryant3, Andreas Matzinger4, Martin Schmid, Beat Müller1

1 Eawag: Swiss Federal Institute of Aquatic Science and Technology, Seestrasse 79, CH-6047 Kastanienbaum, Switzerland, alfred.wuest@eawag.ch, Tel ++41 41 349 21 81, Fax ++41 41 349 21 62
2 Institute of Biogeochemistry and Pollutant Dynamics, ETH Zurich, CH-8092 Zurich, Switzerland.
3 Civil and Environmental Engineering, Virginia Tech, Blacksburg, Virginia, USA
4 Kompetenzzentrum Wasser Berlin (KWB), DE-10709 Berlin, Germany.

Contact email: wuest@eawag.ch

ABSTRACT

Short-term variations of the bottom boundary currents define the local forcing of oxygen fluxes into the sediment. Rapid profiling with oxygen microsensors reveals, indeed, that the diffusive boundary layer shows an enormous variability and loses its oxygen within minutes, if currents fall below turbulence levels. Because the oxygen content of the uppermost sediment (< few mm) is usually only in the range of a few 0.01 mmol m⁻² in meso- to eutrophic lakes, the sediment also becomes anoxic within some 10 minutes. Subsequently, reduced substances (main components are methane and ammonium) diffuse into the overlaying water and deplete oxygen from lake water in the bottom boundary layer. As a result, the oxygen depletion rate is larger than actually estimated from oxygen fluxes into the sediment. For meso-to eutrophic lakes on the Swiss Plateau, we showed that these reduced substances typically contribute about 30% of the oxygen consumption. In order to quantify deep-water oxygen consumption, we conclude that measurements by eddy correlation or by microprofiling need to be complemented by fine-scale profiles of reduced substances.
Influence of the BBL thickness variability on diffusive-induced dissolved-oxygen fluxes in porous water-sediment interfaces

Elena Sánchez-Badorrey

Contact e-mail: elenasb@ugr.es

ABSTRACT

Dissolved oxygen (DO) fluxes between bottom boundary sediments and overlaying water (Water-Sediment Interface, WSI) regulates biological and geochemical processes essential for benthic and pelagic ecosystems (Boudreau & Jorgensen, 2001). Very close to the WSI, where turbulent diffusivity becomes negligible, DO fluxes are mainly governed by molecular diffusion. DO traverses two diffusive boundary layers from the water column into the sediment (which here, it is porous media): (1) the diffusive boundary layer (DBL or $D_1$, aquatic phase) and, (2) the diffusive sediment layer (SDL, porous phase). Under diffusive transport conditions, the thicknesses of the DBL and the SBL play the role of a “bottleneck” in the net DO fluxes. Under unsteady flows, the thicknesses of the DBL and SDL are not constant, but evolve in time responding to the varying flow conditions. In this work, we analyze the influence of variability the DBL and SDL thicknesses on the DO fluxes across a WSI over porous beds. For that, we solve the 1DV mass transport problem of the coupled aquatic and porous boundary layers assuming a multiple piecewise-homogeneous layered system with moving boundaries and discontinuous transport properties. Mass and momentum continuity is imposed between layers. Microbial organic matter degradation occurring in the sediment as well as chemical reactions involving oxygen consumption are taking into account assuming a Michaelis-Menten consumption kinetics model (House, 2003). DBL thickness variability is assumed to be of harmonic type and estimated from the turbulent kinetic energy. The WSI mathematical problem is solved using the classical separation of variables method (SVM). Because of the discontinuous dispersion coefficient, the SVM method leads to a Sturm-Liouville problem which is solved by a successive bisection method. The analytical solution of the 1D-WSI problem evidences that the time variation of the DBL thickness may play an important role in the DO fluxes by introducing two additional transport terms in the WSI transport equation: (1) an advective term with an “effective” velocity depending on and varying linearly across the WSI, and (2) a diffusive term with an “effective” time-dependent diffusivity inversely proportional to the square of the DBL thickness. The influence of these additional transport mechanisms on the dynamics of the DO fluxes will be analyzed during the presentation. In particular, the dynamics of the DO fluxes under oscillatory bulk flows with periods from seconds to hours will be discussed.
Sensitivity analysis of models for the design of hypolimnetic aerators

Tinglin Huang, Xin Sun*, Wushou Zhang
‘Key Laboratory of Northwest Water Resource, Environment and Ecology, Ministry of Education, Xi’an University of Architecture and Technology, Xi’an 710055, China

Contact email: sunxin@xauat.edu.cn

ABSTRACT

A one-dimensional hydrodynamic model for the gas-liquid two-phase flow in the hypolimnetic aerator was developed on the basis of mass equation, momentum equation and energy equation. The flow resistance, drag force and gas holdup were calculated by introducing the resistance coefficient, drag coefficient and correction factor respectively. Using the typical coefficients available from the literature, the hydrodynamic equations were solved to predict the water flow rate by employing MATLAB. The mathematic hydrodynamic model was validated against the experimental data of water flow rate and gas holdup under various conditions of gas flow rate, bubble size and aerator geometry. The water flow rate and gas holdup were predicted within ±20% and ±15% respectively. The oxygen transfers through the bubble-water interface and air-water interface were analyzed in the hypolimnetic aerator by introducing the concept of the mass transfer coefficient and mass flux. The differential equations for oxygen transfer as well as nitrogen transfer were established on the basis of discrete-bubble model and Higbie’s penetration model. The differential equations were solved using a numerical method to predict the efficiency of oxygen transfer and the dissolved oxygen profile in the hypolimnetic aerator. The analysis of models is a considerable problem when there is uncertainty in the model parameters and when the model parameters interact and determine the model output in a non-linear way. Sensitivity analysis was performed by assigning a variety of model parameters to assess the uncertainty of the complex prediction models for the water flow rate and the oxygen transfer. Under different aeration conditions, the dominant model parameters were identified and their appropriate combinations were proposed to accurately predict the performance of hypolimnetic aerators.

Key words: hypolimnetic aerator; hydrodynamics; oxygen transfer; model; sensitivity analysis
One-dimensional evaluation of greenhouse gases emissions in a south-Brazilian reservoir

Mannich, M.; Fernandes, C.V.S; Bleninger, T.; Mine, M.R.M.
Department of Hydraulic and Sanitation of the Federal University of Paraná, Brazil.

Contact email: mmannich@gmail.com

ABSTRACT

Recent evidence from many studies suggest that reservoirs from hydropower plants can emit significant quantities of greenhouse gases (GHG) like CO₂ and CH₄. The literature review shows a great spatial and temporal variability of emissions not only between reservoirs but also in each reservoir where a series of biochemical, hydrodynamic, meteorological, morphological and operational characteristics influence the emission. Most studies focus on direct quantifying the rate emission of gases in the air-water interface in one or more sites with different temporal resolutions. In reservoirs with thermal stratification vertical gradients require a detailed study of the vertical transport processes. This work describes results of field studies in hydropower reservoirs, South-East of Brazil. Measurements were done in single points of the reservoirs determining the vertical profiles for temperature, dissolved oxygen, CO₂, electric conductivity, pH and dissolved organic carbon. Furthermore, meteorological variables were measured on site. The analysis of this set of variables allows to describe the principle biochemical processes of photosynthesis and respiration, involved in the production of methane and carbon dioxide, and the vertical transport of gases and solutes. The profiles clearly show the effect of stratification on the vertical distribution of the measured parameters. A Fickian type interpretation of the vertical gradients allowed the computation of vertical fluxes and comparison with literature data. This data was used to calibrate a preliminary version of a vertical one-dimensional mathematical model to describe the main biochemical processes and the heat balance that governs the diffusive fluxes in the water column.
SESSION 5
Comparative study on dynamics of cyanobacterial bloom and fate of cyanotoxins in lake Taihu, Dianchi and Chao in China (KEYNOTE SPEECH)

Lirong SONG, Wei CHEN, Nanqin GAN, Lin LI, Quan ZHOU, Yanlong WU, Qichao ZHOU, Liming LIU, Lingling ZHENG, Shuang ZHAO, Yunlu JIA

State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, The Chinese Academy of Sciences, Wuhan 430072, P. R. China

Contact email: lrsong@ihb.ac.cn

Abstract

Lake Taihu, Chaohu and Dianchi are three biggest shallow freshwater lakes frequently suffering cyanobacterial bloom, with average size about 2340, 750 and 300Km², respectively. Due to intensive human activities, the lakes have been experiencing cyanobacterial bloom over the last two decades. While high concentration of nutrients are mainly attributed to the problem of cyanobacterial bloom, the dynamics of the bloom and the fate of cyanobacterial toxins in these lakes are different and thus worth to explore. The present study focus on the comparison of cyanobacterial bloom dynamics in terms of species diversities, seasonal variation, toxin-producing ability and driving forces; meanwhile, we also focused on the fate of cyanobacterial toxins in the lakes as well as in artificial harvested-algal biomass treatment system near Taihu Lake. This study provides insight for predicting, forecasting, control and mitigation for cyanobacterial blooms and toxins in three large lakes.

Keywords: Lake Taihu; Chaohu; Dianchi; cyanobacterial bloom; cyanotoxins; dynamics; fate
Using the source as the solution: oxygenation effects on Mn cycling and water quality
(Full Oral Presentation)

Bryant, Lee D.,* Heileen Hsu-Kim, Paul A. Gantzer, and John C. Little

aCivil and Environmental Engineering, Duke University, Durham, North Carolina.
bGantzer Water Resources Engineering LLC, Kirkland, Washington 98034, USA.
cCivil and Environmental Engineering, Virginia Tech, Blacksburg, Virginia

Contact email: lebryan1@vt.edu

Abstract

Hypolimnetic oxygenation systems (HOx) are increasingly used to improve water quality in stratified reservoirs by elevating dissolved oxygen (O$_2$) concentrations in the water column and suppressing sediment-water fluxes of reduced species. Soluble metal flux from the sediment to the water column is one of the most common natural sources of increased metal concentrations in reservoirs, especially during hypolimnetic anoxia. Manganese (Mn) is particularly problematic from a drinking water perspective as source water with elevated Mn levels can be difficult to treat due to complex Mn redox kinetics.

Conceptually, HOx-induced increases in turbulence and near-sediment O$_2$ and metal concentrations will have a direct effect on sediment-water diffusive flux. While previous work has established that oxygenation increases J$_{O_2}$ via elevated near-sediment O$_2$ and turbulence levels, the influence of HOx on other sediment-water fluxes (e.g., J$_{Mn}$ for Mn) has not been comprehensively evaluated. The complex nature of biogeochemical cycling at the SWI must be taken into account when assessing the effect of HOx on O$_2$ and Mn dynamics. We therefore performed a study that focused specifically on how HOx operations affect J$_{Mn}$ and resulting water quality. Our study was based on O$_2$ and Mn data collected primarily in situ characterizing both the sediment and water column in Carvins Cove Reservoir, a primary drinking-water-supply-reservoir for Roanoke, Virginia (USA). Results show that sediment-water fluxes of O$_2$ and Mn are strongly affected by HOx, with significant decreases in total and soluble Mn in source water observed during oxygenation. By quantifying Mn biogeochemical cycling as a function of oxygenation and demonstrating that HOx may be successfully used to improve drinking water quality, this work contributes to the shifting global perspective on water resource management.
Oxygen Diffusers to Enhance Water Quality and Fish Habitat in Natural Lakes, Water Supply Reservoirs and Hydropower Reservoirs  (Full Oral Presentation)

Mark Mobley, PE, Vice President, Mobley Engineering, Inc.
PO Box 600 Norris, TN 37828 mark@mobleyengineering.com (865) 494-0600

Richard Jim Ruane, Reservoir Environmental Management, Inc.
900 Vine Street, Suite 5, Chattanooga, TN 37403
jimruane@comcast.net (423) 265-5820

Paul Gantzer, Ph.D., P.E., Gantzer Water Resources Engineering, LLC,
14816 119th PL NE, Kirkland, WA 98034,
Paul.Gantzer@gmail.com (206) 999-1878

Ed Shallenberger, PhD, Senior Resident Fisheries Biologist, Colville Confederated Tribes
64 Schoolhouse Loop Rd. Nespelem, WA 99155
ed.shallenberger@colvilletribes.com (509) 634-2121

Frank H. Dunlap, Senior Environmental Specialist, NextEra Energy Resources
26 Katherine Drive, Hallowell, ME 04347 Frank.Dunlap@fpl.com (207) 629-1817

Marc W. Beutel, PhD, P.E., Assistant Professor, Department of Civil and Environmental Engineering, Washington State University,
405 Spokane Street, Sloan 101, PO Box 642910 99164-2910, Pullman, WA
mbeutel@wsu.edu (509) 335-3721

Jamie A Sykes, District Fisheries Biologist, U. S. Army Corps of Engineers, Richard B. Russell Project, 4144 Russell Dam Drive, Elberton, GA 30635
james.a.sykes@usace.army.mil (800) 944-7207 Ext. 3425

ABSTRACT

Diffuser systems using pure oxygen gas have been advocated for reservoir water quality improvement since the early 1970's with successful full scale installations in reservoirs dating from the 1980's. Recent oxygen diffuser installations have been applied to obtain a broad range of very specific project goals. For hydropower, oxygen diffuser systems are being used to enhance water quality in the reservoir as well as in the releases from hydropower turbines. In water supply reservoirs, oxygen diffuser systems are being used to blanket sediments with an oxygen rich water layer to reduce or eliminate anoxic products and nutrient cycling that lead to taste and odor problems. Habitat for trout, bass, and other cool and coldwater fishes can be limiting in stratified reservoirs during summer and early autumn as surface water temperatures increase above tolerable ranges and deeper waters are depleted of dissolved oxygen (DO). Usable habitat can be increased in these reservoirs using oxygen diffusers to increase DO concentrations in the cooler deeper waters. Several examples are currently in operation; some with dramatic results. In all of these recent applications, a state of the art bubble plume model has been used to optimize the diffuser design. Actual results of reservoir monitoring will be presented for small water supply reservoirs, a natural lake and large scale hydroprojects.
Operating a Hypolimnetic Oxygenation System to Control Iron and Manganese in Water Supply Reservoirs (Full Oral Presentation)

Paul Gantzer, Ph.D., P.E.
Gantzer Water Resources Engineering, LLC
14816 119th PL NE, Kirkland, WA 98034

Email contact: paul.gantzer@gmail.com

ABSTRACT

During summer months, hypolimnetic anoxia from sediment oxygen demand results in increased dissolved metal fluxes from the sediment in water supply reservoirs, resulting in increased chemical dosages required to remove soluble iron (Fe) and manganese (Mn). Historical observations during periods of destratification show very low dissolved metals concentrations. It is believed the well mixed condition coupled with near DO saturation is the key to controlling dissolved metals flux from the sediment to the bulk water. Installing hypolimnetic oxygenation systems (HOS) in water supply reservoirs is a management strategy used to improve raw water quality. Operation of the HOS in a moderately deep (maximum depth 21 meters (70 feet)) water supply reservoir in Roanoke, Virginia, USA over the past several years has demonstrated success and has helped identify operational guidelines to prevent the formation and subsequent build up of Mn in the water column. Adequate DO maintenance, e.g., 7 – 8 mg/l throughout the bulk hypolimnion, was observed to be very effective in controlling the build up of soluble Mn in the bulk water, whereas maintaining DO in the bulk hypolimnion at a 5 mg/l threshold was observed to be insufficient, and resulted in significantly higher Mn observations. Greater success was also observed during periods of continuous DO maintenance versus allowing hypolimnion conditions to degrade and operating the HOS to recover DO. Through adequate DO maintenance, HOS can be an effective tool to manage raw water quality in water supply reservoirs.
Methane emissions from two reservoirs in a steep, sub-tropical rainforest catchment (Full Oral Presentation)

Bradford Sherman and Phillip Ford
CSIRO Land and Water, Canberra, Australia

Contact email: Brad.Sherman@csiro.au

ABSTRACT

Floating chamber measurements of the seasonal, spatial and diurnal variability of methane (CH₄) emissions from Little Nerang Dam (volume = 9280 ML, area = 49 ha, catchment area 35 km²) and Hinze Dam (volume = 161073 ML, area 972 ha, catchment area = 207 km²) were made using a Picarro 1301 gas analyser.

CH₄ emissions during a typical 15-minute chamber deployment varied across the range of sites from 10 to > 2000 mg CH₄ m⁻² d⁻¹ where bubble release was encountered. During particularly active bubble events, the 'instantaneous' flux could exceed 10000 mg CH₄ m⁻² d⁻¹. CH₄ emissions under nominally 'diffusive' conditions (linear increase in CH₄ with time) ranged from 1 to 445 mg CH₄ m⁻² d⁻¹. Reservoir arms receiving fresh organic matter from the catchment exhibited the highest CH₄ emissions ~ 100 times greater than arms receiving water that had been previously intercepted by an upstream storage. Diffusive fluxes correlated well with water column turbulence. Short term responses in local wind speed were reflected immediately in both water velocity measured just below the air-water interface in the floating chamber and in dCH₄/dt within the chamber. Correlations between local wind speed and a reference wind speed measured at a meteorological station at a fixed location on the reservoir became poorer with increasing distance from the meteorological station. This implies that significant spatial variability in the wind field will be reflected in spatial variability in the diffusive CH₄ flux – a result that has relevance to the modelling of gas transfer across the air-water interface. Because methanogenesis is an anaerobic process occurring primarily within the sediments, spatial variability and the size of the observed CH₄ emissions reflects the extent of anoxia, and the total areal loading of reactive organic matter from both autotrophic and allogenicous sources. Reservoir management strategies such as hypolimnetic oxygenation can drastically decrease the spatial extent of anoxic sediments as well as reducing the internal nutrient loads. In addition, hypolimnetic oxygenation has also been observed to nearly eliminate the accumulation of dissolved CH₄ (and its subsequent outgassing during overturn/ice-out). We suggest that reservoir management strategies that facilitate increasing the oxygen concentration of the hypolimnion may well confer an additional GHG mitigation benefit through affects on both CH₄ production, consumption and transport processes.
Mixing of an interflow into the ambient water of Lake Iseo

Hogg C, Pilotti M, Imberger J, Huppert HE

Contact email: carh5@hermes.cam.ac.uk

ABSTRACT

The intrusion of a river flowing into a lake is an important process in the distribution of nutrients and pathogens through a lake. The ability to model this process is important for design and management of reservoirs and lakes. A major field experiment has been carried out during the summer of 2010 in Lake Iseo, Italy, a deep prealpine lake with major inflows to the north and a single outflow to the south. An extensive network of meteorological sensors and river gauges were implemented for the duration of the experiment to capture the driving forces of the lake motion. Throughout the lake, physical and biological measurements were taken at macro and micro scales with a profiler. The path of the inflowing water is found from the profile measurements and the rate of mixing of the intrusion is calculated from microstructure measurements. Numerical modelling of the lake using the meteorological and river flow boundary conditions is used to calculate the path. The vertical mixing of the intrusion due to internal waves are calculated, giving a description of how the inflows are blended into the ambient lake water. We describe a novel estimation of the length of the intrusion before it is mixed into the ambient fluid. The implications for measuring and modelling inflows into a water body are demonstrated.
Impact of hydraulic management on reservoir residence time

H.Ó. Andradóttir*, F. J. Rueda2 and R. Marcé3

1 Faculty of Civil and Environmental Engineering, University of Iceland, Hjarðarhagi 2-6, IS 107 Reykjavík, Iceland
2 Departamento de Ingeniería Civil e Instituto del Agua, Universidad de Granada, C/Ramón y Cajal, 4 18071 Granada, Spain
3 Catalan Institute for Water Research (ICRA), Scientific and Technological Park of the University of Girona, 17003 Girona, Spain

Contact e-mail: hrund@hi.is

ABSTRACT

Residence time, in its simplest form defined as the ratio of volume and through-flows, is a key water quality parameter as it sets the time frame for biochemical reactions in the water system. Man made reservoirs differ from natural ones in that both the volume and depth of withdrawals can be managed. This study explores the impact of such hydraulic management practices on the residence time in Sau reservoir, one of the key water supplies in Northern Spain. Three outlets are currently used for withdrawals at different depth, allowing for regulation of the water quality of the outflowing water. Average daily residence times over an eight year (1998-2006) time period were estimated from tracer simulations in the one dimensional DYRESM model. Various scenarios of watershed management strategies were considered and compared, including current practices, withdrawal from only the bottom outlet, and no regulation of withdrawal volumes (balanced budget at all times). Results suggest that inter-annual variability in residence time can be modified by withdrawal volume practices. In particular, excessive withdrawals prior to dry years, resulting in lower reservoir water levels and storage volumes, can compensate for lower through flows resulting in less inter-annual variability. Varying withdrawal depth can introduce more short term variability in residence time and can contribute to increased anomalies, such as extremely long residence times in winters and short circuiting in summers.
Seasonal variations in the concentration and distribution of estrogens and pharmaceuticals in drinking water sources and rivers in the Luan River Basin, China

Jianghong Shi*, Jinling Cao, Qingcai Chen, Zhifeng Yang
State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing 100875, China

Contact email: shijianghong@bnu.edu.cn

ABSTRACT

SPE-LC/MS/MS were used to investigate the occurrence and distribution of four estrogens and three anti-inflammatories in four tributaries, two reservoirs and the mainstream in the Luan River Basin (northern China). These compounds were detected at ng/L levels, and their concentration, occurrence and spatial distribution varied clearly with sampling time (April, September and March). Estrone and ketoprofen were the most frequently detected. In the four tributaries, estrone, 17β-estradiol, estriol, 17α-ethynylestradiol, ibuprofen, naproxen and ketoprofen levels ranged from n.d.–0.33 ng/L, n.d.–0.45 ng/L, n.d.–0.12 ng/L, n.d.–0.27 ng/L, n.d.–1.54 ng/L, n.d.–0.72 ng/L, and 0.09–21.35 ng/L, respectively. Of the four tributaries, the Yixun and Wulie rivers received sewage and stockbreeding wastewater from Chengde City and surrounding countries, resulting in higher concentrations of the seven compounds than in the Xiaoluan and Xingzhou rivers. In the mainstream, estrone, 17β-estradiol, estriol, 17α-ethynylestradiol, ibuprofen, naproxen and ketoprofen levels ranged from n.d.–0.38 ng/L, n.d.–0.24 ng/L, n.d.–0.42 ng/L, n.d.–0.48 ng/L, n.d.–2.38 ng/L, n.d.–1.05 ng/L, and n.d.–13.78 ng/L, respectively. The concentrations detected for the three anti-inflammatories were 1–2 orders of magnitude higher in summer than in spring. In the two reservoirs, although some estrogens and anti-inflammatories were detected at low ng/L levels, their detection frequencies and maximum concentrations were lower than those in the mainstream and the four tributaries. Estrone, 17β-estradiol, estriol, 17α-ethynylestradiol, ibuprofen, naproxen and ketoprofen levels ranged from n.d.–0.30 ng/L, n.d.–0.19 ng/L, n.d.–0.03 ng/L, n.d.–0.14 ng/L, n.d.–0.07 ng/L, n.d.–0.88 ng/L, and 0.02–1.91 ng/L, respectively. Estrogen concentrations varied largely over the three seasons, and this was probably due to decreased biodegradation of estrogens in winter with a lower water temperature (0 °C in March). These results suggest there may be a potential ecological risk of induced feminization of male fish in the Luan River Basin, and the risk for drinking water contamination may be higher in wintertime.
Confederación Hidrográfica del Júcar monitors the water quality of the reservoirs in the Jucar River Basin. The monitoring system was implemented in 1994 through the summer control of chlorophyll-a, supervising its temporal development within the water masses, improving the knowledge on processes and finally, verifying the effectiveness of the water treatment programmes in the basin -which are obligations of the Dir 91/271/CEE- and facilitating the decision making processes in the management of the low water level and meteorological drought. Likewise, specific studies on fish health, trophic state, phytoplankton density and the presence of toxic microalgae in certain sensitive reservoirs and under specific problems were conducted. Following the transposition of the Dir 2000/060/CEE, since 2005 water quality control systems are generalized until a total of 25 reservoirs, with the aim of identifying risky situations as well as designing and implementing management strategies to guarantee water uses and the achievement of the environmental objectives. The sampling campaigns were extended outside of the low water level period and over three stations within the reservoir (dam, tail and intermediate stations), and diverse physiochemical and biological variables in water and sediments were determined. The characterization of the reservoirs was completed, and studies on their functional dynamics, trophic state, thermal regime and hipolimnetic anoxia, cyanobacteria bloom in some cases and fish death episodes in others, were developed, with special attention to the water quality conditions in the supply reservoirs, fulfilling the type A1 of the Decree 1541/1994 risks (occasionally A2). The eutrophication processes are now better known and progress in the evaluation of the reservoirs response to variations in nutrient loading and water inflow, as well as to other impacts such as deforestation and fires, have been achieved. Moreover, other water quality risks have been identified, especially those derived of the presence of exotic species, particularly invasive ones such as the zebra mussel, which is object of a specific management strategy. In September 2005, the presence of this species was detected in the Sitjar reservoir (Mijares River) and its colonization process downstream (arriving even to the sea estuary) was verified in later controls. In September 2007, adult individuals of this species were observed in the Forata reservoir (Magre River, tributary of the Jucar River), but the situation did not progress, and larvae have not been found. Nevertheless, the navigation has been forbidden in both reservoirs to avoid the extension of the plagues, and new measures of a Disinfection Protocol are adopted in the boats which are used for the controls. On the other hand, within the SAICA (Automatic System of Information about Water Quality) real time control system, automatic alert stations were deployed in 1995 in Arquillo de San Blas, Guadalest, Amadorio and Alarcon reservoirs to verify the outflow water quality. In the last case, automatic stations were also deployed in the riverine for inflow monitoring, due to the special transcendence of this reservoir for the demarcation.

In the last years, the criteria established by the Order ARM/2656/2008 (by which it is approved the Instruction of the Hydrological Plan and derived works for its modification) are being applied. Thus, due to the lack of the evaluation of the chemical state (due to the lack of data enough as well as the absence of quality environmental norms in sediments and biota) it has been estimated the very modified (27) and artificial (1) water masses state considering its ecological potential and phytoplankton indicators (chlorophyll-a concentration, biovolume, phytoplankton groups index and percentage of cyanobacteria) following the operative criteria of the Instruction. In 2010, just two reservoirs (Bellus y Tibi) presented a moderate ecological
potential, while Beniarres reservoir improved its status from moderate ecological potential in 2009 to good ecological potential in 2010. All the rest of reservoirs obtained a good or maximum ecological potential in 2010. It is necessary to take into account that the hydrologic situation of the last years correspond to a historical maximum of stored volume, so it seems important to acquire more information in the next years, monitoring dry and extremely dry cycles, to achieve significant conclusions.

The Jucar Hydrographical Confederation is also applying new emerging technologies, such as self-positioning probes in water supply reservoirs. Thus, in 2004, it was implemented the first probe of this type in Spain (and perhaps in the world) in the Amadorio reservoir, that forms part of the supply system to the Marina Baja region. In this reservoir other water uses coexists: agricultural irrigation and fishing life. The probe, with centimetre depth resolution, measures: water temperature, pH, conductivity, dissolved oxygen, redox potential, cloudiness, light radiation and chlorophyll-a concentration. An additional sensor to measure cyanobacteria (some of these could be potentially toxic) pigments is going to be added and will be test this summer. 4 new probes have been acquired for the Arquillo de San Blas, Guadalest, Alarcón and Tous reservoirs, to be operative in this exercise. In this context, this Hydrographical Confederation of the Jucar has established collaborations with scientific and research groups in the areas of limnology and technological development to initiate the operating and to maximize the performance in the operation of these systems.

The utility of these technological advanced monitoring systems in real time (integrated in the SAICA System) is huge: it makes possible to determine in real time the trophic state of the reservoir, to carry out vertical profiles and to monitor the time evolution of selected parameters and to record automatic alarms of instruments and water quality (depletion or over-saturation of oxygen, chlorophyll and phycocyanin deep or surface maximums, sudden mix events and, in general, abrupt time variations of any controlled parameter). The use of these probes facilitates the decision making process and the management strategies adoption, such as hypolimnetic withdrawal or others, in order to guarantee the maintenance of the conditions for fish, and most important, the appropriate supply of waters destined to the production of drinkable water (through the multiple specific intakes of the outflow towers installed in some reservoirs such as the Amadorio, Guadalest and Tous), as integrated system of qualitative (probes) and quantitative (selective withdrawal) water quality management, allowing to optimize and to reduce the cost of the potabilization, as well as to advance toward the consecution of the good ecological potential of the reservoir and to avoid its deterioration.
SESSION 6
Application of the functional group concept to reservoir phytoplankton (KEYNOTE SPEECH)

J. Padisák
University of Pannonia, Department of Limnology, H-8200 Veszprém, Egyetem u. 10, Hungary,

Contact email: padisak@almos.uni-pannon.hu

ABSTRACT

Selection of phytoplankton species and dynamics of phytoplankton seasonal changes are determined by morphometric and dynamic features of the habitat. During the last decade, the functional group concept gained overall acceptance among phytoplankton ecologists and there is a growing interest of modelers and reservoir managers towards its application. It was also adapted to needs of the EU Water Framework Directive. The popularity of the concept lies in the fact that it considers present knowledge on ecology of freshwater phytoplankton while reducing the potentially occurring ~ 5000 units (estimated number of freshwater phytoplankton taxa) to a maximum of 45 without considerable loss of information. Experience shows that in any lake or reservoir some 100-200 phytoplankton species are likely to occur while the number of quantitatively important functional groups rarely exceeds 15. The basic feature of the functional group concept is that it closely relates selection of phytoplankton species to habitat templates, or in other words, to the morphological and dynamic features of different types of freshwaters, could they be lakes or reservoirs. Though it is widely accepted that lake and reservoir phytoplankton carries more similarities than differences, higher nutrient load and more dynamic hydrological regime of reservoirs selects for different typical functional groups. In this plenary lecture species selection of phytoplankton will be approached from the principles of the functional group concept and relates them to typical reservoir features. Some case studies assembled from the literature allow an insight to our present knowledge of application of the functional group concept to understanding phytoplankton changes in reservoirs.
Two rapid on-site monitoring methods for toxin-producing *Microcystis* and *Cylindrospermopsis* in drinking water reservoirs (Full Oral Presentation)

Tsair-Fuh Lin*, Atsuko Michinaka, De-Wei Chang, and Hung-Kai Yen
Department of Environmental Engineering, National Cheng Kung University, Tainan City, Taiwan

Contact email: tflin@mail.ncku.edu.tw

ABSTRACT

Two rapid detection methods for on-site monitoring of cyanobacteria and toxin-producing *Microcystis* and *Cylindrospermopsis* were developed and tested in a few drinking water reservoirs in Taiwan. Based on the fluorescent intensity of phycocyanin, the fluorescent probe (FP) is able to instantaneously determine cyanobacterial cell numbers, while based on microcystin and cylindrospermopsin synthetase concentrations, the potable quantitative polymerase chain reaction (qPCR) device is able to quantify toxin-producers of microcystins and cylindrospermopsin. Experimental results indicate that two water quality parameters, turbidity and chlorophyll-a, may strongly influence the measurement of FP. In addition, cyanobacteria species and growth phases, and colony size may also affect the observation. A correlation equation was successfully developed to mitigate the effect caused by water matrix and cyanobacteria colony. After careful calibration, the measurements from FP reasonably matched with those from microscopic cell counting for reservoir water samples. For the monitoring of toxin-producers, the results indicate that the qPCR employed was able to on-site quantify both microcystin and cylindrospermopsin producers within 2 hours after sampling and with detection limit of ~100 cells/ml. The results matched reasonably well with the toxins present in the samples for the reservoir samples. The two methods examined in this study provide a good combination of rapid, on-site monitoring tools for the early warning of cyanotoxin episodes. In monitoring toxigenic *Microcystis* and *Cylindrospermopsis*, FP may be used as a screen tool for cell concentrations and qPCR can be used to determine the production potential of the two toxins for drinking water reservoirs.
ABSTRACT

Water quality controlling in lakes is essential for human to maintain the valuable resource. One of the main challenging issues is to control algae blooms during summer. To control the algae problem, we attempted to install an innovative device, which could generate an artificial density current by mixing upper and lower waters in a reservoir, in Okayama, Japan. The mixing of upper and lower waters provided a destruction of a thermo-cline. The artificial density current could produce a wide diffuse (360° direction) of the mix water at the level of thermo-cline with low electric energy. The field experiment started in 2002 and the water monitoring continued until 2008. The targeted area and volume were approximately 22×10^4 m^2 and 12×10^6 m^3, respectively. The designed device could discharge 30×10^4 m^3/day with 10kW motor. The field experimental area was separated by a stretch of oil fences into two sections; the reference section was main stream in the reservoir and the targeted section was a high turbidity area due to algal blooms before the device installed.

We observed the artificial density current generated diffused over 3km in 2days and observed surface water temperature decrease by ca. 2°C and the thermo-cline weakened at the point of 500m away from the device. An aerial photograph unveiled that the expected effect area from the device was restrained algae blooms. Continuous phytoplankton census showed some changes after the device installed, yet there are more data to be needed for further scientific discussion. The lake situation could be varied from various factors, which made us trouble to obtain robust conclusions for the device effect. However the monitoring data showed a promising effect of the algae blooms control.

In this conference, we would like to introduce our unique device called as a density current generator and show the continuous water monitoring data.

Key word: Density current, thermo-cline, algal bloom, eutrofication.
ABSTRACT

Algicides have traditionally been used in reservoir management to control algae and cyanobacteria (blue-green algae). The algicide of choice is copper sulphate which has been used widely to control algal blooms in water supply storages and lakes for over 100 years. It is generally regarded as effective, economical and safe for operators to use, although increasingly copper is being regarded less favourably as a preferred option as a result of awareness of its adverse environmental impacts on the aquatic ecosystem. Due to these environmental concerns, algicide use is regulated in most states of Australia and also in the US, Europe and Asia to control and limit the application of copper-based algicides. In this context there is awareness within the water industry that the long-term ongoing use of copper sulphate is unsustainable and alternatives need to be found. This project undertook a review of alternative algal control techniques and evaluated a range of selected options that have potential for application in water supply reservoirs. An initial review of possible alternatives to copper sulphate produced a short list of techniques and a list of techniques that are currently commercially available in the US and Australia and therefore have differing degrees of acceptance and testing within the water industry. The techniques vary in their degree of uptake and promise as genuine alternatives to copper sulphate. These options were evaluated in either laboratory bioassays and/or small-scale field trials. The experimental design for each evaluation will enable the study to address the following criteria: (1) Determine cost, toxicity, feasibility, and environmental friendliness; (2) Benchmark against copper sulphate for effectiveness, cost, and ease-of-use; (3) Test selected alternatives in natural water samples, and (4) Address downstream consequences and implications to water treatment utilities. The experimental testing was also designed to assess the mechanisms of action or operation of the proposed control methods. The techniques tested included alternative chemical algicides, nutrient removal and binding, lake circulation, ultrasound and other novel techniques. The aim of a major component of the project work presented here was to compare the activity and effectiveness of two alternative algicides, chelated copper algicide and a stabilized hydrogen peroxide with copper sulphate. This included determining the effectiveness of the three algicides in high and low levels of a model dissolved organic compound (EDTA), the selectiveness of the algicides to cyanobacteria and green algae, the time course of the activity of algicides and the release of odour compounds geosmin from cells damaged by algicides. The effectiveness of the compounds was determined by measuring cell integrity and viability assessment using a flow cytometer in conjunction with fluorescent probes Fluorescein diacetate (FDA) and SYTOX Green. The optimum time for toxic effect for both copper-based algicides appeared to be 48 hours with only slight additional toxic effect after 72 hours exposure in some cases. By contrast the stabilized hydrogen peroxide algicide showed a progressive increase in toxicity up to 72 hours, indicating that it takes longer to be effective than copper based algicides and suggests a different mode of toxic action. The copper based algicides were significantly more toxic to the cyanobacterium M. aeruginosa than to the green alga S. capricornutum. The reverse was found with the hydrogen peroxide algicide which was more toxic to the green alga than the cyanobacterium. This was unexpected based upon the literature reports that suggest hydrogen peroxide is more effective and even selective against cyanobacteria over green algae. Comparisons will be provided for the effectiveness of alternative chemical algicides, algal control by nutrient removal and binding, lake circulation with surface circulators and low power ultrasound.
High-frequency monitoring and modelling of cyanobacteria dynamics in urban lakes: Application of new approaches in Lake Enghien (France) and Lake Pampulha (Brazil) - (Full Oral Presentation)

Talita Silva1,2, Brigitte Vinçon-Leite1, Bruno J. Lemaire1,3, Briac Le Vu1,4, Catherine Quiblier5,6, François Prévot7, Catherine Freissinet8, Martin Seidl1,2, Bruno Tassin1, Nilo Nascimento2
1Université Paris-Est, UMR MA-102 LEESU, Ecole des Ponts ParisTech, 77455 Marne-la-Vallée, France
2Federal University of Minas Gerais, Hydraulic and water resources engineering department, Av. Antônio Carlos, 6627, 31270-901, Belo Horizonte, MG, Brazil
3AgroParisTech, UMR MA-102 LEESU, 77455 Marne-la-Vallée, France
4IRD, LEGOS OMP UMR 5566, 31401 Toulouse, France
5MNHN, USM 505/EA 4105 Ecosystèmes et interactions toxiques, 75231 Paris, France
6Université Paris Diderot, 75013 Paris, France
7IPGP, LGE UMR 7154, Université Paris Diderot, 75205 Paris Cedex 13, France
8SOGREAH Consultants, Water and Territorial Services Group, 38130 Echirolles, France

Contact email: bvl@leesu.enpc.fr

ABSTRACT

In order to better understand the cyanobacteria dynamics in freshwater bodies, a continuous, real-time monitoring system was developed by the PROLPHYC project (funded by the French National Agency for Research ANR). It consists in a measurement buoy equipped with meteorological sensors and immersed probes to measure water temperature, fluorescence and dissolved oxygen at 15-min time step and send them to a database. This new monitoring system offers several advantages over historical techniques: survey of remote sites, reduction of overall cost of data collection and significant increase of quantity and quality of data. In 2009, such a monitoring system was implemented in Lake Enghien (France), an urban lake (mean depth 1.3 m, 41 ha) frequently affected by blooms of the cyanobacterium *Planktothrix agardhii*. The water temperature and the cyanobacteria biomass were simulated with the coupled model DYRESM-CAEDYM during summer and fall. The model was calibrated with the data collected for 15 days and validated over a 5-month period. The goodness of fit between hourly measurements and simulation results showed that DYRESM-CAEDYM is an appropriate model for simulating cyanobacteria dynamics at short and medium time scales in an urban lake. The next step of our research consists in investigating the link between watershed changes and cyanobacteria dynamics. The study site is a tropical urban lake located in Brazil. The inlet and outlet of Lake Pampulha (mean depth 5.0 m, 197 ha) will be equipped with sensors to measure the flow discharge and physical-chemical parameters (temperature, turbidity and conductivity). Automatic samplers will collect water for analysis of quality parameters. The phytoplankton biomass and the water temperature in the lake will be continuously monitored by a buoy equipped with fluorescence and CTD probes. This lake-watershed monitoring associated with the lake phytoplankton modelling will be used to assess the phytoplankton response to watershed management scenarios.

Key word: urban lake, cyanobacteria modelling, high-frequency monitoring.
Toward linking algal boom vulnerability with the hydropower plant operation in Rapel Reservoir

Germán Ibarra & Alberto de la Fuente
Civil Engineering Department, Universidad de Chile

Contact email: geibarra@ing.uchile.cl

ABSTRACT

Rapel reservoir is located at about 120 km from Santiago, the capital city of Chile, and supplies the Rapel hydropower plant whose operation is economically-defined by the Load Economic Dispatch Center, which induces a hydro-peak behavior that modifies, in the semidiurnal timescale, the seasonal evolution of the outflow hydrology. Rapel is a 40 years old dendritic reservoir with bulk retention time between 13 and 73 days, depending on the sector, and it is nowadays presenting severe algal blooms events. The objective of this research is to study the link between both the semidiurnal and the seasonal operation of the hydropower plant, with occurrence of algae patches within the reservoir, in order to identify the areas and conditions most prone to the algal bloom events and design ways to mitigate it. To do so, three-dimensional numerical simulations of summer time conditions of 2009-2010, were conducted with ELCOM (Estuary, Lake and Coastal Ocean Model) and validated based on both field measurements of one thermistor chain located near the dam, and aerial images that allowed identifying algae patchiness and flow patterns within the lake. It shows that the operation of the central define the location of the seasonal thermocline at the same deep of the water withdrawal. As a first approximation, algae were considered as a passive tracer that growth accordingly to a first-order kinetic reaction, thus highlighting the relationship between advection-diffusion transports and growth rates. In this way, numerical results were used to compute renewal rates of different areas of the reservoir, and this parameter was used to compare different case-scenarios that allowed establishing the correlation between the semidiurnal and seasonal operation of the hydropower plant, and mechanical transports processes that control appearance of algal patchiness in the reservoir.
The need to quantify algae and cyanobacteria on-line is typical in water treatment technologies and in the inflow of water to reservoirs. A growing number of reservoirs suffer from extensive cyanobacterial blooms and we need to control the external sources of cyanobacterial biomass to be able to understand the dynamic of dominant cyanobacterial populations. Most of cyanobacteria produce a broad range of compounds with various chemical and toxicological properties. Therefor there is an increasing demand for sensitive on-line devices that can detect cyanobacterial blooms and serve as an alert systems. The objective of our study was to verify the use of new instrument Algal Online Monitor (AOM) in field conditions.

The AOM fluorometer is able to work in continuous mode with remote GSM data transfer to laboratory. Because of the low limit of detection (approximately 20 cells for green algae Staurastrum, 200 cells for cyanobacteria Microcystis) the device is suitable as an early warning system.
Effects of essential oils and aqueous extracts of several plant species on the growth of \textit{ANABAENA CYLINDRICA} (Cyanophyta) and \textit{CHLORELLA VULGARIS} (Chlorophyta)

LILIANA MONTEIRO\textsuperscript{1}, ANA M. GERALDES\textsuperscript{1}, SANDRA BARROS\textsuperscript{1} & CONCEIÇÃO FERNANDES\textsuperscript{1}\textsuperscript{**}

\textsuperscript{1}CIMO, Escola Superior Agrária, Instituto Politécnico de Bragança Campus de Santa Apolónia, Bragança Portugal (geraldes@ipb.pt)

Contact e-mail: geraldes@ipb.pt

ABSTRACT

In the future, the use of plant extracts to control phytoplankton growth might be a promising algal management tool in aquatic ecosystems, due to its low cost and environmental safeness. In the present research, effects of aqueous extracts and essential oils from rosemary (\textit{Rosmarinus officinalis}), lavender (\textit{Lavandula} sp.), poplar (\textit{Populus} sp.), ash (\textit{Fraxinus angustifolia}), laurel (\textit{Laurus nobilis}), mint (\textit{Mentha suavolens}) and elder (\textit{Sambucus nigra}) on the growth of axenic cultures of \textit{Anabaena cylindrica} UTAD_ A212 and \textit{Chlorella vulgaris} CBSC 15-2075 were screened. Plant species were collected in Bragança region (41\textdegree 47'.01"N; 6\textdegree 45'59.21"W) during September 2009. Steam distillation of plants was performed to obtain essential oils and aqueous extracts. Essential oils were tested in 1:1, 1:3, 1:4, 1:10, 1:50 concentrations by disc plate diffusion assay method, against \textit{Anabaena} and \textit{Chlorella} growth. Aqueous extracts were evaluated in batch cultures by testing the effect of 1:4, 1:7 and 1:10 concentrations on algal growth. All the experiments were incubated under optimal conditions. Present results suggest that essential oils had an algaecide potential in all concentrations, except rosemary extract in the 1:50 concentration. Conversely, none of the aqueous extracts had algaecide potential. However, laurel, rosemary and ash aqueous extracts presented algaeptic effect in the concentration of 1:4. Laurel and rosemary extracts had effect on both algal species, while ash only had effect on \textit{Anabaena} growth. Further research to assess the effects of these plant extracts against other non-target organisms is in course.

\textbf{Key words:} Plant extracts, algae, algaecide and algaeptic effects
Potential use of eucalyptus timber and bark wastes for the inhibition of cianobacterial growth in a reservoir in NW Spain

Cobo, F. (1), S. Barca-Bravo (1), M. J. Servia (2), R. Vieira-Lanero (1) & L. Lago (3)

(1) "Encoro do Con" Hydrobiological Field Station. University of Santiago de Compostela. Castroagudín s/n, 36617 Vilagarcía de Arousa, Pontevedra, España.
(3) Department of Zoology and Physical Anthropology. Faculty of Biology. University of Santiago de Compostela. Campus Sur s/n, 15782 Santiago de Compostela, España.

Contact email: rufino.vieira@usc.es

ABSTRACT

We used 6 limnocorral (8 m deep plastic containers enclosing a column of water) for evaluating the effects of eucalyptus wastes on the growth of the phytoplankton community, especially cyanobacteria, in a reservoir in NW Spain (As Forcadas, Galicia). These wastes might provide a carbon source for the microbial community of the reservoir, thus facilitating the uptake of significant amounts of phosphorous by the microbial loop ecosystem. As a consequence, we expect a decrease in the amount of phosphorous available for the growth of cyanobacteria, avoiding the use of chemical compounds for the inhibition of cyanobacterial growth. We started the experiment in May 2010, three months before the peak of the cyanobacterial bloom, and continued it for 12 months. We added eucalyptus bark chips into two limnocorral, eucalyptus wood chips into two others, and left two limnocorral as controls. We measured a total of 18 physico-chemical parameters on a monthly basis, including total P, chlorophyll and microcystin-LR, at 4 different depths. Additionally, we took water samples for the identification of phytoplankton in the laboratory. Results showed a significant reduction in the concentrations of chlorophyll and microcystin-LR in those limnocorral where eucalyptus chips were added. Moreover, we detected significant differences in the taxonomic composition of the phytoplankton community between controls and treatments.
SESSION 7
Reservoir Management Plans for cyanobacterial blooms - a case study (Full Oral Presentation)

Dr Thorsten D. Mosisch
Source Water Quality Manager, SA Water, GPO Box 1751, Adelaide SA 5001, Australia

Contact email: thorsten.mosisch@sawater.com.au

ABSTRACT

Understanding water supply systems and processes, hazards and the integral role of reservoirs in the context of the whole supply system from catchment to tap is critical to successfully achieving water quality targets. This includes targets for problem cyanobacterial metabolites such as geosmin and toxins. To gain real benefit from knowledge into processes and system behaviour as well as new research it is important that this information is properly “operationalised” by developing operational guides and rules. To manage cyanobacterial blooms and their problem metabolites in reservoirs, SA Water has developed comprehensive reservoir-specific management plans, ensuring that the knowledge gained from our risk assessment, monitoring, research and modelling is transferred into clear, systematic operational actions. Water quality challenges can arise very quickly and management responses must be similarly rapid and well informed. These reservoir management plans provide our operators with a detailed “road map” for good water quality management and are very useful when we face potential incidents. This case study outlines the management plan for Myponga Reservoir in South Australia. Major blooms of *Anabaena circinalis* occur in this reservoir during each summer. In the past these were controlled by the application of copper sulphate, however since 2007 a different approach has been taken which excludes copper sulphate dosing and instead relies on the optimisation and integration of reservoir management strategies and water treatment plant operations, providing a best practice approach in managing cyanobacteria without application of copper sulphate. Key inclusions in the management plan are succinct overviews of the various system-specific preventive, management and contingency measures available for *Anabaena circinalis* and its metabolites. This includes a table of recommended operational responses, from monitoring to treatment plant operations, based on step changes in cyanobacteria cell numbers. The presentation will cover the management plan for Myponga reservoir in detail, highlighting how adopting these whole of system approaches helps to manage water quality incidents.
Luxhay is an artificial eutrophic reservoir located within a catchment area of 30.5 km$^2$ in the South West of England. The reservoir receives input from a number of sources including the river Tone. Inputs are variable in quantity and frequency. Water levels in the reservoir are therefore subjected to fluctuations as some inputs are seasonal. The reservoir is used for drinking water and abstracted on demand, contributing to in-lake flux independent of seasonal variations in supply requirements. For a number of years this reservoir has been experiencing problems with water treatment due to the presence of blooms of cyanobacteria, principally *Microcystis* spp. In 2006 an intense bloom occurred with associated high concentrations of cyanotoxins. A research programme was instigated in 2007 aiming to a) calculate a nutrient budget from both internal and external sources, b) consider a more effective mixing regime to try to reduce the size of the blooms. Copper sulphate, P-stripping and bubble-curtain artificial mixing have been successively or in combination applied over a long period since the late 1980's but there have been insufficient analyses to test for their efficacy in the treatment of cyanobacterial blooms or decrease in phosphorus. A fifteen years data series were studied including total phosphorus (TP), total oxidised nitrate (TON) and chlorophyll-a (CHL). A downward trend for TON was observed in the river. TON and TP were markedly seasonal in the reservoir. A Repeated-Measures ANOVA to test for differences in the treatments was significant ($p < 0.01$) for CHL but no TP concentrations. Airline operational hours were changed from 23:00 to 11:00 to 10:00 to 18:00. Significant decreases in phosphorus and chlorophyll concentrations have been observed in Luxhay during the past two years.
Microcystis-targeted restoration strategies (Full Oral Presentation)

Maršálek B.¹, Eliska Marsalkova¹, Lenka Sejnohova¹, Holba M.¹², Miroslav Ploteny ¹, Roman Sladek², Jiří Palčík²

¹ – Institute of Botany, Academy of Science of the Czech Republic, v.v.i., Lidická 25/27, 657 20 Brno, Czech Republic
² – ASIO Ltd., POB 56, Tuřanka 1, 627 00 Brno-Slatina, Czech Republic, tel.:+420 548 428 129, e-mail: marsalek@sinice.cz

ABSTRACT

Cyanobacterial species forming water blooms has a specific life cycle and strategy, which can be used for the selective management of water bodies. Unsuitability of algicides use due to their ecotoxicological impact on aquatic ecosystems promote the research of more ecological alternatives, which can selectively treat cyanobacterial water blooms. We will present the experiences with in situ sediments treatment targeted to decompose the inoculum of Microcystis colonies in sediments. The combination of hydraulic manipulation with the water level in reservoir, lime pretreatment of sediments 1 year before the 1 year of half-empty and pulse manipulation with water level leads to deep mineralization of air-open part of the sediments. Moreover, sediments in the part of the reservoir, where water remind were covered by mineralized and lime-treated sediments from the upper part of the reservoir and created the 20-25cm mineral barrier for Microcystis reinvasion. This effect was reached without any transportation or dredging, we used just natural forces in the reservoir. The concentration of Microcystis cells decreased from 35-37mils cells/ g of sediments up to 3-7.000 cells/g of sediments.

Aeration of hypolimnion and destratification technology is currently used as well. The aim is to promote diatoms by Si activation and replace cyanobacteria. Two systems are used – the mixing pumps, which pump water with oxygen to the bottom and the second system, which pumpe air, which is installed in the deepest part of the reservoir. System is installed according to the recommendation of limnological expertise and mathematical models. Effect on the phytoplankton composition will be presented.

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Freshwater Lake Restoration in China: History and Prospective (Full Oral Presentation)

Boqiang Qin
Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences
73 East Beijing Road, Nanjing 210008
PR China

Contact e-mail: qinbq@niglas.ac.cn

ABSTRACT

China has many freshwater lakes. The most are shallow lakes located in middle and lower reach of Yangtze River. Because of the over-emphasis on resource exploitation, especially the fishery resource exploitation, a great amount of grass carp had been introduced into these shallow and macrophyte dominated lakes, caused these lakes shifted to phytoplankton dominated lakes. Eutrophication is the main issue of these lakes currently confronting with. During the tenth-five-year (2001-2005), ecological restoration, i.e. macrophyte restoration, to control the eutrophication was over-emphasized. But very few lakes were successfully restored. The reason of lake restoration failure is the macrophyte dominance ecosystem restoration was simplified as the macrophyte crop, and alleviation of environmental stressors which influence the macrophyte growth was completely neglected. These environmental stressors include trophic level, hydrodynamic action, depth, underwater light availability, sediment physic-chemical feature, fish community, etc. During eleventh-five-year, changes the environmental conditions has been emphasized and some lake restoration showing hopeful.
Cyanobacterial bloom dynamics - some lessons from the Nineties

Bradford Sherman, Phil Ford, and Ian Webster
CSIRO Land and Water, Canberra, Australia

Contact email: Brad.Sherman@csiro.au

ABSTRACT

The 1990s was a period of active research into cyanobacterial blooms in Australia. Three large CSIRO-led projects were undertaken in two weir pools and one reservoir covering a range of catchment, meteorological and hydrological conditions. These studies examined hydrodynamic-chemical-biological coupling and revealed striking similarities as regards the onset and growth of cyanobacterial blooms. In all systems, the cyanobacteria population growth did not occur until after the onset of persistent stratification and populations only grew when the mixed layer depth, $Z_{sml}$, was $\leq 3$ times the euphotic depth, $Z_{eu}$. In the case of river weir pools, a period of time following the onset of stratification was required for the water column to clear sufficiently through sinking of suspended sediment to provide suitable light conditions to sustain cyanobacterial growth. i.e. for $Z_{sml}:Z_{eu} \leq 3$. Following the onset of stratification, cyanobacterial populations in all three systems grew at their light-limited rate ($0.31 - 0.37 \text{ d}^{-1}$) until either the bioavailable phosphorus was depleted or seasonal deepening of the surface layer resulted in light exposure below the compensation level required for net growth. There was no evidence of nutrient-mediated population growth rates in these systems. Neither was there any evidence that buoyancy regulation conferred any benefit to the cyanobacteria. Positively buoyant phytoplankton (Anabaena, Microcystis, Cylindrospermopsis) occupied the surface layer but were not observed to migrate vertically to exploit light-nutrient gradients in these systems. Surface layer populations remained static until physical processes introduced additional nutrients to the surface layer following which the populations commenced growing. These systems typically exhibit $Z_{sml}:Z_{eu} \sim 2$ and metalimnetic maxima in phytoplankton are not observed. For this sort of system, reservoir management measures that target nutrient load reduction can be expected to reduce the average annual cyanobacterial biomass but not necessarily eliminate the cyanobacterial dominance of the population.
Evaluation of cascade effect of reservoirs on water quality and relationship with biological community composition

*Saldaña-Fabela P.; **Gutiérrez-Hernández A.; **Diaz-Pardo E. and *Gómez-Balandra M.A.

*Instituto Mexicano de Tecnología del Agua. **Universidad Autónoma de Querétaro

Contact email: psaldana@tlaloc.imta.mx

When several reservoirs are located one behind another in a river basin, a cascade effect by water liberation is produced downstream, resulting in changes on abiotic and biotic components of the ecosystems. In the San Juan River sub-basin at the Querétaro State, Mexico; three reservoirs in cascade are located to regulate the water quantity for agriculture, and they consequently modify its quality. The present work includes an integral assessment of changes in the biological communities composition and structure and their correlation with water quality. Eight sites along 86 km of the river bed were selected for sampling; three of them represented reservoirs and the other five river conditions. From eleven water quality parameters, five represented 73% of variation and not significant differences were exhibited between reservoirs and river sites. According to water quality criteria, water in reservoirs can be used for irrigation and nutrient enrichment conditions were presented; classifying the reservoirs as eutrophic with a siltation process, not only by the nutrients entrance but also by their life span reduction. Phytoplankton composition indicated the presence of species with characteristics of strategists C (Chlorophyceans) in autumn and winter, substituted by species R (diatoms) in spring. *Microsystis aeruginosa* dominance in reservoirs is a common feature of eutrophic environment. This condition is worsened by the continuous agricultural, industrial, and municipal discharges that affect water quality and determine the biological communities composition. Reservoirs with continuous nutrient loads entrances were found in eutrophic and siltation processes. The analysis of water quality conditions, phytoplankton communities structure relationship show a clear evidence that the ecosystem deterioration is associated to nutrient enrichment in reservoirs, the hydraulic management and the opportunistic species predominance.

**Keywords:** Reservoirs in waterfall, quality of the water, eutrophication, ecological changes, phytoplankton.
Manganese sources and cycling in a tropical eutrophic water supply reservoir, Paso Bonito Reservoir, Cuba

Carmen Betancourt, Fanny Jorge, Roberto Suárez, Marc Beutel & Seyoum Gebremariam
Centro de Estudios Ambientales de Cienfuegos
Ministerio de Ciencia Tecnología y Medio Ambiente, Cuba.

Contact email: carmen@gestion.ceac.cu

ABSTRACT

Paso Bonito Reservoir (Zmean = 6.5 m; V = 8.0 hm³) is a small raw water reservoir in south-central Cuba. This study evaluated sources of high levels of manganese in the reservoir causing taste and odor problems. Watershed monitoring showed that levels of total manganese (Mn) and total iron (Fe) were high (Mn 0.14–0.64 mg/L; Fe 5.3–12.4 mg/L) during the first flood of the wet season in river sampling stations near historical pyrite mining operations. Monitoring in the reservoir showed that Mn and Fe were present in bottom waters throughout the year, with peak levels (>8 mg/L of Mn and >30 mg/L of Fe) coinciding with low levels of oxygen in summer months. Empirical modeling of Mn concentration in the reservoir water column showed that it correlated significantly with Fe (positive correlation), redox potential (negative correlation) and dissolved oxygen (negative correlation). Statistical evaluation of the temporal cycle of Mn in raw water delivered to the Juan Gonzales Water Treatment Plant showed that Mn accumulation was highly seasonal, peaking annually around September when dissolved oxygen in raw water was at a minimum. Data suggest that during first-flood conditions early in the wet season, mass loading of Mn and Fe from the watershed to the reservoir is high. During the subsequent drier low-flow summer period, external mass loading of metals drops dramatically and the reservoir becomes a large exporter of Mn and Fe as the metals are internally recycled under anaerobic conditions in bottom waters.

Key words: dissolved oxygen, iron, manganese, reservoir water quality
Sedimentary phosphorus in a cascade of five reservoirs (Lozoya River, Central Spain)

Pilar Lopez¹, Rafael Marcé¹, Iñaki Urrutia², Mª Carmen Gordo², Joan Armengol¹

²Canal Isabel II. Laboratorios Centrales. C/Engracia, 125. 28003-Madrid

Contact email: jarmengol@ub.edu

ABSTRACT

The concentration of phosphorus, carbon and nitrogen in superficial sediments in a cascade of five reservoirs (Pinilla, Riosequillo, Puentes Viejas, El Villar and El Atazar) located along the Lozoya river (Central Spain) has been determined. The mean reservoir values of sedimentary phosphorus, nitrogen and carbon increased from the first reservoir (Pinilla) to the central one (Puentes Viejas) where they reached 62 molP/g(dw), 5.36 mmolC/g(dw) and 0.56 mmolN/g(dw). Then, they followed a decreasing trend until the last reservoir (El Atazar) which presented concentrations close to those of Pinilla. Phosphorus and nitrogen usually tended to increase from the river end to the dam at each reservoir, whilst carbon did not show a regular trend associated to the river flow. Sedimentary phosphorus was positively related to nitrogen and small particles (Ø: 2-10 μm) and negatively related to silicon and sands (Ø: 125-250 μm). The ratio Fe/Al, which is an indicator of authigenic iron precipitation, explained more than 90% of the sedimentary phosphorus variance in four reservoirs (Pinilla, Riosequillo, El Villar and El Atazar). In the other reservoir (Puentes Viejas) Psed variance was explained by Fe/Al ratio as main factor, but also nitrogen as secondary factor. Hence, association of sedimentary phosphorus to iron oxides appeared as the main factor determining phosphorus accumulation in the sediments of the Lozoya reservoirs. The concentration of dissolved phosphate in the water overlaying sediment surface was mainly related to the sedimentary N/P ratio depending on carbon concentration. This suggested a bacterial influence on the retention of phosphorus in sediments in this system.
SESSION 8
Lake restoration by nutrient loading reduction and in-lake measures (KEYNOTE SPEECH)

Erik Jeppesen, Martin Søndergaard & Lone Liboriussen
National Environmental Research Institute, Aarhus University, Vejlsøvej 25, PO Box 314, DK-8600 Silkeborg, Denmark; ej@dmu.dk

Contact email: ej@dmu.dk

Abstract

Freshwater lakes provide water for consumption and irrigation, constitute valuable food sources, are used for recreational activities, and add to biodiversity on Earth. For 50-100 years eutrophication has posed the most serious threat to lakes worldwide. High nutrient loading has resulted in turbid water, excessive blooms of nuisance cyanobacteria, dominance of coarse fish and loss of biodiversity. In recent years major efforts have taken in the rest of the world to combat eutrophication. The measures applied include treatment or diversion of sewage and numerous actions to reduce diffuse loading. Lakes often respond slowly to reductions of external nutrient loading, which may be due to release of phosphorus stored in the sediment during the eutrophication period. To re-enforce recovery several physico-chemical and biological methods have been used. These include sediment removal, aluminium treatment of sediment and biomanipulation (fish removal, restoring plant communities). Such measures have provided short-term and often considerable improvements in ecological state, but the long-term perspectives are less clear. So far, sediment removal seems to have the highest probability of producing a long-term effect, while other methods need further refinement, and it is likely that treatments need to be repeated several times during a prolonged period.

Removal of planktivorous fish (mainly roach, *Rutilus rutilus*, and bream, *Abramis brama*) has commonly been used as a method to improve the ecological quality of Danish lakes for the past 10-15 years. We analyze the general and long-term effects obtained after the removal of 40-1,360 kg fish ha\(^{-1}\) in 36 mainly shallow and eutrophic lakes. In lakes where less than 200 kg fish ha\(^{-1}\) were removed within a 3-year period only minor effects were observed, but at higher removal marked effects could be traced on both chemical and biological variables. The concentrations of chlorophyll, total phosphorus, total nitrogen and suspended solids decreased to 50-70% of the level prior to the removal. The most significant and long-lasting effects were found for suspended solids and Secchi depth, while the lowest and most short-lived effects were seen for chlorophyll, probably reflecting an efficient and persistent reduction of the bream stock and, with it, reduced resuspension, while the biomass of roach sooner returned to former levels. Total algal biomass also declined after fish removal, particularly that of bluegreens, whereas the biomass of cryptophytes increased, indicating enhanced grazing pressure by zooplankton. The abundance and species numbers of submerged macrophytes increased in a majority of the lakes. For most variables the effects of the fish removal were significant for 6-10 years, after which many lakes tended to return to pre-restoration conditions, probably mainly because of consistently high external and internal phosphorus loading. We conclude that a sufficiently extensive removal of planktivorous fish is an efficient tool to create clear water with cascading effects on most trophic levels; however, repeated fish removal is probably required to obtain long-term effects in the most nutrient rich lakes. In the talk I will also discuss the potential for using biomanipulation in lakes and reservoirs in warm countries where fish predation naturally is higher than in north temperate lakes.
The Effects of Nitrate on Nutrient Cycling at the Sediment-Water Interface of a Thermally
Stratified Water Supply Reservoir (Full Oral Presentation)

Francisco Cubas, John T. Novak, Adil N. Godrej, and Thomas J. Grizzard
Virginia Polytechnic Institute & State University

Contact email: franjcs@vt.edu

ABSTRACT

The Occoquan Reservoir is a constructed drinking water impoundment serving the Virginia suburbs of Washington DC. For over 30 years, the reservoir has been part of an indirect potable reuse system where an advanced water reclamation plant (WRP) discharges high quality reclaimed water into a major tributary, thereby increasing the drinking water safe yield by supplementing natural streamflow. The WRP is operated to either remove nitrogen or produce a nitrified discharge. The latter helps to reduce the release of undesirable substances from deposited sediments by delaying or preventing the establishment of anaerobic conditions in the reservoir during periods of thermal stratification. Field observations during periods of deep water anoxia and continuous flow microcosms, built with similar water volume to surficial sediment area ratio as the reservoir, were used to study the effects of various nitrate concentrations on releases of selected constituents from the sediments. Results showed that nitrate concentrations lower than 2 mg/L nitrogen were insufficient to prevent the release of phosphorus, iron, and manganese from the deposited sediments. Anaerobic conditions were delayed when initial concentrations of nitrate were increased, and when inflow concentrations exceeded 5mg/L N, anaerobic conditions were prevented, resulting in low concentrations of phosphorus, iron, and manganese to the water column. Denitrification rates as well as phosphorus release rates were similar in both microcosm experiments and field observations having the same water volume to sediment area ratio. Sediment ammonium release was found to be similar for all nitrate concentrations observed at the sediment-water interface, suggesting that the sediment ammonium release mechanisms were different from those for other constituents. However, correlations between ammonium release and organic matter, and between organic matter and nitrate at the sediment-water interface were found, suggesting a possible indirect relationship between sediment ammonium release and nitrate concentration in the water column.
Characterization of Bottom Sediments in Lakes Using Hydroacoustics and Comparison with Laboratory Measurements (Full Oral Presentation)

Michael A. Anderson

Department of Environmental Sciences, University of California, Riverside, CA 92521, USA.

Contact email: michael.anderson@ucr.edu

ABSTRACT

The acoustical properties of bottom sediments in two lakes were shown to be strongly correlated with clay content, organic C and total N concentrations, and other important sediment properties. The fractal dimension of the bottom echo was more strongly correlated with sediment physical and chemical properties than energy-based measures. The fractal dimension was also correlated with rates of PO₄-P and NH₄-N release from intact sediment cores and sediment oxygen demand. Measurements made at 430-kHz were more sensitive to differences in sediment properties than 201- or 38-kHz. Hydroacoustic measurements allow rapid assessment of properties important in lake restoration, benthic habitat assessments, and water resource management.
Improvement of eutrophication in the Ancient Canal by active zeolite barriers capping (Full Oral Presentation)

Jinlan Xu, Junchen Kang, Tinglin Huang, Sen Wang
School of Environmental and Municipal Engineering, Xi’an University of Architecture and Technology, Xi’an 710055, China

Contact email: xujinlan@xauat.edu.cn

ABSTRACT

The application of an active zeolite barrier was investigated to improvement of eutrophication in the Ancient Canal. For this, four types of zeolites (diameter: 1〜2 mm) were applied in order to investage the effect of barrier materials on N removal. The dosage of the zeolites was 1.46 kg.m-2 and the ammonium concentrations in overlying water were 3.47, 14.39, and 25.88 mg/L, respectively. In addition, the long term effect of the zeolites on eutrophication improvement was tested for 3 work-regeneration cycles. It is found that the capacity of elimination total N of the four zeolites was significant and decreased with the following order: Haiyu Zeolite> Olympus Zeolite> Zeolite> Calcium Zeolite. Therefore, it is considered that the Haiyu zeolite should be the best barrier materials in this study. In addition, it is found for Haiyu Zeolite that 10, 15 and 65 days elapsed before ammonium concentrations decreased to zero while initial ammonium concentrations were 3.47, 14.39 and 25.88 mg/L, respectively. Besides, 71% of total nitrogen (TN) could be removed within 24 days at the lowest initial ammonium concentration. Accordingly, around 50% of TN was removed within 65 days at other two cases by Haiyu Zeolite. A long term experiment shows that Calcium Zeolite significantly lost its ability of remediation since TN was always constant at 17.81 mg/L during the 3rd circle. Finally, it is concluded that the Haiyu Zeolite accompanied by the best regeneration capacity could constantly remove ammonium released by sediment of the Ancient Canal and offer better capacity of improving eutrophication.

Key words: eutrophication; active zeolite barriers capping; Ancient Canal; ammonium
European experiences in lake restoration and cyanobacterial control through in situ phosphorus binding with Phoslock®, a lanthanum enriched bentonite (Full Oral Presentation)

Patrick Van Goethem
Environmental Engineer, Phoslock Europe GmbH, Belgium

Contact email: pvangoethem@phoslock.com.au

ABSTRACT

Pollution with phosphorus is known to increase eutrophication and the occurrence of cyanobacterial blooms. Catchment management alone is often insufficient to restore a water body to a good ecological status as internal loading can deliver a substantial percentage of total bio-available phosphorus, especially in the case of water bodies with a limited catchment. A technique developed by the Australian CSIRO uses a lanthanum enriched bentonite to bind phosphate in situ and prevent phosphorus release from the sediment without altering water chemistry or causing negative effects on aquatic life. Here we show the effectiveness and longevity of the modified clay in binding phosphorus and reducing trophic status by presenting results from a number of large scale applications on European water bodies. A number of other effects are also attributed to the removal of phosphorus from the water column through the addition of the clay. These include an overall reduction in algal biomass and an increase in macrophyte growth.
ABSTRACT

A watershed application of HSPF using the nutrient algorithm PQUAL was calibrated for a four-year period (2002-2005) and verified for a two-year period (2006-2007) for the 126.21 km² Upper Broad Run basin, a rural watershed in Virginia that drains to Lake Manassas, a water supply reservoir. Based on annual, seasonal and monthly loading comparisons, the calibration and verification varied between very good and reasonable for flow and other constituents (sediment, ammonium, nitrate, and orthophosphate phosphorus). “One-variable-at-a-time” sensitivity analysis, using the normalized sensitivity index (S), was performed on the calibrated model to examine the sensitivity of model outputs (flow, sediment and nutrient loadings) with respect to model inputs and parameters. Results were compared on both average yearly and average seasonal values. Seven weather-related inputs and 47 parameters related to streamflow generation, sediment and nutrient transport, and interactions on lands and within streams were included in the sensitivity analysis. Generally, all model outputs were quite sensitive to weather-related inputs, especially precipitation, indicating the importance of accurately representing climate conditions for the watershed. Most of the sensitive parameters were associated with flow, sediment and nutrient generation processes on land. Parameters for in-stream processes only had significant impacts on sediment loading. It was also found that most of the sensitive inputs and parameters became a little more significant in summer. Accurate hydrologic simulation is of first important because of its significant impact on sediment and nutrient loadings. It is hoped that the tabulated values of the normalized sensitivity index will indicate which variables are more important to pay attention to in the development of HSPF applications.
Chemical interferences when using High Gradient Magnetic Separation for phosphate removal: consequences for lake restoration

I. de Vicente¹, ², A. Merino-Martos¹, F. Guerrero³, L. Cruz-Pizarro¹ and J. de Vicente⁴

Contact email: ivicente@ugr.es

ABSTRACT

A promising method for lake restoration is the treatment of lake inlets through the adsorption of Phosphate (P) on strongly magnetizable particles (Fe) and their subsequent removal using in-flow High Gradient Magnetic Separation (HGMS) techniques. In this work we report an extensive investigation on the chemical interferences affecting P removal efficiencies in natural waters from 20 Mediterranean ponds and reservoirs. A set of four treatments were considered based on different Fe particles / P concentration ratios. High P removal efficiencies (> 80 %) have been found in freshwater lakes (conductivities < 600 µS cm⁻¹). However, a significant reduction in P removal was observed for extremely high mineralized waters. Correlation analysis has shown that major cations (Mg²⁺, Na⁺ and K⁺) and anions (SO₄²⁻ and Cl⁻) present in lake waters were the driving factors controlling the effectiveness of P removal. Complementary analysis has shown that after the addition of Fe microparticles, a notable reduction in dissolved organic carbon (DOC) and dissolved reactive silicate (Si) concentrations, apart from the P reduction, as well as in water color is observed. Our results suggest that P removal by magnetic seeding comes from specific interactions although the absolute electrophoretic mobility of Fe particles dramatically decreases when increasing the conductivity of lake waters as predicted by the Derjaguin, Landau, Verwey and Overbeek (DLVO) theory.

Keywords: High Gradient Magnetic Separation, phosphorus, eutrophication, magnetic particles, chemical interferences.
Application of iron sulphate on the reservoir inflow as the control measure for external phosphorus and cyanobacterial load

Maršálek B., Jancula Daniel, Eliska Marsalkova, Lenka Sejnohova, Holba M., Miroslav Ploteny, Roman Sladek, Jiri Palcik

1 – Institute of Botany, Academy of Science of the Czech Republic, v.v.i., Lidická 25/27, 657 20 Brno, Czech Republic e-mail: marsalek@sinice.cz
2 – ASIO Ltd., POB 56, Tuřanka 1, 627 00 Brno-Slatina, Czech Republic

ABSTRACT

Economical, limnological and ecotoxicological evaluation of the iron sulphate use in the inflow to the reservoir is evaluated. Experiences show, that the external phosphorus load id decreased by application od 20mg of Fe from 0,120-0,140mg P to around 0,01mg P within a 400-600m of inflow. The measures seems to be very effective and is installed with remote system of control of inflow-dependent automatic dosing. Actual experiences proved, that this system is effective not only for the external phosphorus load, but also for the external sources of cyanobacterial inoculum.
Field Test of Reservoir Management Practice Pollutant Removal Efficiencies in Southern China

Ru ZHANG¹,², Wenbin ZHOU¹,², Richard FIELD³, Anthony TAFURI³, Shaw L YU⁴

1 Key Laboratory of Poyang Lake Ecology and Bio-resource Utilization, Nanchang University, Nanchang 330047, China
2 School of Environmental and Chemical Engineering, Nanchang University, Nanchang 330031, China
3 National Risk Management Research Laboratory, US Environmental Protection Agency, Edison, NJ 08837, USA
4 Department of Civil & Environmental Engineering, University of Virginia, Charlottesville, VA 22904, USA

Contact email: susanzhanru@hotmail.com

ABSTRACT

This paper presents a study on the use of wetland as best management practices (BMPs) for controlling nonpoint pollution in the Xikeng Reservoir watershed located at Shenzhen and Qian Lake watershed at Nanchang in southern China. The Shenzhen experiments tested a construct wetland at the reservoir location, while the Nanchang experiments were conducted for treating stormwater on the campus of Nanchang University. Samples were collected during storm events and were analyzed for total suspended solids (TSS), biochemical oxygen demand (BOD₅), ammonia nitrogen (NH₃–N), and total phosphorus (TP). The removal efficiencies of both BMP systems were evaluated using the Efficiency Ratio (ER) method based on the event mean concentration (EMC) data. In summary, the wetland treatment system removed 50%—90% of TSS, 20%—60% of BOD₅, and 30%—70% of TP and NH₃–N, respectively. The wide range of performance results indicates the importance of design parameters such as length and the presence of check dams. Minimum design guidelines for use of wetland as a BMP are suggested.

Keywords: wetland, nonpoint source (NPS) pollution control, best management practices (BMPs), reservoir
POSTERS SESSION
From the ocean to the reservoir: the influence of the Gulf Stream position on the phytoplankton community in El Gergal reservoir (SW Spain)

E. Moreno-Ostos¹, D. G. George², J. Rodríguez¹, J. Lucena¹, V. Rodríguez¹, R.L. Palomino-Torres¹, C. Esco³, A. Basanta³ and J.M Blanco¹

¹Grupo de Ecología Marina y Limnología. Departamento de Ecología, Universidad de Málaga. Campus Universitario de Teatinos S/N. 29071. Málaga (Spain)
²Institute of Geography and Earth Sciences. University of Wales. Aberystwyth SY23 3DB (UK)
³Empresa Metropolitana de Abastecimiento y Saneamiento de Aguas de Sevilla, S.A. EMASESA, Calle Escuelas Pías 1, 41003. Sevilla (Spain)

Contact email: quique@uma.es

Abstract

It is well-known that the latitudinal position of the north-wall of the Gulf Stream influences the climatic conditions in the Atlantic North and western Europe. Southerly movements of the Gulf Stream typically induce unstable meteorological conditions in this region, while north displacements of the oceanic current are associated with stable weather. In the present paper we explore a seven years data set including annual Gulf Stream Index, meteorological records and phytoplankton community structure to suggest that the position of the Gulf Stream influences the phytoplankton dynamics in El Gergal, a reservoir located in the vicinity of the Atlantic coast of Andalusia (SW Spain). We also describe the dynamic response of the main phytoplankton functional groups to the meteorological variability induced by changes in the Gulf Stream position. Implications for the stored water quality management are pointed out.
Current situation of Cyanobacterial abundance in Spanish reservoirs, with emphasis on differences related to basin bedrock categories.

Caridad de Hoyos (Centro de Estudios Hidrográficos, CEDEX), José Pahissa (Centro de Estudios Hidrográficos, CEDEX), Jordi Catalán (Centro de Estudios Avanzados de Blanes, CSIC)

Contact email: caridad.dehoyos@cedex.es

ABSTRACT

In Spain, fresh water stored in reservoirs is the main source of drinking water and is also subject to recreational use. This work presents the current situation of the cyanobacterial problem in Spanish reservoirs. The data includes 278 reservoirs distributed throughout all the Spanish geography, sampled from 2006 to 2009 (Source: Data base of the Ministry of the Environment). The reservoirs are classified according to the WHO guidelines levels of cyanobacteria for recreational waters and drinking water supply, respectively. 41 % of the reservoirs (114) have cyanobacterial biovolume above $0.2 \text{ mm}^3/\text{l}$ (at least during summer maximum values). Cyanobacterial problems are more intense in the reservoirs on siliceous bedrock areas of western Spain than in the calcareous bedrock areas of the Eastern part, although the level of pressures is similar for both reservoir groups.
Hydrological sustainable management of anthropized wetlands in mediterranean climate: a case study of northern Algeria.

W. MARTÍN-ROSALES (1); B. TOUAIBIA (2); T. TORÁN (3), M. ALONSO (3) and T. FERNÁNDEZ (3)
(1) Departamento de Geodinámica. Universidad of Granada. E-18071, Granada, Spain;
(3) GHI-Gabinete Hispano de Ingeniería. E-28020, Madrid, Spain

Contact email: wmartin@ugr.es

Abstract

Knowledge of the water balance of lakes and wetlands is an essential component of water management, especially in semi-arid areas, characterised by high hydrological variability and potential evapotranspiration values greater than rainfall during most months. The lack of available data and the extensive and intensive anthropogenic impacts that had suffered these areas, limit the development of a sustainable hydrological management. This is the case of Fetzara Lake (150 km²), a RAMSAT site located about 15 miles south-west of Annaba, in Algeria, and one of the most important freshwater lakes of northern Africa. The lake was unsuccessfully drained in 1937, and the site remained dry for long periods of time, losing a lot of its ornithological value. Retaining winter floods in recent years has allowed Lake Fetzara to regain some of its importance as an ecological site. Several industries also discharge effluent that contains heavy metals and other pollutants into the lake. This study discusses a water balance model, and also describes the methods employed in obtaining the different components. The dataset includes watershed and lake morphometry, meteorological data (temperature, rainfall and evaporation), geological and geomorphological information of the watershed and geometric and hydraulic characteristics of the channel. The information is used to simulate the monthly lake water levels in various hydrological scenarios. Results indicate that groundwater plays an important role in the hydrological behaviour of this wetland. Finally, the communication focus the need to develop an hydrometeorological network that could provide a scientifically and hydrology-based management of this important wetland.
Hydrogeochemical characterisation of coastal wetlands in the Campo Dalías (SE Spain)

Francisco Sánchez Martos[1], Luis Molina Sánchez[1] and Wenceslao Martín Rosales[2]


Contact email: wmartin@ugr.es

Abstract

The study area comprises two coastal wetlands (“Punta Entinas” and “Salinas de Cerrillos”) situated on the coastal margin of the Campo of Dalías. The wetlands are endorheic and consist of two partially-silted tidal lagoons, separated from the sea by sandbanks and dunes. Punto Entinas is a natural lagoon while Salinas de Cerrillos is a man-made lake arising from an abandoned traditional saltworks. The lagoons have a permanent water regime, and are surrounded by Mediterranean semiarid ecosystems that include steppe, sandy beaches, and dunes stabilized. The water chemistry of these coastal wetlands shows a marked variability due to a diverse factors. The active geological dynamics of the area has favoured the development of endorheic basins where surface water accumulates, and where the permeable deposits provides contact between groundwater and the sea. In addition, anthropic exploitation of the terrain, in terms of the salt extraction, has strongly impacted the natural hydrodynamics in certain sectors, leading to the precipitation of evaporite salts. All these factors mean that it is quite difficult to establish what the reference conditions are for defining “good” water quality in the surface waters – as required by the WFD – and to understand the influence of groundwater on these coastal wetlands. The use hydrogeochemical tools provide a useful and rapid method for establishing a preliminary model of coastal wetlands. At the same time, they facilitate the design of more precise studies, especially in areas where there are no historical piezometric data to determine the evolution of water levels in wetlands and their associated aquifers.

The hydrogeochemical method applied in the Campo de Dalías coastal wetlands has enabled the principal processes determining the diversity of surface waters to be identified. Salinity of the waters is related to the different salts present in the lagoon beds; these mostly have a marine origin, but there is an additional groundwater influence in the Hornillo Lagoon (in the east) and in some parts of Punta Entinas, which corresponds to the area least impacted by man. The hydrogeochemical methods supply valuable information for establishing the environmental demands of these ecosystems, which needs to be integrated into management plans if sustainable management of wetlands under pressure from anthropic activities is to be achieved.
Distribution of invasive species by wind-driven currents


(1) Water Research Institute, University of Granada
(2) Department of Computer Architecture, Univ. of Granada
(3) Department of Civil and Environmental Engineering, Univ. of California-Davis
(4) Department of Civil Engineering, Univ. of Granada

Email contact: fjrueda@ugr.es

ABSTRACT

Since its initial introduction in Washington State along the Columbia River in the late 1930s, the invasive freshwater bivalve Corbicula fluminea (Asian clam) has spread in the United States rapidly and extensively. Because of its economic and ecologic effects it is considered to be the most important aquatic non-indigenous aquatic animal in N. America. Nowadays, it has been found in water bodies of 38 states. It was first observed at Lake Tahoe in very low numbers in 2002, but its population has apparently increased to a level where it is now having apparent environmental impacts. Its current known distribution (area ~1 million m^2) is patchy along the southeast shore from Zephyr Cove (NV) to El Dorado Beach (CA) is changing due to its rapid growth rate and ability to colonize in the abundant sandy bottom. Asian clam has both pelagic and benthic life stages, enabling it to spread long distances by boats and lake currents and locally by diffusive growth. Management concerns for Lake Tahoe and surrounding water bodies are focused on the effective in-lake control of Asian clam as well as the prevention of future introduction and establishment of invasive species, such as the zebra mussel. This information is intended to advance the scientific literature in invasion biology and to assist managers in developing a management plan for Asian clam in Lake Tahoe. Our ultimate goal is to develop a long-term risk assessment of Asian clam growth, spread and impact, and in this work we focus on understanding the role of lake currents in the transport of larval/juvenile stages to other locations in the lake. A high-resolution transport model of Lake Tahoe is used to simulate the pathways of transport of young life stages of Asian clams from the existing beds to other near-shore areas, and the environmental conditions that larvae are subject to as they travel around the lake.
Physical modeling of lake Lagarfljót, Iceland

Morgane Priet-Mahéo¹, Hrund Ó. Ándradóttir¹ and Francisco J. Rueda²
¹Department of Civil and Environmental Engineering, University of Iceland
²Instituto del Agua & Departamento de Ingeniería Civil, Universidad de Granada

Contact mail: hrund@hi.is

ABSTRACT

Temperatures and turbidity are two quality characteristics of water that control density and thus influence hydrodynamic processes within a water body. Lake Lagarfljót is a sub-arctic lake located in NE Iceland, it is 53 km² and up to 112 m deep. The lake is fed both by freshwater and glacial tributaries. Global warming consequences on this lake are expected to be twofold: direct, affecting the heat budget of the water system; indirect, melting glaciers and hence increasing the flow rate of turbid glacial rivers. Continuous monitoring of water bodies is costly. Models, once calibrated and validated, allow to fill up spatial and temporal gaps and eventually forecast the impacts of global warming on the lake. The aim of this research is to set up a functional 3D model of the lake using a semi-implicit 3D model described by Smith (2006) which has been validated for lake modelling purposes by Rueda and Cowen (2005) and used by Rueda and McIntyre (2009). The first results of the 2D/3D modeling work will be presented during the conference.
An analysis of multi-reservoir operation using multi-objective optimization algorithms

Gerald A. Corzo P 1 Jie Wen 3 Oscar Hernandez Murcia2 CongJiao Zhang 3 HongLi4

1. Hydrology and Quantitative Water Management Centre for Water and Climate. Wageningen University, The Netherlands.
2. Colombian School of Engineering Julio Garavito, Bogota, Colombia
3. North China University of Water Conservancy and Electric Power, Zheng Zhou, China

Contact email: hong.li@iwahq.org

ABSTRACT

The main target of the study is to analyze the river basin management decision support systems (DSS) with the state of the art mathematical algorithms that represent optimal water management. A model has been built in MODSIM software in the program “OPTIMIZATION TECHNIQUES FOR THE MANAGEMENT OF WATER RESOURCES AND THEIR SURROUNDINGS IN BOGOTA”. A Lagrangian optimization with a combination of expert knowledge has been used to determine the optimal operation rules for the reservoirs. The study presented here makes a comparative analysis of the operation in terms of integrated water management in the Chingaza system in Bogotá, Colombia. The procedure is based on evaluating the deviation between the mean monthly water reservoir levels used in operation of three connected river basins and the relative optimal value of the mean for operation. Three objectives are defined to minimize the water supply cost, maximize the power generation profit and maximize the production of vegetables. As there are some needed data missed, we assumed some parameters of about irrigation and water supply. The model was solved by non-dominated sorting Genetic Algorithm II (NSGA-II). The results show that with this procedure is possible to validate the operation rules of multiple reservoirs and multiple operation rules in term of economical and environmental variable.
Characterization and biogeochemical modelling of a water reservoir that receives acid mine drainage in the Odiel basin, SW of Spain.

Ester Torres and Carles Ayora

Institute of Environmental Assessment and Water Research. IDAEA-CSIC. C/ Jordi Girona 18-26. 08034, Barcelona (Spain)

Contact email: etogeo@cid.csic.es

ABSTRACT

Oxidation of pyrite produces an extremely acidic mine drainage (AMD) that contains high levels of sulphate and metals. The Tinto and Odiel Rivers drain materials from the Iberian Pyrite Belt, and although mining activity is over, the rivers still release to the ocean a very significant percentage of the global flux of metals. The building of a water reservoir (Alcolea, 363 hm³) is foreseen in the Odiel basin, and a detailed prediction on the quality of the water expected in the reservoir is needed. For this purpose, the hydrodynamic and biogeochemical model of an existing reservoir in the same basin is investigated. Sancho reservoir (58 hm³) reservoir receives AMD and has pH value close to 4 and decreasing with the years. The reservoir behaves as a holomictic lake showing thermal stratification during most of the year and homogenization during January. A hydrodynamic model (DYRESM) predicts the mass balance and the outflow salinity measurements, but overestimates the temperature. Ecological and chemical parameters of the water body are being preliminary modeled (CAEDYM). Stratification causes an oxic epilimnion and an anoxic hypolimnion, with high impact in the metal cycling. Fe(III) shows low mobility in the epilimnion, whereas Fe(III) oxyhydroxides particles are reduced and adsorbed As(V) is remobilized under the anoxic conditions of the hypolimnion at expenses of organic matter. The rest of metals (Cu, Cd, Co, Pb and Zn) are sorbed in the organic matter particulate and show opposite behavior. Sediments are rich in organic matter and play a significant role in the metal and sulfur cycling. Its behavior during diagenesis has been investigated by sequential extraction. Sulfate diffuses from the water body, it is reduced in the first mm of sediment and is incorporated into the organic matter. Metals follow similar trend and are precipitated as sulfides or linked to organic matter. Fe(III) oxyhydroxides in the sediment are dissolved and Fe and As release to the pore water. A reactive transport model allows to calculating the rates of element fluxes across the water-sediment interface.
Simulation of the growth and movement of *Microcystis* colonies with a size distribution by particle trajectory modeling

Yu-ching Chien and Shian-chee Wu

Graduate Institute of Environmental Engineering, National Taiwan University, 71 Chou-shan Rd. Taipei, Taiwan 10673, Republic of China

Contact E-mail: scwu@ntu.edu.tw

ABSTRACT

It is believed that *Microcystis* is able to dominate in stably stratified water system with their capability of buoyancy regulation through the change of density and competitive colony size distribution. Models for the vertical migrating behavior of *Microcystis* had been developed based on single colonies or on the averaged behavior of many algal colonies, without the consideration of colony size distribution. Furthermore, the processes of nutrient uptake and growth of *Microcystis* are critical for the dominance of *Microcystis* and greatly affected by the colony size, but rarely considered in modelling before. In this study a trajectory model was developed and used to simulate the growth rate, vertical migration behaviors and spatial concentration of *Microcystis* of uniform-sized colonies or colonies with a distribution of size in a calm water body. It is more reasonable to simulate the migration or behaviour of *Microcystis* population by using trajectory approach rather than advection-diffusion approach, for the history of a colony can be considered by the trajectory approach. The factors affecting the growth and migration such as colony radius, nutrient history, light history and temperature profile were investigated. The particle trajectory model was shown to be a useful tool to simulate and investigate the dynamics of the population of *Microcystis*.

Keywords
*Microcystis*, buoyancy regulation, vertical migration, stratification, trajectory, nutrient limitation, growth rate
Circulation and mixing at the confluence of two rivers entering a meandering reservoir

C. Ramón¹, J. Dolz², J. Armengol³ and F. Rueda¹

(1) Instituto del Agua, Universidad de Granada, Spain.
(2) Grupo FLUMEN, Universidad Politécnica de Catalunya
(3) Grupo FLUMEN, Universidad de Barcelona

Contact email: fjrueda@ugr.es

Abstract

The results of a recent study on the distribution of zebra mussel in Ribarroja reservoir and the environmental factors that control its growth (Navarro et al. 2006) suggested that there exists an intimate link between the growth of the zebra mussel individuals and the hydrodynamic processes of circulation and mixing in the reservoir. In particular, the study suggested that the growth rates of zebra mussels seems to be determined by the availability of dissolved oxygen in the water column, which, in turn, are tightly linked to the density profiles. These results suggest that we need to build up our understanding of how stratification develops and evolves in Ribarroja reservoir to design successful strategies to control invasive species, such as the zebra mussel. With low residence time of less than 30 days, stratification observed near the dam is most probably the result of the interaction between two masses of water (Ebro and Segre rivers), with distinct physical-chemical characteristics, which meet at the upstream end of the lake. Our goal is to understand the physical processes of mixing and transport that control the spatial distribution of Ebro and Segre rivers as they enter into the Ribarroja reservoir and downstream towards the dam, and to understand the changes experienced at diurnal and seasonal time scales.

Based on inflow rates and temperatures from Ebro and Segre rivers, three scenarios were defined to describe the fate of both rivers sources downstream of the confluence. Three-dimensional simulations of mixing and transport processes in the upstream of the end of the reservoir and experimental data collected in the field in two of those scenarios will be presented. Model results are validated against field data. Tracer release experiments were simulated, and their results were used to quantify mixing between both sources at different locations downstream of their confluence. The processes determining mixing between both sources are explored.

Complete mixing does not occur in none of the two scenarios analyzed within the computational domain. During winter time, with almost unstratified conditions, inertial forces dominate, and Ebro/Segre water flows side by side, the interface being mainly vertical. Mixing during this time of the year is exacerbated by weak temperature differences developing on diurnal scales, which cause the interface between the water masses to tilt. Horizontal eddies develop ~2 km downstream of the confluence, where the channel widens, acting to increase the mixing rate between water masses. In summer time, Segre river (with less density) flows on top of Ebro river (and even flows upstream into the Ebro channel) and the interface is mainly horizontal. The tilting of the isotherms at that time may develop as a consequence of strong wind forcing and centrifugal forces associated to flow in a meandering channel, and could be favoring the rate of mixing between sources.
Developing a Coupled Bubble-Plume/Reservoir Model for Carvins Cove Reservoir

Mallory Barkdull1, Vickie Singleton1, Kevin Bierlein1, Francisco Rueda2, and John Little1

1Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA
2Instituto del Agua and Departamento Ingenieria Civil, Universidad de Granada, Granada, Spain

Contact email: jcl@vt.edu

Abstract

Depletion of oxygen in lakes and reservoirs impairs water quality, kills fish, and exacerbates algal blooms. To reduce these harmful effects, bubble plumediffusers are commonly installed to replenish oxygen while maintaining thermal stratification. Linear diffusers have been installed in Spring Hollow Reservoir and Carvins Cove Reservoir, both located in South West Virginia. A coupled bubble plume/reservoir model has been created to predict oxygen and temperature distribution in Spring Hollow Reservoir. A linear bubble plume model was coupled with a three dimensional hydrodynamic model, and was successful in predicting the build-up of oxygen during bubble plume operation. This model will be adapted and applied to predict the performance of the oxygenation system in Carvins Cove Reservoir. Inputs for the model include diffuser size and configuration, oxygen gas flow rate, reservoir bathymetry, inflows and outflows, meteorological data, and initial conditions. Because Carvins Cove is more susceptible to wind driven mixing, this will need to be carefully checked when developing the coupled model. Field data collected during 2005 and 2006 will be used to validate the model. The resulting validated model should prove useful in the design and operation of a wide range of lake and reservoir oxygenation systems.
River inflow mixing in a stratified Mediterranean reservoir (Béznar, Spain)

A. Cortés(1), F. Rueda(1), I. de Vicente(1), M.A. Escobar(1), A. B. Hoyer(1), W. Fleenor(2) and E. Moreno-Ostos(2)

1 Instituto del Agua, Universidad de Granada, Spain
2 Department of Civil & Environmental Engineering, University of California Davis, CA – USA
3 Grupo de Ecología Marina y Limnología. Departamento de Ecología, Universidad de Málaga, Spain

Contac email: fjrueda@ugr.es

ABSTRACT

Limnologists have traditionally accepted that a negatively buoyant inflow entering a larger water body will plunge beneath the surface and flow downward along the bottom as a density current until reaching the level of neutral buoyancy, where it forms intrusions. Laboratory experiments, though, suggest that a significant fraction of inflow water entering linearly stratified water bodies might be distributed throughout the water column above the theoretical level of neutral buoyancy. The general goal of our study is to characterize the fate of river inflows in a Mediterranean reservoir (Béznar, Spain), with thick metalimnetic layers, both at seasonal and shorter (hourly) time-scales. Experimental data collected in situ, supported by a three dimensional (3D) hydrodynamic model (Smith, 2006) are used here to understand the processes controlling the fate of river inflows at short-times scales. Detailed tracer experiments demonstrated that vigorous mixing between reservoir and river water occurred prior to the formation of intrusions. Intense dilution rates, of O(10), occurred in the first 100 m after the inflows entered the reservoir, as a consequence of shear driven mixing, in a region where the behavior of the inflows was dominated by the initial inertia. Furthermore, data collected during the tracer experiments showed that the weak stratification and vigorous mixing rates made the river water formed several intrusions, exploring several depths in the water column above the theoretical level.
The radiological characteristics of sediments from several reservoirs in Granada

Piñero García F., Drozdzak J., Ferro García M.A.
Radiochemistry and Environmental Radiology, Department of Inorganic Chemistry, Faculty of Sciences University of Granada

Contact email: ferro@ugr.es

The analysis of sediments differentiates into: biological, chemical, or physical and may be used to determine various purposes: toxicity, biological availability, effects of contaminants, extent and magnitude of contamination, contaminant migration pathway and many more. The aim of this paper is to present the determination of even extremely low levels of radionuclide signatures which are present in sediments. Some radionuclides are mobile and can migrate from sediments to water and vice versa and subsequently may become significant danger for a human. Therefore the investigation results were also provided with the measurement of water. The samples were taken from March 2011 to April 2011 in three places situated in province of Granada: (1) Quentar – which is located about 18.8 km from sylvan area Quentar-La Peza, near river Aguas Blancas, in National Park Sierra de Huétor. The sample of this water is used to supply Granada; therefore the investigation provided with this sample is essential. (2) Cubillas – marine reservoir located about 15 km from Granada, near to the river Cubillas. Water from this reservoir is not potable, used only for utility aims. (3) Colomera- which is located about 30 km from Granada. The water is not potable, used only for utility aims.

The samples of sediments were collected from beneath an aqueous layer, the surface layer of sediments in range from 0 to 5 cm in depth. Afterward they were weigh, dried, comminuted and sieved into size of 0.5 mm grains. The level of radioactivity of the samples was primarily non-destructively analyzed by high sensitivity gamma spectrometry and ICP. Measurements of gamma emitting radionuclides, that were present sediments samples, were perfomed using an intrinsic germanium detector, coaxial, reverse type in vertical configuration (Canberra Industries Inc., USA 7500SL model GR-2020) with a relative efficiency of 20%. According to the recommendations of the Nuclear Safety Council (CSN) the analysis conducted with the gamma spectrometer consisted of two measurements: (1) 1st measurement conducted receipt and preparing of the sample: in Marinelli geometry for 1500 minutes, which allowed the detection of short-lived and long-lived radionuclides; (2) 2nd measurement was carried out about 25-30 days after sampling. This analysis allows detecting the level of Ra-226 and Pb-214 and Bi-214 produced through the secular equilibrium from Ra-226.

High sensitivity gamma spectrometry analysis has detected the presence of naturally-occurring radionuclides with the exception of the anthropogenic fission product Cs-137. The content of Cs-137 is indicative of fallout from the Chernobyl accident that occurred in April 1986. The difference in amount of Cs-137 depends on the altitude of each reservoir; consequently sample from Quentar contains more. All the others radionuclides discovered through the investigation occur naturally is such abundances in the environment. Typical nuclides identified were Be-7, K-40, Ti-208, Ra-226, Th-234, Pb-210, Bi-212, Pb-212, Bi-214, Pb-214 and others from the decay chains of uranium-238 and thorium-232 radioactivity family. The differences in levels of K-40 radioactivity depend on hydrogeological surroundings and their functions (especially the agricultural one) of each reservoir. It has to be noticed that according to current Spanish regulations, none of the analyzed sediments contain the radionuclide activity levels that exceed the maximum annual intake values for the members of the public.

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Effect of Water Release Operations on the Turbidity Distribution in Dae-Cheong Dam Reservoir

J. Y. Lee and S. R. Ha*†

Department of Urban Engineering, Chungbuk National University
410 Seongbongro Heungduk-gu Cheongju Chungbuk 361-763, South Korea

Contact e-mail: simplet@cbnu.ac.kr

Abstract

This study aims to identify the dynamic behaviour of diffused pollution substances introduced by storm turbidity flows into a reservoir. Effects of the gate operation on the duration of turbid matters in impounded water are depicted using the load duration curve. As analytical indicators for the object water body that is being at 5 m below from the water surface in the vicinity of two intake towers, turbidity in NTU represents a precursory substance and total nitrogen to total phosphorus ratio (N/P) substitutes the chemical condition of lake algal bloom. Reflecting local quality standards mandated turbidity< 5 NTU and N/P ratio>20-25 are applied to evaluate the preferred conditions of a raw water quality and an oligotrophication, respectively. As water release operations, intake water depth for hydropower generation at the dam location is changed to provide a momentum alteration to hydraulic balance in the deep water of reservoir and then, the dynamic response of turbidity distribution as well as nutrient balance in the object water bodies established are monitored on the basis of simulation results by CE-Qual-W2. For a scenario analysis, two different water release operation conditions as elevations 42 m and 57 m at the dam location are set up and then, the duration curves at intake towers are made. In 2003, the reference case, in which water release operation at dam gate was followed the guide line mandated by the reservoir water authority, the durations (day) to exceed 5 NTU at Muneui and Daejeon intake towers were 121 and 89, respectively. N/P ratios were 69 and 67, respectively. The turbidity durations calculated to compare the reference with alternative cases are increased 2 days and 8days more, respectively at Muneui tower whereas, 13 and 3 days respectively at Daejeon tower. Even though there is no significant impact of water release operation changes on the duration difference in terms of N/P ratio in both object water bodies around two intake towers but the duration of total phosphorous concentration in the water is reduced by active release of turbid regime. It is identified that a prompt release of turbid water regime in the reservoir promises the water quality at the objective water body that the duration of turbidity is significantly reduced and the probability of eutrophication decrease simultaneously through reducing total phosphorus concentration increase in the subject water body around intake tower during monsoon period within N/P>25.

Keywords
Turbid density stratification; reservoir; CE-QUAL-W2; selective intake tower; water release operation; nitrogen to phosphorus ratio
On the water thermal response to the passage of cold fronts over a tropical hydroelectric reservoir

Enner Alcântara
National Institute for Space Research, Remote Sensing Division, São José dos Campos, SP, Brazil

Contact e-mail: enner@dsr.inpe.br

ABSTRACT

The passage of meteorological systems such as cold fronts or convergence zones over reservoirs can cause significant modifications in several aquatic variables. Cold fronts coming from higher latitudes and reaching the Southeastern Brazilian territory modify the mean wind field and have important impact over physical, chemical and biological processes that act in the hydroelectric reservoirs. The mean period of cold front passages along the southeastern Brazilian coast is 6 days during the winter and between 11 and 14 days in the summer. Most of these fronts also affect the hinterland of São Paulo, Minas Gerais and Goiás states. The objective of this work is to analyze the influence of cold front passages in the thermal stratification and water quality of the Itumbiara hydroelectric reservoir which is located in Minas Gerais and Goiás. The characterization of cold front passages over the study area was done through the analysis of GOES satellite images. The analyzed data set includes time series of meteorological (wind direction and intensity, short-wave radiation, air temperature, relative humidity, atmospheric pressure) and water temperature in four depths (5, 12, 20 and 40 m). The data set was acquired in the interior of the reservoir by an autonomous anchored buoy system at a sampling rate of 1 hour. The stratification was assessed by non-dimensional parameter analysis. The Lake Number, an indicator of the degree of stability and mixing in the reservoir was used in this analysis. We will show that during the cold front all atmospheric parameters respond and this response are transferred immediately to the water surface. The main effect is observed in the water column, when the heat loss in the surface allows the upwelling events caused by convective cooling due to the erosion of thermal stratification.
The effects of selective withdrawal on the succession of phytoplankton communities in reservoirs

Rigosi, A., Rueda, F.
Instituto del Agua, Universidad de Granada

Contact email: arigosi@ugr.es

ABSTRACT

Phytoplankton composition and abundance in reservoirs are controlled to the greatest extent by a combination of different factors as light-nutrient availability, mixing regimes and biological interactions between species. Few studies, based on the analysis of field observations, showed the importance of withdrawals effects, as a fundamental allogenic factor controlling phytoplankton composition and abundance in reservoirs. In this work we want to understand the mechanisms by which withdrawal could induce changes in the composition of phytoplankton community at short term (10 days). Our analysis was conducted with the help of an ecological model including two algal groups with variable sensitivity to environmental conditions. Results showed that the phytoplankton community response to withdrawals depend on: (a) the modification of the algal group position with respect to the surface level; (b) the specific tolerance of algal groups to environmental condition (in particular light availability); (c) the shape and size of the reservoir; (d) the magnitude of the vertical mixing rate; (e) the relative position between the level of water extraction and the depth of the layer hosting the algal group. Results also pointed out that changes in phytoplankton dominance are mostly controlled (80% of the cases) by flushing effects and only partially by changes in the environmental conditions. Conditions at which change in dominance occurs (e.g. relative position and growth rates differences between groups) withdrawing from surface or bottom level were univocally defined. Our work, understanding how withdrawals affect phytoplankton behavior, is oriented to the developing of alternative strategies for reservoir water quality management.

Keywords: phytoplankton behavior, ecological model, water management, short-term prediction, withdrawals
Modelling the longitudinal distribution of phytoplankton in a periodically forced reservoir

Javier Vidal\textsuperscript{1,2}, Anna Rigosi\textsuperscript{1}, Andrea Hoyer\textsuperscript{1}, Francisco Rueda\textsuperscript{3}

\textsuperscript{1} Instituto del Agua, Department of Ecology, University of Granada, Spain.
\textsuperscript{2} Marine Science Institute, UCSB, USA.
\textsuperscript{3} Department of Civil Engineering, University of Granada, Spain

Abstract

Understanding how plankton spatial patterns are produced and maintained is a crucial issue required to interpret the structure and the distribution of aquatic communities and to identify the constraints on the sequencing of phytoplankton population. In small to medium size reservoir horizontal patchiness is produced by the interaction between wind-driven circulation and processes controlling the vertical phytoplankton distribution, which include mixing and the physiological ability of algae to move vertically in the water column. The horizontal distribution of algal cells in El Gergal reservoir, in southern Spain, is analyzed through simulations conducted with a 3D hydrodynamic and ecological model. Wind forcing is weak, subject to diurnal changes in speed and direction, being aligned mainly with the lake thalweg. The mixing environment in the surface layer, in turn, was largely energized through cooling at the free surface. The longitudinal circulation that develops at night time, when the vertical gradients in algal concentrations fade away, are not effective in creating horizontal patchiness. The time required to reach an equilibrium distribution varies depending on the particular strategy of the algae to regulate its vertical position, and the lag existing between the diurnal variations of wind forcing and surface cooling.

Keywords: horizontal distribution, 3D ecological model, phytoplankton groups behavior, wind forcing
Implications of macrophyte abundance on algal growth management: the case of three natural swimming pools with distinct macrophyte abundance

Ana M. Geraldes¹, C. Schärzer² & U. Schärzer²

¹CIMO, Escola Superior Agrária, Instituto Politécnico de Bragança Campus de Santa Apolónia, Bragança Portugal
²Bio Piscinas, Lda. Apartado 1020, P-8671-909 Aljezur, Portugal

Contact e-mail: geraldes@ipb.pt

ABSTRACT

Natural swimming pools are small constructed lakes for recreational proposes. They are composed by a swimming area merging with an area planted with emergent and submerged macrophytes, which function as biological filters. Fish are absent, however a wide diversity of phytoplankton, zooplankton and macroinvertebrate species colonize these pools. Therefore, pools can be regarded as the ideal systems to extrapolate the implications of macrophyte abundance management on algal growth control. The present study was taken in three pools (A, B and C) located in Minho Region (Northern Portugal). In early summer the macrophyte area had a 30% of cover in Pool A, in B 40% and in C 60%. Phytoplankton, zooplankton and filamentous algae abundance as well as conductivity, pH, dissolved oxygen, hardness, nitrates, nitrites, ammonia, phosphates were recorded in February, April and June. The lowest densities of phytoplankton were observed in pool C. Besides, filamentous algae were abundant in the pool A, whereas in B and C they were recorded only in summer. In Pool A, zooplankton assemblage was always dominated specialists on small particle feeding, which food preference are detritus and bacteria. Conversely, in the Pool C herbivorous zooplankton was predominant. The low algal densities observed in the Pool C are explained by the presence of a well established macrophyte assemblage. These plants contribute to the reduction of algal densities by (1) creating of areas of shade; (2) removing nutrients from water column and (3) provide refuges for herbivorous zooplankton. Therefore, the present study stresses the pertinence of take in account the key role of aquatic macrophytes when management practices for algal growth control are developed.

Key words: algal growth management, macrophytes, natural swimming pools
Dominant bacterioplankton phylotypes in geographically distant Portuguese water bodies under a severe summer drought scenario

de Figueiredo D.R., Pereira M.J. & Correia A.

CESAM & Department of Biology, University of Aveiro, 3810-193 Aveiro, Portugal

Contact email: dfigueiredo@ua.pt

ABSTRACT

During the year of 2005 one of the strongest droughts over the last decades was observed for the Portuguese territory. In the region of Alentejo (southern Portugal) those effects were more intense, with several reservoirs becoming dry. A set of 20 Portuguese water bodies were analysed through denaturing gradient gel electrophoresis (16SrDNA-DGGE) to assess its bacterioplankton diversity under these particular conditions. The trophic status of the water bodies was evaluated though determination of parameters such as pH, conductivity, total suspended solids and chlorophyll a, soluble reactive phosphorus, nitrite, nitrate and ammonium concentrations. Most of the water bodies fell into the meso- to eutrophic and hypereutrophic state, except for Caldeirão reservoir which showed oligotrophic conditions. In general, the levels for conductivity, pH and total suspended solids at the studied water bodies were higher than the average data from previous years. Generally, dominant phylotypes belonged to Cyanobacteria, Actinobacteria Alphaproteobacteria, Betaproteobacteria and Bacteroidetes groups. Bacteroidetes dominance was observed at Sousa River and related to high nutrient levels while Cyanobacteria (Nostocales and Oscillatoriales) dominated in Alentejo reservoirs and were related with higher conductivity values. However, Actinobacteria showed ubiquitous phylotypes throughout several samples suggesting its persistence over geographically distant water bodies. Further investigation should be conducted to assess the real impact of the drought on bacterioplankton communities at these water bodies by comparing to different climatic conditions on subsequent summers.

Keywords
Portuguese water bodies, drought, bacterial diversity, 16S rDNA-DGGE analysis.
Water level fluctuations in reservoirs: a challenge for algal control growth and water quality management

ANA M. GERALDES & PEDRO SILVA-SANTOS

1 CIMO, Escola Superior Agrária, Instituto Politécnico de Bragança Campus de Santa Apolónia, Bragança Portugal (geraldes@ipb.pt)
2 NOCTULA: Modulação e Ambiente. Urbanização Vilabeira Lote 6 4º Frente 3500-733 Viseu. Portugal

Contact e-mail: geraldes@ipb.pt

ABSTRACT

Azibo Reservoir (41°34′32, 25″N; 6° 53′51, 63″W) is located in Douro catchment. Reservoir surroundings are occupied with several villages. Extensive farming and cattle grazing are the most important activities. Furthermore, during the summer the reservoir is used for recreation. Other uses are water supply and irrigation, yet these activities are not significant. Consequently, water level fluctuations are of small magnitude, allowing the existence macrophytes in the reservoir shallow areas. Aguieira Reservoir (40°19′53, 83″N; 8° 11′47, 76″W) is used to generate hydroelectrical power and to urban water supply. Consequently, accentuated water level fluctuations occur. The catchment is occupied with intensive forestry, agriculture and livestock production and with several medium sized towns. Reservoirs were sampled for the following water quality parameters: Phosphate, nitrate, chlorophyll a, temperature, dissolved oxygen, conductivity and transparency. Phytoplankton assemblages were characterised. Trophic state was assessed by computation of Carlson’s Trophic State Index. Phosphate, nitrate and chlorophyll a were significantly higher in Aguieira, which was classified as eutrophic. Azibo was considered mesotrophic. Cyanophyceae were abundant in Aguieira. Conversely, in Azibo phytoplankton assemblage was dominated by Bacillariophyceae and Cryptophyceae. Aguieira trophic state can be explained by the internal disturbance induced by the intense water level fluctuations, causing an increment of suspend particulate material in water column. Besides, the exposure of littoral sediments to cycles of drying and wetting also increases nutrient availability and prevents the establishment of macrophytes. These phenomena plus the input of allochthonous nutrients originated from human activities in the catchment area lead to the increase of phytoplankton biomass. Recreational activities probably are the factors with greatest influence on Azibo trophic state. Based upon the obtained data, management measures are suggested to control excessive algal growth and increase ecological integrity of both reservoirs as proposed in Water Framework Directive.

Key words: reservoirs, water level fluctuations, algal growth management
Spatial bacterioplankton diversity at Vela Lake (Central Western Portugal) during cyanobacterial blooms and under severe drought conditions

d e Figueiredo D.R., Castro B.B., Pereira M.J. & Correia A.  
CESAM & Department of Biology, University of Aveiro, 3810-193 Aveiro, Portugal

Contact email: brunocastro@ua.pt

ABSTRACT

The shallow Vela Lake (Central western Portugal) suffers frequently from cyanobacterial blooms development during summer months. The present work aimed to study the spatial diversity of bacterioplankton assemblage during cyanobacterial blooms occurring under the severe summer drought of 2005. The diversity of bacterioplankton and microcystin potential producers was analysed through 16S rRNA- and mcyA-DGGE (denaturing gradient gel electrophoresis), respectively. A set of recorded environmental parameters was used for multivariate analyses. PCA showed spatial differentiation among sites mainly related to the levels of oxygen, pH, temperature, ammonium and chlorophyll a. 16S rDNA-DGGE results showed that the bacterial community clearly differed among the East and Western sampling sites, particularly under drought intensification. RDA analysis suggested that differences between spatial bacterioplankton assemblages were mainly related to oxygen levels, conductivity and water temperature. Dominant phylotypes belonged to Cyanobacteria, Betaproteobacteria and Actinobacteria groups. The dominance of bloom-forming cyanobacteria such as Aphanizomenon aphanizomenoides, Aphanizomenon gracile and Microcystis viridis was recorded. In August, the chlorophyll a levels on the west side of the lake (more used for recreational purposes) rose above the guidelines established by WHO under cyanobacterial dominance. Furthermore, the potential for microcystin production was recorded in all samples, indicating health risks for lake users; mcyA-DGGE showed spatial differences in the dominant phylotypes, mainly related with factors such as chlorophyll a and total suspended solids.

Keywords

Shallow lake, cyanobacterial blooms, spatial bacterial diversity, 16S rDNA-DGGE, mcyA, multivariate analysis.
Phytoplankton community dynamics in a recent reservoir, La Breña II (Córdoba, Spain)

C. Hidalgo Lara (1), M.J. Fernández-Rodríguez (2), P. Peñalver (1), D. León (1), & J. Toja (1)

(1) Departamento de Biología Vegetal y Ecología, Universidad de Sevilla, C/Profesor García González s/n, C.P.: 41012 Sevilla, España.
(2) Facultad de Ciencias Experimentales, Universidad Pablo de Olavide, Sevilla, España.

Contact email: hidalgolarac@us.es

Abstract

La Breña II is a reservoir of recent construction located on Guadiato river (a right margin tributary of the Guadalquivir river, Andalusia, south of Spain) which principal use is to irrigate cropfields. This study started in September 2007 and is included in the reservoir project of compensation measures of affected areas. Our aim is to analyze the phytoplankton community dynamics, which is very important to get information about the ecological state of the reservoir and, therefore, to provide guidelines for its management. Two clearly different phases were considered: one before the new dam was placed into service (located approximately 100 m downstream from the old dam) and another one from then until now. In order to prevent a possible eutrophication process, most of the vegetation of the newly flooded land was removed. Nonetheless, the decomposition of the remaining herbaceous plants have contributed to the increasement of nutrients in the reservoir. This fact has been compensated by the increasement of depth (from an average of approximately 25 m to almost 80 m reached in November, 2010) and volume of the reservoir (from 53 Hm³ average to the 709,46 Hm³ registered in January, 2011). The phytoplankton community composition and abundance is compared before and after the new dam is put into service.

Keywords: Guadalquivir river, phytoplankton, reservoir.
Physical tools to removal of Cyanobacterial Bloom

Darina Vinklárová¹, Blahoslav Maršálek¹, Eliska Marsalkova¹, Petr Lukeš²,

¹ Institute of Botany, Academy of Sciences of the Czech Republic, Lidicka 25/27, 65720 Brno, Czech Republic

² Institute of Plasma Physics AS CR, v.v.i., Za Slovankou 1782/3, 182 00 Prague 8, Czech Republic

ABSTRACT

Eutrophication in drinking water supplies brings about serious problem on the drinking water safety. Nutrients pollution causes cyanobacterial blooms and the subsequent decomposition of blue-green algae by bacteria, an oxygen-consuming process. Chemical methods to control certains species of phytoplankton, but have side-effects in ecotoxicological level. In our study we have proposed plasma induced reactor to removal of algal bloom. We have used several type of natural algal bloom (Microcystis, Planktothrix and Aphanizomenon) in our study. Experimental results show the removal efficiency of cyanobacteria and the inactivation constant were increased with the increased time of application and with power of induced plasma pulses. The difference between species composition of natural algal bloom on their removal efficiency, was unobvious, but the effects of pulse repetitive rate and applied peak pulse voltage on the inactivation of cyanobacterila bloom were significant. The changes in the visible spectra of cyanobactrial bloom solution demonstrated that photosynthetic pigments, such as chlorophyll-a, phycocyanins, carotenoids have been decomposed. These results implicate that cyanobacteria cells were inactivated by a plasma reactor, demonstrating the considerable potential of such an alternative process for efficient water purification without any chemical treatment.
Global database of methods for cyanobacterial blooms management

Blahoslav Maršálek¹, Eliska Marsalkova¹, Daniel Jancula¹ . Darina Vinklárková¹.

¹ Centre for cyanobacteria and their toxins, Institute of Botany, Academy of Sciences of the Czech Republic, Lidicka 25/27, 65720 Brno, Czech Republic

Contact email: marsalek@sinice.cz

ABSTRACT

We prepared the global database of methods for management of cyanobacterial water blooms. Systém will include in-lake methods and measures managing nutrients and water quality in catchments. If the action will be successful, data and experiences sharing including methods for measuring water composition, set of parameters needed for the lake restoration projects and experiences with lake and reservoirs restoration projects will be available. Both companies offering advanced methods for cyanobacterial blooms treatment or pretevention, projectans and academics will have this forum available on the page www.cyanodata.net
Six years of experiences with the application of polyaluminiumchloride for cyanobacterial blooms treatment and lake restoration

Blahoslav Marsalek, Daniel Jančula, Eliska Marsalkova, Darina Vinklárková,
Centre for cyanobacteria and their toxins, Institute of Botany, Academy of Sciences of the Czech Republic, Lidicka 25/27, 65720 Brno, Czech Republic

Contact email: marsalek@sinice.cz

ABSTRACT

Published mode of action for the use of polyaluminium chloride for the lake restoration is the phosphorus inactivation. Usual concentrations used for this purpose is 15-50mgAl/l. We have six years experience, that polyaluminium chloride can be used in the concentrations 3-7mg/l as the coagulant of bioseston (phytoplankton and water blooms) from the water column. This application removes phytoplankton (targeted to cyanobacterial blooms) and zooplankton from the lake within several hours after application. Water transparency increased from 0,6-0,8 up to 3-4m. Zooplankton community is restored within 2 week and the cyanobacterial abundance was under hygienical limit 6-8weeks after application, so recreation in the lakes was not restricted. Such a reduced dose seems to be ecotoxicologically more acceptable than the classical way of use, especially in the ecosystems, where external phosphorus load is not controlled.
Microbial food web biomanipulation: a low cost tool for control of eutrophication in Mediterranean reservoirs.

Dorado-García, I.; Medina-Sánchez, J.M.; Carrillo, P.

Contact email: idorado@ugr.es, pcl@ugr.es

ABSTRACT

Human activities, by altering nutrient fluxes (increasing loads of P and N), are promoting eutrophication of aquatic ecosystems. As a consequence, algal growth is enhanced, resulting in blooms of potentially harmful algae which alter trophic web dynamics, and decrease ecosystem services. Several approaches to reduce the problems caused by eutrophication processes have been proposed, but few have been successful when applied to deeper and fluctuant inland-waters, such as reservoirs. We investigate a low-cost biomanipulation approach at microbial scale by increasing load of allochthonous labile organic carbon to promote competitive growth of heterotrophic food web against phytoplankton. The aim is to enhance biomass and nutrient transfer to higher trophic levels, thus favoring a clear-water state. We provide preliminary results of an in situ experimental setup performed on a Mediterranean eutrophic inland-waters system (Cubillas reservoir, Granada, Spain) designed to seek the thresholds of labile organic carbon inputs which maximize changes in the structure and function of planktonic microbial community. The variations in abundance, composition and activity of planktonic microbial community may enhance its role as link for nutrient transfer to higher trophic levels.
Characteristics of nutrient runoff in a eutrophic lake watershed by golf course and resort

J. H. Cho, S.J. Yun
Department of Environmental Engineering, Kwandong University, Gangwon-Do 215-800, Korea

Contact email: jhcho@kd.ac.kr

ABSTRACT

Lake Youngrang is a lagoon whose effluent flows into the East Sea of South Korea. Mainland is mostly used as arable land, residential area and resort area with golf course. Two resort towns and two golf courses are situated at the lake basin, attracting many tourists to this area. Mean water qualities of the lake for the year 2007 were COD 17.4mg/L, TN 0.83 mg/L, TP 0.057 mg/L and Chl-α 34.1 mg/m³, trophic status was eutrophic. Because the wastewater discharged from the residential area surrounding the lake are transported to the wastewater treatment plant, most of pollution loads affecting the lake are diffuse pollution loads from stormwater runoff. Sokcho city has a plan to construct diffuse pollution control facilities, such as wet pond and wet land, to rehabilitate the water qualities of the lake. Surveys on stormwater runoff were carried out on the four storm events from 2006 to 2007 at five points in the eutrophic lake watershed. Pollutographs for SS, COD, TN, NO₃-N, TP, PO₄-P were drawn, event mean concentrations (EMC) were also calculated. Dimensionless mass-volume curves for each storm event were adopted to analyze the characteristics of nutrient runoff in the eutrophic lake. EMCs of nutrients at the point affected by the discharge of the golf course and the agricultural land were higher than those of the other tributaries. And first flushing for nutrients was shown at the point affected by the discharge of the golf course and the condominium. We consider that these runoff survey data plays an important role as basic data for diffuse pollution load control of the lake watershed.
ABSTRACT

This study examines the process by which soil dryness induced by climate change causes fine soil particles to fuse and discusses the potential effects of this process on forest hill slope. The relationship between forest-soil dryness due to temperature raise and soil-particle fusion is expressed by four factors: increased evaporation (amount of water vapour discharged from soil) due to an increase in air temperature, decreased soil moisture content, fusion (and effusion) of ultrafine soil particles and effects of these processes on forest plants. To clarify the relationship between climate change and the fusion of fine soil particles, a numerical model was developed to reproduce soil fusion in actual ground surface condition. To study such processes, a dynamic model of moisture, and sand and gravel soil, applicable to forest basins is useful. In this study, we first modelled the fusion of ultrafine soil particles within the A layer or B layer of forest soil layers using inter-particle stress and the true adhesive force generated by the effect of soil-particle sedimentation. We combined this model with a dynamic basin-scale model for moisture and sand and gravel soil, which we developed with colleagues, to construct an integrated dynamic model applicable to forest basins in Japan. Application of the model to the Nagara River basin of Japan confirmed its validity. The simulation results suggested that soil fusion creates problems in the forest environmental condition. If air temperatures continue to increase and soils become drier, dieback of forest vegetation may occur due to insufficient moisture availability.

Key words

Fine particles; global environment change; global warming; ground dryness; silt
Changed cycling of P, N, Si, and DOC in Danish Lake Nordborg after aluminum treatment

Sara Egemose1, Inmaculada de Vicente2, Kasper Reitzel3, Mogens R. Flindt4, Frede Ø. Andersen5, Torben L. Lauridsen6, Martin Søndergaard7, Erik Jeppesen8 & Henning S. Jensen9

Email contact: ivicente@ugr.es

ABSTRACT

Loading, retention and in-lake cycling of phosphorus (P), nitrogen, silica and dissolved organic carbon (DOC) were studied one year before and 3 years after P-inactivation by aluminum (Al) hydroxide in Danish Lake Nordborg in 2006. Simultaneously, external P loading was reduced by 40% via establishment of precipitation ponds in two inlets. After Al treatment, the internal P loading (sediment P release) during summer declined 90-94% due to adsorption to aluminum hydroxide. Also silicate regeneration from the sediment was reduced by 69-76%, and sediment oxygen uptake as well as ammonium release declined markedly. Consequently, lake water total P, dissolved inorganic P, silicate and DOC decreased by, respectively, 73%, 97%, 87%, and 46%. The Secchi depth increased in the summer period during the first post-treatment year, but declined afterwards to pre-treatment levels, even though the summer mean lake water total P concentration was reduced from ~240 µg•L⁻¹ before treatment to 26-65 µg•L⁻¹ in the first three post-treatment years. We conclude that a further reduction in external P loading is needed to obtain the full effect of the Al treatment in Lake Nordborg.

Keywords: Lake restoration, mass balances, pigment analyses, phosphorus, silica.
Restoration of a North German shallow lake using lanthanum modified bentonite

Dr Said Yasser
Institut Dr Nowak (Germany)

Contact email: sy@limnowak.com

ABSTRACT

An application to reduce phosphorus using the lanthanum enriched clay mineral, Phoslock (known in Germany as Bentophos), was undertaken for the first time in Schleswig Holstein at the end of 2009. The aim of the application was to bind the internal phosphorus load in the lake, which is located to the south east of the city of Luebeck. The 22.5 ha shallow lake, has an average depth of 1.6m and is of European wide significance due to its classification under the Fauna Flora Habitat Guidelines (FFH) as a rare ecosystem. The lake has suffered for many years from high nutrient loadings caused by discharges of waste water from surrounding settlements, industry and agriculture. Although the lake was originally nutrient poor, in recent years it has become highly eutrophic. This condition has given rise to re-occurring intensive algal blooms, which in turn have increased oxygen consumption in the lake. This deficiency in oxygen has stimulated phosphorus release from the sediment. Monitoring in the year following the application shows that phosphorus concentrations have dropped significantly. As a result, one of the main aims of the restoration - an improvement in growth conditions for macrophytes - has been achieved. The restoration of the lake was financed by the Schleswig Holstein Ministry with responsibility for the environment (MLUR - Ministerium fuer Landwirtschaft, Umwelt und Laendliche Raeum) and the Hanseatic City of Luebeck (Blankensee). The measures were also supported through the involvement of LLUR and the local municipality of Lauenburg.