Specialist Group on
Use of Macrophytes in Water Pollution Control

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MESSAGE FROM THE CHAIR

Dear Group Members,

Time is flying and we are slowly getting ready for the 13th biennial group conference in Perth, Australia. Therefore, it is also time to think about the conference in 2014 and the institutions which are interested in organization of this event should prepare a proposal. The proposals should be sent by the end of June to the Chairman and Secretary of the Group. If you have any questions concerning the proposal preparation, feel free to contact me or Suwasa.

In July, a joint conference of Society of Wetland Scientists, Wetpol and Wetland Biogeochemistry Symposium was held in Prague, Czech Republic. During the conference, 67 oral and 44 poster presentations were devoted to constructed wetlands. Most oral presentations are still available at www.sws2011.com (Symposia and Sessions folder).

Hans Brix gives a lecture during the SWS-Wetpol-BWS conference in Prague and Yves Comeau enjoys the constructed wetland.

I would also like to draw your attention to 9th Intecol International Wetland Conference which will take place on June 3–8, 2012 in Orlando, Florida. The topic of constructed wetlands has been a regular part of the conference program since 1992 and hopefully this will continue in Orlando. You can find information about the conference at www.conference.ifas.ufl.edu/intecol.

I wish all group members a nice and peaceful Christmas and a prosperous New Year.

Jan Vymazal
Group Chair

INTERVIEWING PAUL COOPER

By *Frank van Dien*

Probably most people know you as one of the people behind the CWA, the Constructed Wetland Association. You've been a keynote speaker at many conferences on wetlands so surely many people have seen your face. But maybe it's time to find out more about you. For starters, I wonder:

Where in your life did things definitely turn in the direction that resulted in your role in the constructed wetlands?

I worked at the Water Research Centre [WRc] from 1971 until 1998. My background was in Chemical Engineering and during the reorganisation of the water industry in the UK that took place in the 1970s and 1980s the process engineering approach in which chemical engineers were trained became applied widely in evaluating the treatment processes in the industry. I had worked on activated sludge, biological filter and fluidised bed processes with an emphasis on nitrogen and phosphorous removal.

In July 1985 I was the head off one of the Process R & D groups and was invited to a presentation by two colleagues who had visited Germany to look at Root Zone Method systems at various locations. They had been evaluating the system for the previous 9 months and this had resulted in a group of 25 people from the UK water industry visiting the sites in Germany and making contacts in Denmark as well. It was clear from what they reported that the process had some potential but there were also reports that some of the systems had failed for reasons that have become very familiar to all of us in the field, namely hydraulic problems and lack of oxygen transfer. I came away from the meeting thinking "Interesting process that has potential for rural treatment but it doesn't always work and so it needs a great deal of work to make it reliable". To my surprise our Director of Processes at WRc, Rolf Clayton, called me in the next week and said that he wanted me to take charge of the project. I said that I was surprised since I had no knowledge of plants and had not even studied botany at school. I was assured that this was just another process engineering and management situation.

We put together a nationally coordinated programme which ran for 5 years until the end of 1990 and drew together contributions from all the UK water utilities and it also sponsored research at universities and government research laboratories. We covered many aspects such as; growth of reeds; oxygen transfer; selection of media with respect to hydraulic conductivity; and the bacterial activity in the rhizosphere. We very quickly benefited from this national cooperation and expanded it in 1986 to cooperation with 8 other partners in the EU. At that first meeting I met Hans Brix, Raimund Haberl and Alain Lienard and we have exchanging experiences ever since.

1943 born in Sheffield, Yorkshire, United Kingdom
1967 Bachelors degree in Chemical Engineering
1968 Masters degree in Chemical Engineering
1971-1998 worked for Water Research Centre [WRc] at Stevenage and Swindon
1985 first wetland project
1988 Founder member of IWA wetland group; Group Secretary for a total of 15 years, 1988 to 1993 and 1996 to 2006
1999 co-founder CWA
1998 to 2009 Independent wastewater process consultant

And from that, an enormous network evolved with scientists and students and professionals, from all over the world! So you were right at the start of all this (if we skip the "founding fathers and mothers" for this moment) ... But now you have reached the age of retirement ... Will we (please) keep on seeing you?
Well, I haven't done any paid work for 2 years now but I have maintained an interest in the CW technology and have attended two conferences in that time. I still get the occasional email asking for advice or historical facts to which I am very happy to reply. I hope to attend the next Trebon workshop if Jan Vymazal has not removed me from his mailing list! So I would hope to see the many friends that I have made over the past 26 years as a result of our work and cooperation in this interesting process.

Wouldn't it be great if we could make the term "wastewater" obsolete?
I can completely understand why you suggest this but it does describe what has happened to the water and how it came to be like it is. I always look at things from a practical viewpoint- it is the engineer speaking! However nothing should be waste – it is a source of future product or an intermediary. I find it deeply ironic that the material that causes the water stream to be called "wastewater" is really a product which is being wasted. I usually start an industrial wastewater treatment project by recommending that the "housekeeping" on the site is improved to reduce the loss of product since this a] reduces the concentrations of product in the wastewater which have to be removed and b] can potentially reduce costs by recovering product and hence reduces the cost of treatment. A so called win, win result ! The paper that I presented at the 2008 conference in India is a prime example of this – fertiliser was being lost into the site effluent: stop wasting fertiliser and you will have less trouble with the wastewater.

What do you prefer as a "name": Constructed Wetland or Treatment Wetland?
I strongly prefer Constructed Wetland system. When I first heard of these type of systems they were called Root Zone Method systems [RZM] but this name was specific to one commercial company and within the UK Water Industry Coordinating Group we felt that we could not become tied to one commercial company. It was clear that the same sort of sentiment existed in the other European countries who became part of the EU Specialist Contact Group in 1986. Within the UK we adopted the descriptive name Reed Bed Treatment Systems [RBTS] and to this day in the UK these systems are generally all referred to as Reed Beds. There was a lot of time wasted over talking about different names for the same thing. Over the past 20 years I have generally used the term Constructed Wetlands when writing for or presenting at international conferences as this the most widely-accepted terminology. There have been several attempts/discussions to change this to other names [and also to change the name of the group] but all have foundered because of lack of agreement. I really cannot see any benefit in re-opening this debate since in 26 years involvement in the field I cannot recall any real misunderstanding between speakers. All real life systems are slightly different and the best description is a flowsheet diagram.

Ha, nice how you put this matter in a larger time frame and I can understand how you can grow tired of such a discussion over time! The next question that comes up is: do you see Constructed Wetlands as an ultimate solution for waste water? And if so, in general or just occasional, i.e. when no sewer system is available?
I don't believe that there is a universal "one size fits all" solution and that many processes have their place in the treatment spectrum dependent upon many aims such as effluent quality, energy input etc. In the UK I have been criticised from both sides for being too much pro-Reeds Beds and occasionally for being anti-Reed Beds, which tends to make me feel that I

have got it about right. I always assess a treatment problem as a process engineer and work out which is the appropriate process fitting all the facets of the wastewater, site, construction and operating costs and most importantly the future use of the treated water.

Here's a daring question for you! Do you think the horizontal system is superior to the vertical or is it the other way around or do we simply need them both?
I think that generally the Vertical Flow systems are superior for the simple reason that they transfer oxygen much more effectively and so are also much more compact. However Horizontal Flow systems require less attention and are more effective in solids removal. I have long championed the benefits of Hybrid Systems where the advantages and disadvantages of HF and VF systems can balance out and complement each other so that a complete all-round package is produced. For example if you have a vertical stage and a horizontal flow stage you can nitrify and denitrify in the same package and recycle nitrogen gas back to the atmosphere which is the perfect recycling solution.

What does our own (waste) water world need most at the moment?
A consistent reliable method of removing and recovering, for re-use, of phosphates.

Is there, to your knowledge, a Constructed Wetland that is an example for us all?
My favourite system is that at Oaklands Park near Gloucester which is only about 50 km from where I live. It is a Camphill Community which is part of an international charity set up by Karl Koenig in Scotland in the 1940s which cares for handicapped people on a community system with Christian principles and using the Rudolf Steiner teaching techniques. It is based on an old country estate with a grand house as the hub, smaller community houses around the site and with a large amount of farm land and an old walled garden. The agricultural aspects play a large part in the practical learning experience and so a "green" low energy wastewater treatment system fits perfectly with their ethos. I had no previous contact with this organization until a visit there in 1986. I was particularly interested because they had Vertical Flow stages in their system which they were testing in a house with 9 residents. It was derived from the Seidel system which was well known in Germany but not in UK. This was the first system in UK to include the use of VF stages. The pilot system worked well and they proceeded to build a bigger system in 1989 for the whole site designed to treat up to 100 residents but at that time serving just 65 people. Let me make this very clear I had no involvement in the design or building of the system.

Pic. 1: The Oaklands Park system in its first year of operation showing the newly-planted stages down the hillside being inspected by the UK coordinating group.

However I liked what they were doing and was keen to get some data on the performance of the vertical flow stages and so with the cooperation of Uwe Burka the designer my WRc group monitored its performance for 2 years from 1989 to 1991. From the detailed data set of 49 fortnightly samples that we gathered through the stages in the system I was able to calculate the mass loading and removal rates for BOD5 and NH4N in the VF stage sand NO3N in the HF stages. Using this information I was able to put together the method that I have used since for designing nitrifying and denitrifying systems.

This information was used in the 2 stage VF system that I designed for WRc's Medmenham site located on the River Thames in 1992 where complete nitrification was a requirement. There are several reasons why I think that Oaklands Park is a good example. Firstly and most importantly, it works in producing an excellent effluent; secondly it is very picturesque; thirdly it is still working after 22 years operation and fourthly it is a completely appropriate technical answer for the location on sloping hillside which allows the stages to be gravity fed. Finally the fact that it was designed, built and operated by the site owner I am sure that leads to commitment and good performance. Uwe Burka returned to Germany in the early 1990s to help with reconstruction in the eastern sector of the re-united country but since them Mark Moodie has carried on the development and operation of the system.

Pic. 2: the site after 10 years operation looking like a garden.

I have visited the system many times and continue to be impressed by its simple design and practical appropriateness. It is a wonderful example of a simple common-sense solution and commitment on the part of the owners.

And the last question: who would you like to be interviewed the next time?

I would suggest that your next interviewee should be Hans Brix with whom I have been talking and learning from for the past 26 years. It was his idea to start this group and called a meeting at the IAWPRC [a predecessor of IWA] Biennial conference in Brighton in 1988 which about 20 people attended. He became the first Chairman and also started this Newsletter initially financing it from his university funds.

These are very solid reasons to ask him to be next! Thank you very much Paul, for your contribution!

NEW ZEALAND GUIDELINES FOR ON-SITE TREATMENT OF HOUSEHOLD WASTEWATERS

Chris Tanner, Tom Headley and Andrew Dakers

Constructed wetlands have the potential to supplement conventional on-site wastewater treatment systems to reduce pollutant discharges, but there has been no readily available information to guide appropriate usage under New Zealand conditions. Thisguideline aims to assist designers, plumbers and drain-layers to construct reliable wetland treatment systems that can provide dependable performance and treatment of effluent to secondary standards.Rather than provide a myriad of different design options, it attempts to distil the first-hand practical experiences gained by the authors in New Zealand and Australia, with those developed elsewhere around the world where on-site wetland treatment has been widely practiced.

The guideline focuses on passive, horizontal subsurface-flow constructed wetlands in which wastewater flows horizontally through a shallow gravel bed vegetated with emergent plants adapted to wetland conditions. These systems have been used widely around the world in this role for a number of decades. If correctly designed, installed and serviced, they are capable under New Zealand conditions of providingreliable long-term, secondary treatment of septic tank pre-treated domestic wastewaters with average effluent Total Suspended Solids (TSS) levels < 30 and Biochemical Oxygen Demand (BOD_5) levels <20 g m^{-3}.Median levels of faecal bacteria (*E. coli*) will also be reduced by ~99% (2 log reduction). Treated effluents from the wetland should be discharged to an appropriate land application system.

Wetland surface areas, dimensions, lining, media, inlet and outlet structures, and planting requirements are given, based on expected wastewater flows specified in New Zealand and Australian standards for on-site domestic wastewater management (AS/NZ1547; 2000). Conceptual design drawings show the recommended wetland layout and provide detail of key components of the wetland. Operation and management requirements, including plant care and weed management, are outlined, and potential sources of lining materials and wetland plants are listed in the appendices.

The horizontal subsurface-flow wetlands described in this guideline have the advantage that they are simple to construct and can operate passively without need for mechanical apparatus or external energy sources if there is sufficient fall to provide for gravity flow. They are able to cope well with fluctuating wastewater loads, and to function with minimal, but not zero, maintenance and management. Other more complex constructed wetland systems that operate with pulsed loading, vertical- or tidal-flows and/or recirculation have potential to provide higher levels of tertiary treatment, including advanced levels of nitrogen removal. These alternative systems, not addressed in the current guideline, should be considered where higher treatment levels are desired.

Tanner, C.C., Headley, T.R., Dakers A. (2011). Guideline for the use of horizontal subsurface-flow constructed wetlands in on-site treatment of household wastewaters. NIWA Client Report HAM2011-065 for Gisborne District Council. June 2011. 35 pp.

http://www.envirolink.govt.nz/PageFiles/677/909-GSDC85%20Guidelines%20for%20use%20of%20constructed%20wetlands%20for%20on-site%20treatment.pdf

REPORT FROM THE MIDDLE EAST REGION: LARGE-SCALE TREATMENT OF OILFIELD PRODUCED WATER USING WETLANDS IN OMAN

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Introduction

Perhaps surprisingly for what is predominantly an arid landscape dominated by desert environments, treatment wetland systems are becoming an increasingly popular technology option for dealing with a range of contaminated water issues in the Middle East. Various full and pilot-scale treatment wetland projects have been realised in recent years for treatment of sewage and sludges in Oman, Qatar, the UAE and Jordan. Wetlands are also playing an important role in treating industrial wastewaters on a large scale, such as the 600 ha wetland-pond system described below that was designed and built by BAUER Environment for treating residual water from an oil field in Oman.

The Nimr water treatment plant (NWTP) project (Plate 1) is located 700 km south of Muscat in Oman for treatment of oil contaminated produced water from the Nimr oil fields. Located in a desert environment, the temperatures in the region can be as high as 60°C in the summer months. This water treatment project was co-executed by Bauer Environment and Petroleum Development Oman (PDO). The plant came online in late 2010and has been treating water since 18 December 2010. Large volumes of water come to the surface with the oil when it is extracted from deep below the ground surface. The water:oil ratio at the Nimr oil fields is approximately 10:1, resulting in 250,000 m^3 of oil contaminated produced water being generated per day following the separation of the oil. Injecting the water back into deep aquifers under high pressure and energy consumption has been the traditional disposal method for produced water. By adopting an approach such as the Nimr WTP, the issues of lost revenue from oil left in produced water, tightening environmental regulations, high energy costs and the carbon footprint associated with disposal wells can be addressed.

Project overview

The Nimr WTP is designed to treat 45,000 m^3/d, which is approximately one fifth of the daily volume of produced water generated by the oilfield. It is a build–own–operate (BOO) project under a 20-year operation and maintenance contract. This is a unique model, for which BAUER designed and built the facility and is now operating it. BAUER has taken full liability for managing the water from the oil and gas producer. The composition of the produced water from the Nimr oilfield is brackish, with total dissolved solids (TDS) ranging between 7,000 mg/l and 8,000 mg/l. The oil in the water is higher than 400 mg/l on average.

The plant layout includes a pipeline, which enters the NWTP system and leads to an oil and water separator (Figure 1, Plate 1). The water is then distributed into a wetland facility where it is channelled through six surface flow wetland terraces by gravity feed (Figure 2, Plate 2). The overall area of the wetland is 2.4 million m^2 (240 ha), divided into 24 ten-hectare cells. For planting the surface flow wetlands, 1.2 million reed seedlings were propagated using salt-tolerant *Phragmites australis* plant stock sourced from the local region. Finally, there are 350 ha of evaporation ponds used for salt recovery in order to reuse the salt for drilling operations in the oilfields of Oman.

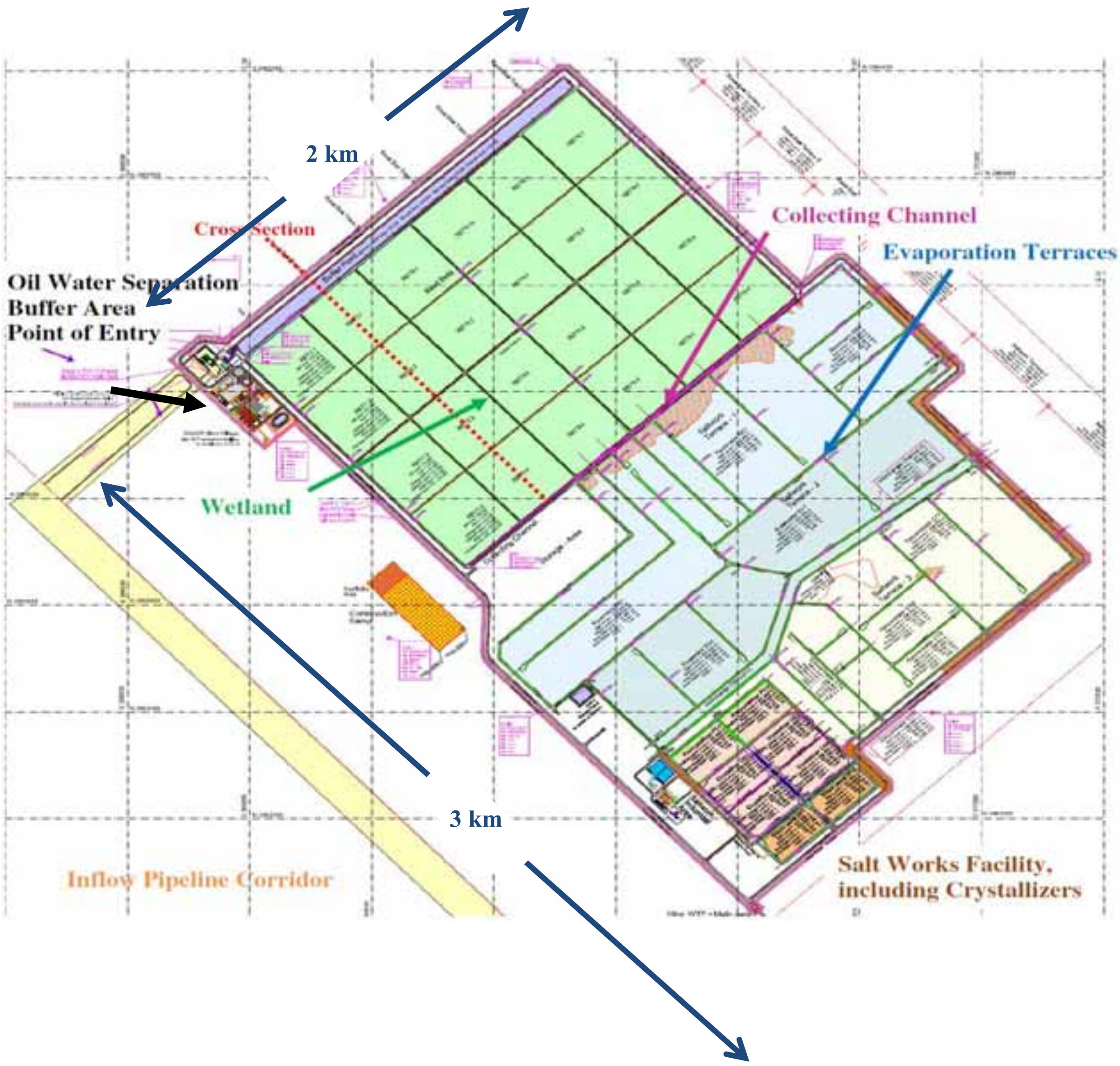

Figure 1: Plan view showing the layout of the wetland system treating 45,000 m^3/day of produced water at the Nimr oil field, Oman.

Plate 1: View from the inlet works of the Nimr water treatment system. The oil contaminated water passes through the oil separation facilities in the foreground before flowing down the long inlet buffer pond which enables even distribution of the water into the 240 hectares of wetlands, seen in the right of the photo.

Figure 2: Cross-sectional profile through the Nimr wetland treatment system.

Plate 2: Inlet structure of one of the 24 ten-hectare surface flow wetland cells.

Reducing the environmental footprint

The Nimr WTP project is reducing the environmental footprint of the Nimr oil field operations in several ways. This project is able to recover as much as > 200 bbl/d of oil from the produced water. An approximate average of 155bbl/day of crude oil is being recovered from the produced water stream, equating more than 56,000 barrels per year. Apart from minor energy consumption for the oil separator at the head works of the system, the entire treatment process operates via gravity without electricity, thus significantly reducing the energy footprint for produced water management. Treating 45,000 m^3/day of produced water without pumping also greatly reduces the operational costs and requirements.

To protect underground aquifers, the wetland area is lined with a mineral sealing layer rather than a HDPE liner, which is typically used. The climate and large surface area made using HDPE liners unfeasible. Local materials were sourced to establish the sealing layer. For added value the project will also research how to reuse the biomass that the wetland will produce over time. Compared with deep disposal wells, this wetland approach has lower energy requirements and less carbon footprint (Table 1).

Table 1: Operational energy requirements for treatment wetland plant and deep disposal wells

Disposal options	**Power required**	**Total power used in project**	**CO_2**
Deep well disposal	Up to 5.5 kWh/m^3	3,630,000 MWh	1,960,000 t
Treatment Wetland	0.1 kWh/m^3	66,000 MWh	35,700 t

Project success and outlook

The use of a mineral sealing layer rather than a HDPE liner has reduced the energy footprint during installation by 80%. The oil content in the produced water is reduced from 400 mg/l when entering the NWTP to less than0.5 mg/l when leaving the wetland system. Despite the hot climate, the winter months provide temperatures, which are suitable for the growth of *Phragmites australis* plants. Petroleum Development Oman and BAUER are currently increasing the NWTP capacity to 95,000 m³/d. As a testament to the success of the project, the Nimr wetland treatment system was awarded the "Industrial Water Project of the Year" in the 2011 Global Water Awards (Plate 3).

Plate 3: 2011 Global Water Awards. The awards were presented by guest speaker Kofi Annan. BAUER Resources GmbH's wetland treatment plant in Oman won the 'Industrial WaterProject of the Year' category, beating off competition from three other nominations.

THE FUSINA TREATMENT WETLANDS: FROM CONCEPT THROUGH CONSTRUCTION

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Abstract The Fusina wetlands are a key component of the Progetto Integrato Fusina, a project developed to reduce pollutant loads to the Venice Lagoon. One hundred ha of constructed wetlands have been specifically designed to polish wastewater effluent for industrial reuse and create habitat types historically lost. Development of this wetland has been a ten-year process of political and regulatory approval, iterative design, construction, and adaptive management that has overcome many of the challenges typical for constructed wetlands of this size. We present an overview of the implementation process, innovative techniques employed to overcome design challenges, and water quality and habitat data collected to date. With few other natural treatment systems at this scale in Europe, the Fusina treatment wetlands will serve as a valuable example for future projects in Italy and around the continent.

Keywords treatment wetlands, effluent polishing, water reuse.

INTRODUCTION

Urbanization, industrialization and agricultural development in the areas surrounding the Venice Lagoon, Italy, during the 20th century have had a dramatic impact on the water and sediment quality and ecosystem function of the lagoon, including chemical contamination, biological toxicity and eutrophication. A series of actions to improve the health of the lagoon have been conducted by the local regional government (Regione del Veneto) in the past decades for the collection and treatment of wastewaters in the vicinity of the lagoon, and has been progressively extended to include all the pollution sources over the whole lagoon watershed.

The most important extension was the 'Master Plan 2000', initiated by the Regione del Veneto to reduce nutrient and other contaminant loads to the lagoon as a pre-emptive measure to prevent further deterioration and ensure the protection of humans from adverse effects associated with the consumption of fish and shellfish.

Progetto Integrato Fusina (PIF) Overview

The most ambitious and innovative intervention identified by the Master Plan 2000 is the Fusina Integrated Project (PIF), which enhances and upgrades the Fusina wastewater treatment plant, located directly west across the lagoon from Venice itself. Figure 1 shows the general location of the project.

The PIF will expand treatment capability to include previously untreated sources such as industrial wastewater and contaminated groundwater and will construct a new discharge pipeline to the Adriatic Sea to replace the existing outfall in the Venice Lagoon (Figure 2). Domestic wastewater will be treated in a conventional enhanced biological plant and be polished in a 100 ha free-water surface treatment wetland sited directly on the lagoon. The treatment wetland system has been designed to maximize treatment performance, simplicity and flexibility of operation, recreational use, and ecological benefit (Casarin et al. 2005). Its design has been based on lessons learned from the implementation of similar systems worldwide.

Wetland effluent will undergo chemical-physical corrective treatment (when necessary), sand filtration, and UV disinfection before pumping to the nearby Porto Marghera industrial complex for process use, replacing and conserving the current supply from Sile River.

Constructed Wetlands for Water Treatment

Constructed treatment wetlands are natural treatment systems that harness physical, chemical, and biological processes present in wetland ecosystems to remove and trap pollutants. Treatment wetlands are increasingly used as a cost-effective alternative to conventional advanced treatment of wastewater. Wetlands, both natural and constructed, have demonstrated effective treatment of numerous types of wastewaters, and offer many ancillary benefits, making them especially advantageous considering modern concerns over wetland losses and the focus on natural and open space (Crites et al. 2006).

Increasingly, the marketability and public appeal for constructed treatment wetlands hinges on these ancillary benefits they provide. Unlike conventional wastewater treatment facilities, free-water surface treatment wetlands provide a diverse array of open water and vegetated areas that can provide a significant benefit if public access is designed into the system (EWRI 2004). Interpretive signage and exhibits, education programs, passive recreation facilities for bird watching, hiking, and other outdoor activities all provide functions that make treatment wetlands unique among civil infrastructure. In recent years, increasing attention has been paid to design of constructed treatment wetlands that incorporate education programs, public visitation for passive recreation and wildlife observation, and diverse habitat features. These benefits are often the "selling point" that assists in obtaining public and government support for wetlands when a variety of alternative water treatment technologies are considered (Bays 2002). Numerous treatment wetland facilities have shown that balancing wildlife needs with treatment is not only compatible (USEPA 1993, SCCWRP 2003) but part of a realistic strategy to maximize the total environmental benefit of these systems (Fleming-Singer and Horne 2006, Knight et al. 2001).

FUSINA WETLANDS: DESIGN CONTEXT

Treatment wetlands were first investigated in Europe in the 1950s, and by the end of the 20th century they had become a primary decentralized wastewater treatment solution. The main technological focus of constructed wetlands in Europe has been on subsurface flow systems rather than the free-water surface systems more common in North America (Vymazal et al.1998). In Italy, proliferation of constructed treatment wetlands was slow prior to 1999 due to lack of official recognition by legal frameworks as an acceptable treatment technology (Masi et al. 2000). However, because of favorable climatic conditions throughout the majority of the country and habitation by a significant percentage of the population in small rural communities, treatment wetlands have grown significantly in the last decade with numerous small subsurface flow systems for agricultural and domestic wastewater treatment as well as hybrid systems employing both subsurface flow and free-water surface wetlands treating municipal wastewater for communities up to 60,000 P.E.s (Masi 2008). However, presumably due to the established technological trend towards subsurface flow systems and a premium on land precluding the widespread development of land-intensive water treatment technologies, large-scale European free water surface wetlands are generally rare compared to North America, particularly in Mediterranean countries such as Italy (Vymazal 2011).

The Fusina wetlands therefore represent a unique opportunity for free-water surface wetland treatment because of a number of key factors not typically present in Italy. First, the presence of a large dredge spoil basin near the Fusina wastewater treatment plant provided the opportunity to site a constructed treatment wetland system that would restore ecosystem services to natural marshlands that were reclaimed in the 1960s. Second, the relatively low-level nutrient and trace contaminant concentrations expected in the wastewater effluent are ideally suited to "polishing" treatment in a large, multi-objective natural treatment system. Third, demand for industrial process water at the nearby Porto Marghera petrochemical complex creates a reuse market for significant quantities of highly-treated wastewater that meet applicable water quality standards and a significant opportunity for water conservation. And finally, because a major benefit of multi-objective natural treatment systems is the opportunity to provide public recreation, education, and promotion of sustainable technology solutions, the proximity of the site to a major tourist center such as Venice provides a remarkable locale to recognize such benefits.

Site History

The Fusina treatment wetlands have been constructed at the so called "Cassa di Colmata A", a reclaimed area facing the Venice Lagoon that offers views of the historic city of Venice. Beginning in 1963, dredged sediments from the construction of a navigation canal connecting Porto Marghera to the Adriatic Sea were used to fill natural salt marsh wetlands for future industrial expansion. The industrial expansion never occurred, and when the dredging works ceased in 1969, three large areas had been reclaimed called Cassa di Colmata A, B and D-E.

While Cassa di Colmata B and D-E were restored to more natural conditions by cutting new canals to recreate the former tidal hydrology, Cassa di Colmata A was never restored. Over time, due to its uneven topography, a variety of vegetation communities colonized including upland, transitional, and wetland. However, these vegetation communities did not provide ecosystem functions that formerly existed adjacent to the Venice Lagoon. Therefore, this site was chosen as an ideal location for redevelopment into a natural water treatment system.

Wetland Design Challenges

Despite the opportunities Cassa di Colmata A provided, significant obstacles to construction of wetlands existed. Reflecting its historical use as a disposal site for dredged lagoon sediments, Cassa di Colmata A consisted of highly variable topography and sediment quality due to differential placement of fill in space and time. The dredged materials placed at the site were primarily sandy soils with elevated salt concentrations not ideally suited for freshwater wetland plant species. The Cassa di Colmata A site and the Fusina wastewater treatment plant are separated by agricultural fields, industrial facilities, and two major canals, requiring significant tunneling to construct the conveyance pipelines. The cost and logistics of constructing such a pipeline forced co-located inflow and outflow lines at the approximate middle of the north side of Cassa di Colmata A. This presented a significant challenge, as it dictated a more complex routing of water through the wetlands. Finally, there was a lack of a local supply of proper quantities of many of the wetland plant species typically used in treatment wetlands because such a large-scale wetland construction project was unprecedented in Italy; this necessitated creation of a site-specific nursery.

DESIGN METHODS

Treatment Performance Modeling

The primary goal for construction of the treatment wetland system as part of the PIF project was the final "polishing" of wastewater plant effluent to meet Venice Lagoon discharge water quality standards. This allows wetland effluent to be reused by industrial processes within the Porto Marghera industrial complex. Because the available area for construction of a treatment wetland was fixed by the size of Cassa di Colmata A (approximately 140 ha, with approximately 100 ha allocated for the wetlands) treatment performance modeling was performed to ensure that the required pollutant levels could be achieved. With a design flow of approximately 100,000 m^3/d, the Fusina Wetlands will operate at a 10 cm/d hydraulic loading rate, which is typical for free-water surface systems (Kadlec and Wallace 2009).

Treatment performance estimation was performed with the first-order, tanks-in-series model detailed in Kadlec and Knight (1996) with modification to account for changes in water storage and discharge due to evapotranspiration, infiltration, and precipitation. Approximately 55 contaminant species regulated in discharges to the Venice Lagoon are anticipated to be present in trace amounts in Fusina wastewater treatment plant effluent. These stringent Venice Lagoon discharge requirements required a comprehensive review of reported literature removal rates and extensive study of data from existing wetland treatment systems in similar climates to help develop first-order reaction rate constants for use in treatment performance modeling.

Vegetation Selection and Planting Plan

Several vegetation objectives needed to be met at the Fusina wetland. Consistent with its goal of a multi-objective facility that provides wildlife habitat, biodiversity, and opportunities for recreation and education -- the choices of wetland species and planting plan focused on providing four major vegetation communities. These included emergent marsh vegetation in shallow water; submerged aquatic vegetation on transition slopes between shallow marsh areas and deep, open water zones; floating plants in open water areas; and transitional species on the wetland fringes at the berm/water interface. These four community types provide a diverse array of habitat for nesting and foraging for birds, amphibians, reptiles, fish, and invertebrates. At the same time, this diversity of vegetation communities will aid in treatment efficiency. Figure 3 illustrates the layout of the cells and the general planting plan.

The primary polishing treatment will occur in the shallow vegetated marsh beds, which require a dense, uniform coverage of emergent plant species to provide microbial attachment sites, oxygen transfer to root zones, and the yearly cycle of growth and senescence that creates a detrital layer that provides additional microbial habitat, labile carbon, and sorption sites. *Phragmites australis*, which commonly exists in adjacent natural wetlands and existed in many areas of the Cassa di Colmata A site prior to construction, was the primary emergent vegetation species chosen. *Typha latifolia* and *Schoenoplectus lacustris* were also planted in some marsh zones to promote an initially diverse assemblage of emergents. Over time, we expect that the local conditions will select for either dominance by one species or a mix of those planted. Figure 4 represents a view of the general vegetation cover and condition as of 2010.

Deep zones have been alternately planted with submerged vegetation (*Potamogeton crispus*), floating leaved plants (*Nymphaea alba*), or left open. It is anticipated that over time, both submerged and floating plants will colonize all deep zones. Submerged aquatic vegetation and open water systems containing *Potamogeton* spp. have been shown to enhance denitrification through provision of epiphyton attachment sites on the submerged vegetation (Erickson and Weisner 1997). Floating leaved plants such as *Nymphaea alba* may provide a barrier to atmospheric oxygen transfer (enhancing anoxic pollutant removal processes), shading for the reduction of algal solids production in open zones, as well as provide attachment sites for epiphyton. Decomposition of both the submerged and floating vegetation provides a labile carbon source for heterotrophic bacteria. Finally, *Juncus effusus* was planted at the interface between water and berms given its tolerance for lower water depths and less flooded conditions than the other emergents and will provide enhanced habitat diversity and berm erosion protection.

Because of the unprecedented scale of the Fusina wetlands construction, some of the specified plant species could not be locally obtained in sufficient quantities for planting of the 100-ha full-scale system. The one-hectare pilot system, constructed two years in advance of the full-scale system, served as a nursery for some plant species.

Layout and Topography

Before wetland construction, the Cassa di Colmata A site was ringed by a containment berm with highly variable topography in the interior ranging over a few metres above mean sea level. Early in the design process, the site was subdivided into four major regions -- a parcel that will eventually become the site of a visitor's center and three functional wetland areas called "Lotti" 1, 2, and 3. Each "Lotto" was further subdivided into two halves (west and east) that would eventually become the six wetland treatment cells. Because of the requirement that the inlet and outlet piping be co-located in the middle of the north side of the site, the wetland was laid out as two parallel flow paths circling in opposite directions, each occupying approximately half of the basin. Splitting the flow into two parallel flow paths enables redundancy and the opportunity to take one flow path off-line for maintenance if required. Each flow path is made up of an initial wetland cell that discharges into two parallel final cells which each discharge into a single collection and outflow structure. The two parallel final cells that make up each flow path further enable redundancy and the ability to take as little as one cell off-line at a time, leaving the other five performing treatment. Compartmentalization of a treatment wetland site into subcells linked in series as at Fusina is an important factor in achieving high levels of contaminant removal, particularly when approaching contaminant background limits as is the case for the polishing function of the Fusina wetlands (Kadlec and Wallace 2009).

The general design of each of the six cells that make up the Fusina wetlands is the same. An initial deep zone accepts inflow and ensures a uniform distribution of flow across the first marsh zone. A terminal deep zone serves as a flow collector to discourage short-circuiting of flows by development of preferential topographic channels that bypass corners of wetland area away from the outlet structure. Each of the six cells contain between three and six intermediate deep zone areas that redistribute flows. This function prevents short-circuiting channels from existing over the full length of the wetland flow path and can increase the areal treatment efficiency of free-water surface wetlands (Lightbody et al. 2008). An approximately 70/30 percent ratio of shallow marsh to open water deep zones was chosen to optimize the benefits of each (Crites et al. 2006). Wind and wave action at the water surface of the deep zones also provides oxygen to the water column, which can promote the removal of contaminants such as BOD. The shape and alignment of each open water deep zone was optimized to take advantage of existing depressions in topography (to reduce earthmoving costs) while also minimizing dimension parallel to the prevailing Bora and Scirocco winds to reduce potential for wind-induced wave erosion at wetland berms. Deep zone and marsh zone bottom elevations were designed at +0.50 m and +1.50 m above sea level, respectively, in the initial cell in each flow path and at +0.20 m and +1.20 m, respectively, in the two terminal cells in each flow path. This creates a drop of 0.3 m across the water control structures separating the cells.

Hydrology, Hydraulics, and Infrastructure
Flow is pumped 1,500 m from the Fusina wastewater treatment plant and approaches the Cassa di Colmata A from the north. It enters a concrete box diversion structure that splits flow to achieve equal hydraulic loading rate between cells 3E and 3W (Figure 4). These two cells flow generally southwards and then turn east and west, respectively to deep zones at the terminal end of these cells that connect to cells 2E and 2W (from 3E) and 1E and 1W (from 3W) via concrete box structures contained within the internal berms with adjustable weirs. Cells 1E, 1W, 2E, and 2W circle back toward the middle of the north side of Cassa di Colmata A where a four-way concrete box collection structure brings together outflow from all four cells and send them via piped back to the Fusina wastewater treatment plant.

The Fusina wetlands design flow rate is 4000 m^3 per hour during normal conditions, which corresponds to a hydraulic loading rate (HLR) of approximately 10 cm per day and a nominal residence time (HRT) of approximately 7 days at depths of 0.3-0.5 m in marsh zones and 1.3-1.5 m in deep zones. During storm events, the wetlands have been designed to accept up to 8000 m^3 per hour for a period of up to two days. During this period, design depths will be approximately 0.7 m in marsh zones and 1.7 m in deep zones.

Potentially significant friction losses can occur in free-water surface wetlands as shallow water flows past dense stands of emergent vegetation. This head loss phenomenon can be exacerbated by very shallow flows, dense vegetation in very large patches relative to the overall size of the wetland, and in wetland layouts with very high length to width ratios. These head losses cause a hydraulic profile that slopes upwards from downstream to upstream, even in a wetland cell with a level, horizontal bottom. The practical reality is that while wetland depth can be controlled via a weir at the outlet of a wetland cell, depth at the inlet will be greater and determined by friction losses experienced by the flow through the emergent vegetation. Given the size of the wetland cells at Fusina (some up to 1 km long or longer) it was important to verify that head losses in the second cell in each flow path did not back water up at the inlet end to the extent the water control structures are flooded or berm freeboard is exhausted. For the wetland system to flow by gravity, there must be a sufficient elevation drop across each water control structure; extreme head losses can create a condition where the water surface at the downstream end of the water control structure becomes higher than that upstream of the structure.

The hydraulic performance of each of the four flow paths was modeled using emergent marsh friction loss calculations detailed in Kadlec and Knight (1996). Plotting the estimated hydraulic profiles showed that the 0.3 m elevation differential between the upstream cells (3E and 3W) and the downstream cells (1E, 1W, 2E, and 2W) was more than sufficient to ensure a hydraulic gradient across the connections between wetland cells at both typical (4000 m^3 per hour) and storm surge (8000 m cubed per hour) conditions.

CONSTRUCTION AND CHANGE MANAGEMENT

Pilot System

Construction at Cassa di Colmata A began in spring of 2007 with earthmoving activities for the one-hectare pilot system. The system was planted in mid-summer with a mix of the species planned for the full-scale system, as plants were to be harvested from the pilot system in 2008 and 2009 for the full-scale system planting effort. A temporary pump station was established to convey water from the nearby Naviglio Brenta -- a freshwater navigation channel -- to the pilot system. Between June of 2007 and July of 2008, water was pumped to the wetlands to maintain an approximately 0.3 m water depth for the purposes of establishing vegetation. Outlet structures and the ability for flow through the pilot system were established in July of 2008; discharges were conveyed to the inlet of the full-scale system.

The pilot system, which consists of two parallel wetland cells with five deep zones and for marsh zones each, was planted with *Nymphaea alba* and *Potamogeton crispus* in two deep zones each, *Typha latifolia* and *Schoenoplectus lacustris* in two marsh zones each, *Phragmites australis* in three marsh zones, and *Juncus effusus* in one marsh zone. Over the course of the first year, vegetation established quite readily and densely in the southerly cell. The vegetation established much less densely and to a lesser height in the northerly cell. Presumably due to lack of flow through and stagnant water conditions, floating surface algae was common in the pilot system during the first year. By the end of the second growing season, however, both cells had developed dense, mature stands of all vegetation. Algal mats also subsided once flow-through was established.

During July through November 2008, after establishment of flow through the one-hectare pilot system, a series of water quality measurements were made to monitor treatment performance. Median results from the sampling are summarized in Table 1. Concentration reductions are summarized in Mietto et al. 2010(a).

Table 1. Fusina pilot system monitoring data, July 2008–November 2008

Contaminant (µg/L)	Inflow	North Cell Outflow	South Cell Outflow
Ammonia as N	63	20	20
Nitrate as N	1000	300	100
Total Dissolved N	2100	540	491
Total N	2300	590	530
Orthophosphate as P	57	6	4
Total Dissolved P	85	14	17
Total P	148	26	23
Total Suspended Solids	23100	4500	1300
Total Copper	17	13	13
Total Zinc	13	8	4

These results, although captured over a limited timeframe, exhibit removal of all contaminants measured, with particularly high phosphorus concentration reductions. This phosphorus removal phenomenon is often observed in young treatment wetlands, when soil sorption capacity is high and vegetation is maturing (Kadlec and Wallace 2009). Over time, as soil sorption sites are exhausted and vegetation is fully established, phosphorus removal can be expected to reach equilibrium via sustainable processes such as detritus sorption, precipitation, and burial / soil storage.

As part of the baseline studies of the pilot system startup, detailed measurements of sediment and tissue quality associated were performed by A. Mietto for her dissertatation research (Mietto et al., 2010b). Key findings included the following:

- Water concentration of As, Cd, Cr, Pb were below detection limits; Cu and Zn were removed by the system.
- Higher growth of *S. lacustris*, *T. latifolia* and *P. australis* were observed in Cell 2, which characterized by a clayey soil with higher content of organic matter , total nitrogen, and metals.
- Greater metals concentrations were found in belowground tissues than in aboveground parts.
- Measurable translocation of TKN from the aboveground parts to the belowground tissues prior to fall senescence
- There was a positive correlation between sediment and plant (particularly in belowground tissues) metals concentration

The work by Mietto and colleagues is an excellent example of the kinds of detailed studies that can and should be undertaken at treatment wetlands, particularly during start-up. The Fusina wetlands is expected to provide a productive platform for research in the future on the performance, hydraulics, and ecology of large-scale treatment wetlands.

Full-Scale System

Earthmoving work began on the 100-hectare full-scale system in fall 2007 and continued through late 2009. Planting of each zone of the wetland proceeded shortly after completion of earthmoving activities, such that both were simultaneously ongoing for much of the approximately 2 years of construction. Change management was an important part of the wetlands realization; the areal and temporal scales of the project meant that design modifications, unexpected problem solving, and tolerance of delays were required. The significant hurdles overcome during construction included:

- Due to a surplus of local earth fill requiring use or disposal, all berms, all marsh zones and several deep zones were raised +0.15 m above the design elevations. Some of the sediment requiring disposal originated in the Venice lagoon and contained salinities too high for some plant species, most notably *Nymphaea alba*. To increase survivability and establishment, this plant species was placed in small mounds of clean soil to provide a suitable medium for establishment until the eventual initiation of freshwater flows will "flush" salt out of the dredged sediments (Figure 6). Additionally, *Ruppia maritima,* a submerged aquatic species, has spontaneously colonized many of the deep zones (presumably originating from the Naviglio Brenta) and may replace some of the treatment benefits expected from *Nymphaea alba*.

- Delays in construction activities for upgrades to the Fusina wastewater treatment plant postponed the ability to deliver water from the treatment plant to the wetlands approximately 2 years. To provide sufficient water to establish the required vegetation, the temporary pump station that had been bringing freshwater from the Naviglio Brenta to the pilot system was significantly expanded.

- Uneven consolidation of soils in some areas required regrading or acceptance of elevations outside of design tolerances. Because of scheduling demands, all grading deficiencies could not be corrected. In projects of this scale, such construction issues are often unavoidable and can be somewhat mitigated by careful design and specification. For example, the inclusion of numerous lateral deep zones to mix and redistribute flow prevent any topographic short-circuiting channels that may develop from bypassing flows any further than one individual marsh zone. Some cells at Fusina have as many as 6 marsh zones separated by redistribution deep zones. Also, the grading plans specified that the small “furrows” left behind by grading machinery be always oriented perpendicular to flow. This ensures that the small linear depressions left by machinery do not serve as initial short-circuiting paths. Together, these measures are anticipated to render grading deficiencies insignificant, and as the wetland matures and several growing seasons of decomposing plant litter are laid down, such construction issues should be undetectable.

Earthmoving and planting were completed in late 2009. Pumped water from the Naviglio Brenta continued to support the wetlands at a rate equal to evapotranspiration losses while the wetland awaited completion of the effluent pipeline from the Fusina wastewater treatment plant, which was finished in April 2011.

Owned by the Veneto regional government, the treatment wetlands were developed by Sistema Integrato Fusina Ambiente (SIFA), a Venice-based consortium of engineering and construction firms. Among these firms, Studio Altieri S.p.A, of Thiene, Italy, led the engineering team and conducted construction management. As the entity responsible for the design and management of the wetlands, Thetis S.p.A., of Venice, subcontracted with CH2M HILL to provide the technical design of the wetlands. SIFA will operate the wetlands for 20 years, under contract to the regional government.

CURRENT STATUS

Beginning on May 15 2011, the flow from the WWTP began being pumped at a rate of 2250 m^3/h for a period 6 hours per day during the evening to allow completion of construction activities at the WWTP during the day. Flow returned from the wetland to the WWTP continuously by gravity. For 2011, because of a low demand for reclaimed water, flows to the wetland were limited to a small volume appropriate to hydrate the wetland. Wetland vegetation communities had received the benefit of three growing seasons during the construction and startup period and have achieved a virtually complete cover through growth of initial plants supplemented by natural recruitment.

In the interim, the Fusina wetlands are attracting wildlife. Herons, coots, swans, and reed-warblers have been observed to forage, nest, and rear young in the wetlands. Amphibians, reptiles, and fish have likewise colonized the former dredge spoil basin.

During the 12th International Conference on the Use of Wetland Systems for Water Pollution Control, held October 4–8, 2010 in Venice, conference attendees were taken on a boat excursion to the facility and given a walking tour of the Fusina Wetlands (Figure 7).

CONCLUSIONS

The PIF project and Veneto Region Master Plan 2000 of which it is part represent a first for Italy: a multi-objective, integrated approach to environmental problem solving that proactively addresses the health of the Venice Lagoon. The Fusina wetlands is an innovative water resources project in a world-famous location that continues Italy's advancement of natural treatment system technologies to meet human and ecological needs.

ACKNOWLEDGEMENTS

The Fusina Wetlands project represents the successful culmination of over a decade of dedicated planning by environmental professionals in Italy and the United States. Particular thanks for their support, dedication and vision are warranted to the following: the staff of CH2MHILL, Studio Altieri and Thetis for engineering and planning, R. Casarin/Regione del Veneto, G. Pineschi/Ministry of the Environment, B. Hooley/CH2MHILL, and the construction engineering staff of Impresa Ing. Mantovani S.p.A. This paper was presented at the 12th International Conference on the Use of Wetland Systems for Water Pollution Control, held in Venice Italy October 4-8, 2010 and is updated and expanded version of the paper included in the proceedings.

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Figure 1 Fusina Location

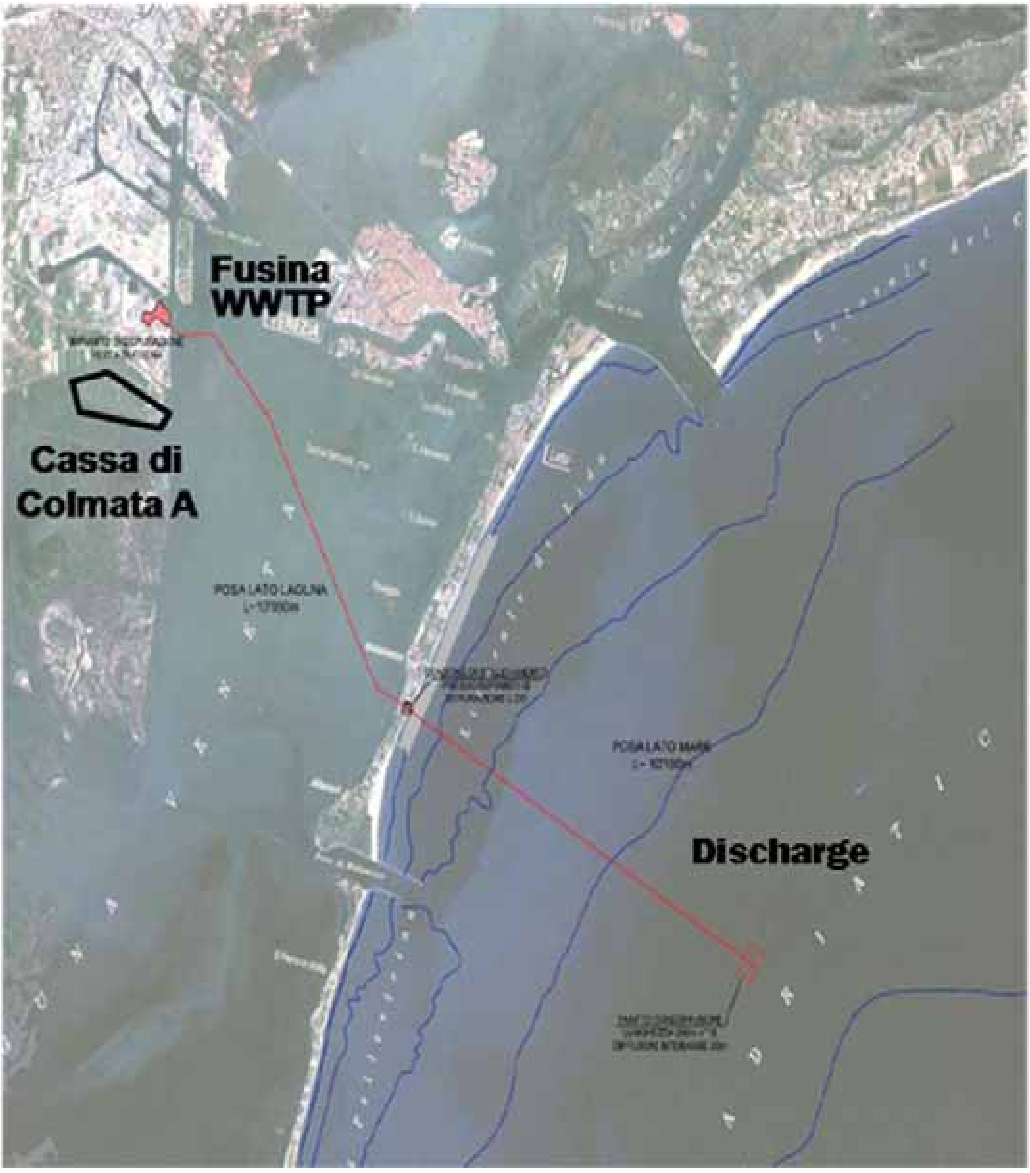

Figure 2 Progetto Integrato Fusina: Overview

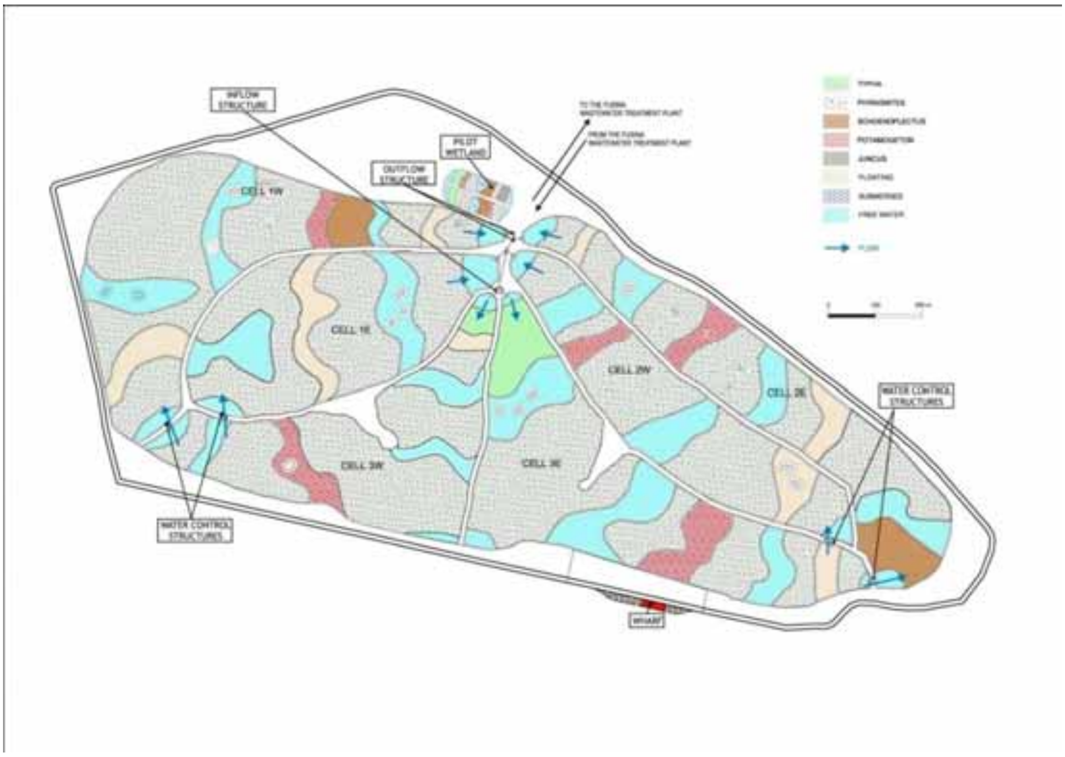

Figure 3 Fusina Wetlands Layout and Vegetation Plan Overview

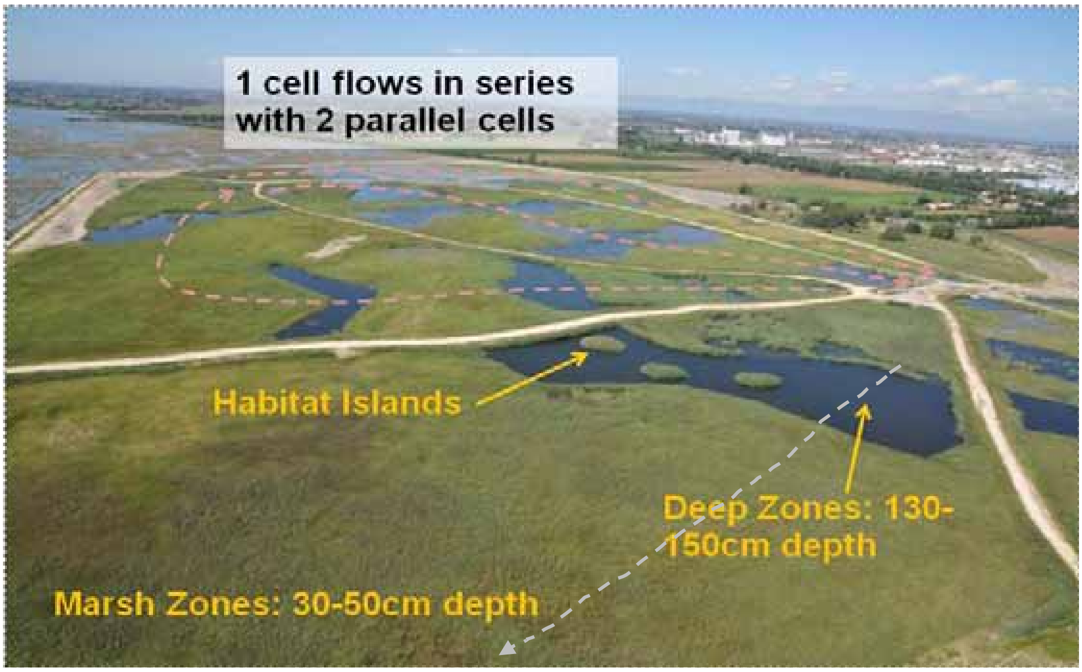

Figure 4 Representative Views of the Cell Habitats and Flow Directions

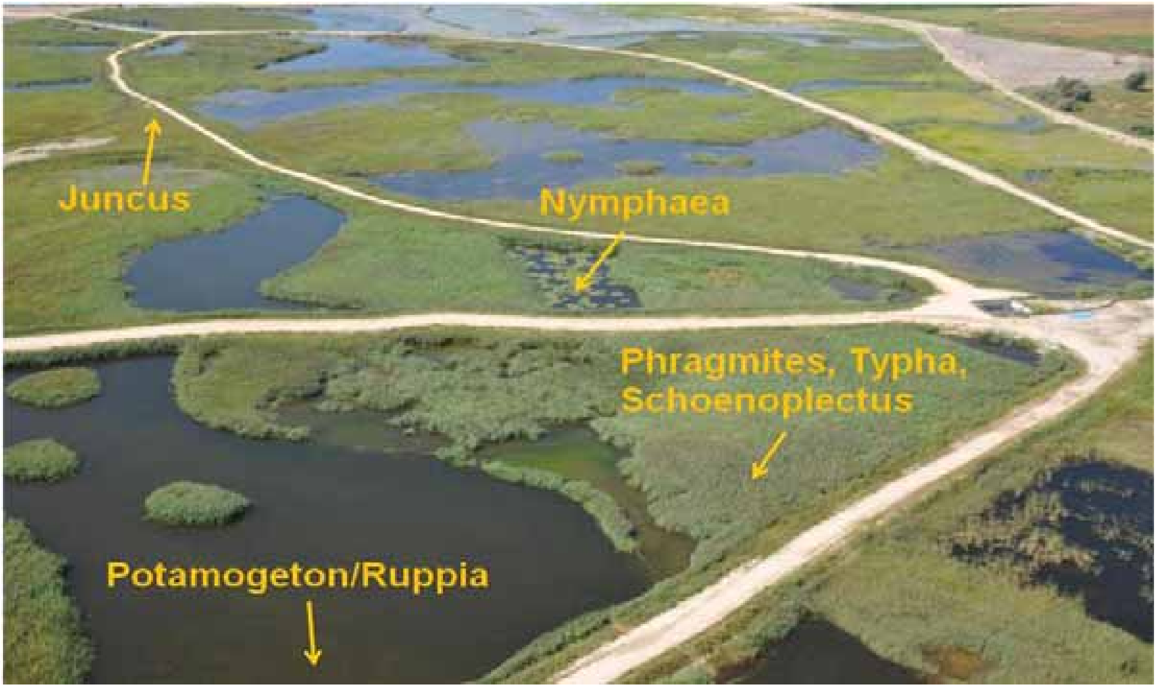

Figure 5 Vegetation Types in the Fusina Wetlands

Figure 6 *Nymphaea* Planting Beds

Figure 7 Scenes from Conference Tour of the Fusina Wetlands, October 7, 2010.

EFFICACY OF A HORIZONTAL SUBSURFACE FLOW SYSTEM IN REMOVING PHARMACEUTICALS FROM SECONDARY DOMESTIC WASTEWATER

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INTRODUCTION

Pharmaceutical compounds (PhCs) and other emerging contaminants have provoked increasing concern in recent years due to the growth in their use and the increasing awareness of the their environmental impact once discharged into surface water bodies. Due to their complex structure and the variety of their functions, PhCs generally possess a wide range of physicochemical and biological properties. Moreover, their bioactive ingredients do not remain stable, being subject to alteration by human metabolism, and both the excreted metabolites and the unaltered parent compounds can then undergo further transformation in sewage treatment facilities. Furthermore, as many of these compounds survive biodegradation, they are only partially eliminated in conventional wastewater treatment plants (WWTPs), and are therefore eventually discharged into receiving waters, where metabolic conjugates can even be converted back to their free parent forms.

Hence, in recent years research has been focussed on testing the ability of wastewater treatment technologies to reduce the concentrations of these persistent organic micropollutants in the final effluent. The most intensively studied thus far have been: ozonation, O_3/UV, O_3/H_2O_2, ultrafiltration, reverse osmosis and membrane biological reactors. In contrast, very little research has examined the efficacy and reliability of constructed wetlands (CWs) in removing PhCs (among them Matamoros et al., 2006, 2007, 2008). What few studies have been carried out were conducted on *pilot plants* predominantly featuring horizontal subsurface flow systems (H-SSF), surface flow systems (SFS, such as lagoons or anaerobic or facultative ponds) and their combinations, the so-called hybrid systems.

To date, the most investigated PhCs are analgesic and anti-inflammatory drugs (ibuprofen, naproxen, diclofenac, ketoprofen and salicylic acid), psychiatric drugs (carbamazepine, diazepam and fluoxetine) and lipid regulators (clofibric acids and gemfibrozil). These studies have observed a wide variation (20–90%) in removal efficiencies, depending on the compound in question.

In order to shed more light on this issue, the present study was aimed at evaluating the removal rates of a wide range of PhCs during their passage through a H-SSF pilot plant, which, in this case functions as a polishing treatment and receives the secondary urban effluent. 73 compounds present in domestic secondary effluent were considered (12 analgesics/anti-inflammatories, 25 antibiotics, 1 anti-diabetics, 3 anti-hypertensives, 3 barbiturates, 9 beta-blockers, 1 diuretic, 7 lipid regulators, 5 psychiatric drugs, 4 receptor antagonists, 2 beta-agonists and 1 anti-neoplastic), selected for their high human consumption and their ubiquity in the aquatic environment, as documented in the scientific literature.

MATERIALS AND METHODS

This study was performed at the municipal WWTP of Ferrara, Italy, (44°83'N and 11°62'E), where a CW pilot station, fed directly with real wastewater from the nearby WWTP, has been in operation since 2003. This H-SSF, which features spontaneous plants and grass turf, is a long, narrow bed (28 × 1) filled with a layer of gravel (8–10 mm grain) with a depth ranging from 0.7 at the influent to 1.75 m at its effluent end. The average flow rate through the H-SSF is roughly 8 m^3/d.

During the course of the experimental investigation, which lasted two months from March to April 2010, T ranged between –2 and 25 °C, on average 11 °C, and precipitation amounted to 150 mm, with 10 rainy days being recorded (rain > 2 mm/d). As evapotranspiration under these environmental conditions corresponded to a daily water loss from the H-SSF bed of only 1–2%, this factor was not considered influential. 24-hour composite water samples were withdrawn at the inlet and the outlet of the bed, during dry weather, four times during the observation period.

RESULTS AND DISCUSSION

Of the 73 PhCs investigated, 17 compounds were never found above the quantification limit in any water sample, while the remaining 56 compounds were detected in every sample.

On the whole, corresponding average values and SDs for the detected compounds showed wide variation, ranging, in the influent, from few ng/L to more than 1400 ng/L and, in the effluent, from 1 to 630 ng/L. Table 1 reports the average values and the corresponding SDs recorded for the different therapeutic classes (the reported value is the sum of the average values found for the PhCs belonging to the same class) in the influent and effluent of the bed. The last column shows the observed variability range of the concentration of compounds in the same class.

Figure 1 shows the observed average percentage removal rates for the main therapeutic classes, and Figure 2 the average percentage removal rates for the investigated analgesics and antibiotics.

On the basis of the collected data and the results of the cited studies reported in the literature, it appears to be quite difficult to predict the behaviour of a PhC during its passage through a H-SSF bed, as physicochemical, environmental, and operational conditions and low concentration may all have an effect. Indeed, analysis of the correlation between common parameters (for instance Log K_{ow}, k_{biol}) and the observed percentage removal rates for the different compounds fail to evidence a clear trend, confirming previous reports (Kummerer, 2009; Park et al., 2009). Indeed, in some cases PhC release occurred in the CW, resulting in higher effluent concentrations with respect to the influent; this was true for the analgesic propyphenazone, the antibiotics roxythromycin and sulfadiazine, and the psychiatric drug fluoxetine.

Nonetheless, the coexistence of several microenvironments in CWs does favour both the thermodynamic conditions required for chemical reactions and the development of a great variety of microbiological communities able to guarantee the enzymatic capacity necessary to achieve the target biogeochemical reactions. This microenvironmental coexistence can promote various metabolic pathways, thereby leading to PhC degradation; it is due to the variation in physicochemical parameters on different gradients inside the CW (D'Angelo, 2002; Dusek et al., 2008; Imfeld et al., 2009), created by the organisms inhabiting the CW and/or the presence of ramified roots within the medium. These tend to create aerobic zones in proximity to anoxic or anaerobic areas (Stottmeister et al., 2003; Imfeld et al., 2009), consenting dynamic oxic/anoxic interfaces to be established in wetlands as a result of water level fluctuations, oxygen diffusion/advection through the water column and filling medium, and active oxygen transport through the rhizosphere via plant tissues.

Table 1. Average values (±SD) of the concentrations of the main therapeutic classes in the influent and the effluent of the bed

Therapeutic class	Influent, ng/L	Effluent, ng/L	Variability range of PhC concentrations, ng/L
Analgesics/Anti-inflammatories	1697±257	1301±215	9–906
Antibiotics	2100±594	964±224	4–1120
Anti-diabetics	55±29	42±14	14–77
Anti-hypertensives	1167±199	434±174	1–1050
Barbiturates	258±33	181±31	9–174
Beta-Blockers	1265±325	865±289	6–980
Diuretic	274±128	179±85	83–346
Lipid Regulators	292±108	173±42	7–175
Psychiatric Drugs	552±96	538±73	9–440
Receptor Antagonists	114±43	71±31	4–104

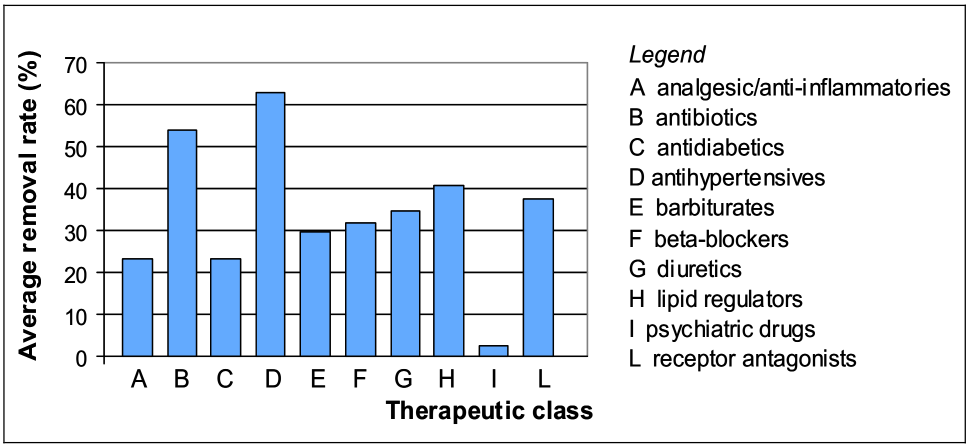

Figure 1 Average removal rates of the different therapeutic classes

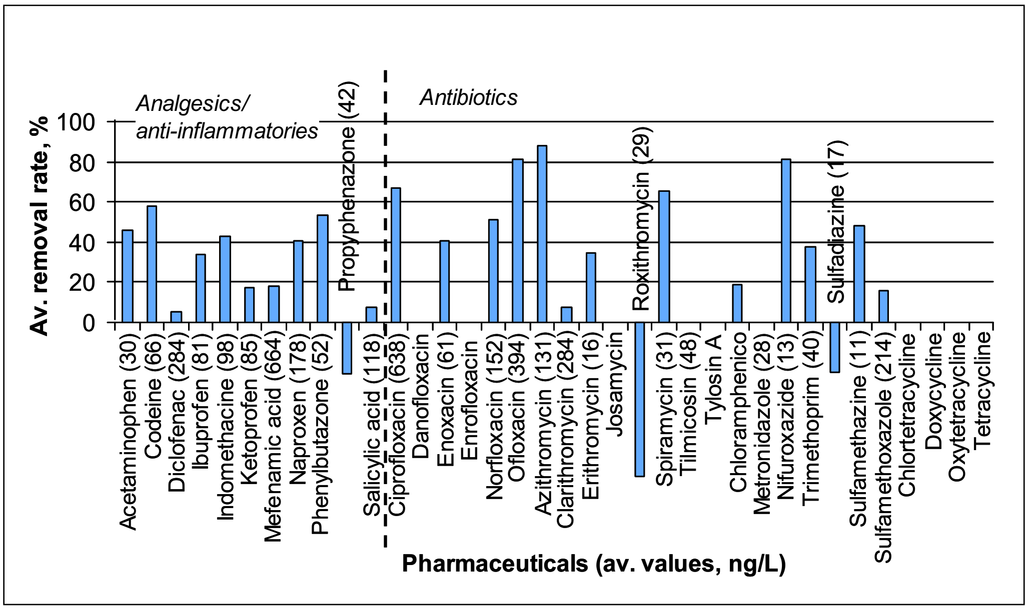

Figure 2 Average removal rates of analgesics and antibiotics together with, in brackets, the observed average influent values.

CONCLUSIONS

An investigation was carried out on an H-SSF constructed wetland, functioning as a polishing treatment treating secondary urban effluent, with the aim of analysing it ability to remove 73 commonly administered PhCs belonging to different therapeutic classes from a secondary urban effluent.

The constructed wetland showed different removal rates for the investigated therapeutic classes (from 1% for psychiatric drugs to 26% for anti-hypertensives, on average 16%, with an SD of 7), thereby suggesting that some pharmaceutical residues can be dealt with by this kind of tertiary treatment.

Experimental data also confirm the complex behaviour of these persistent compounds during a polishing treatment by a constructed wetland.

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CONSTRUCTED WETLANDS HELP CHINA WITH RURAL SEWAGE TREATMENT

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In the past few years, great changes have taken place in the infrastructures and living condition in China's rural area. However what should draw our attention is that the water pollution and the sanitary condition in the country side trend to be more serious than ever before. By the end of 2010, the annual discharges of rural sewage have exceeded 8 billion ton in China, yet it still kept increasing every year. More than 96 percent of the villages are lack of sewer pipes and wastewater treatment facilities. Untreated rural wastewater discharges randomly into the environment, bring various kinds of contaminants into water body.

There is a huge population in the rural area in China. Most of the people live separately, which lead to the difficulty for sewage collection. The sewage that comes mainly from kitchen, shower, washing and toilet flushing features with small and unstable in flow rate and low concentration of contaminants with vigorous fluctuations. As surveyed, the COD concentration in China's rural area normally varies from 60 to 300 mg/L, with NH_3-N from 3.5 to 40mg/L.

Chinese government started to show concern for rural environmental problems in 1970, but the first investigation was coming from "Chinese agriculture and environment quality report", which was published by Ministry of Agriculture in 1985. Several laws and policies concerning rural environment had been established in the following twenty years. It was till October 2006, the "Ecological Protection Eleventh-Five Year Plan" proposed measures: implementing "Rural Environment Protection Action Plan", carrying out rural environment comprehensive improvement and making sure more than the environment problems in 20 percent of rural areas could be controlled effectively.

In the recent years, many programmes have been established by Chinese central government and provincial government for the rural sewage treatment. A portion of the programmes were listed in Table 1.

Compared with conventional, high energy demanding technologies, constructed wetlands (CWs) are low-cost both in construction and operation, stable performance for organics, nutrients (N, P) and heavy metals removal, easy-operated maintenance, as well as its aesthetic values. It is obvious that CW is the most popular technology applied in the existing rural sewage treatment in China. There are four types of CWs applied in the decentralized sewage treatment in the country side of China: free water surface system (FWS CWs), horizontal subsurface slow system (HSSF CWs), vertical flow constructed wetland (VF CWs), hybrid CWs, among which the hybrid CW is the most used for the systems treating the sewage of more than 1000 PE.

Table 1 New rural environment protection infrastructures projects in recent years

Province	Title of the Programme	Starting time	Number of villages involved	Mainly sewage treatment technologies applied
Beijing	Changping new countryside rural wastewater treatment project	2008	286	BF, CW, BCO
Tianjin	Yuqiao reservoir rural wastewater treatment project	2010		CW
Hebei	Yushugou decentralized rural wastewater treatment project	2011		
Shanghai	Pudong New Area rural wastewater treatment project	2008	2149	
Jiangsu	Zhenjiang rural wastewater treatment project	2008		ST, AT
Zhejiang	Zhenhai rural wastewater treatment project	2009	41	CW
Anhui	Tongling rural wastewater pilot project for central treatment	2010		SP
Anhui	Huainan rural wastewater treatment project	2011	18	
Hubei	New countryside rural wastewater treatment programme	2005		CW
Chongqing	Chongqing rural sewage treatment and solid waste programme	2010	248	CW
Yunnan	Xishan rural wastewater treatment project of Kunming	2011	19	SP
Yunnan	Erhai rural sewage collection and treatment systems of Dali	2011	30	AT
Yunnan	Panlong rural wastewater treatment project of Kunming	2009		CW
Guizhou	Rural xiaokang environment protection plan	2010	85	CW
Sichuan	Suining rural wastewater treatment project	2010	4021	AT, CW
Hainan	Wuzhishan constructed wetlands wastewater treatment project	2009	3	CW

Notes: a) BF-Biological filter, CW-Constructed wetland, BCO-Bio-contacting oxidation, ST-Septic tank, AT-Anaerobic tank, SP-Stabilization pond

IWA International Water Association

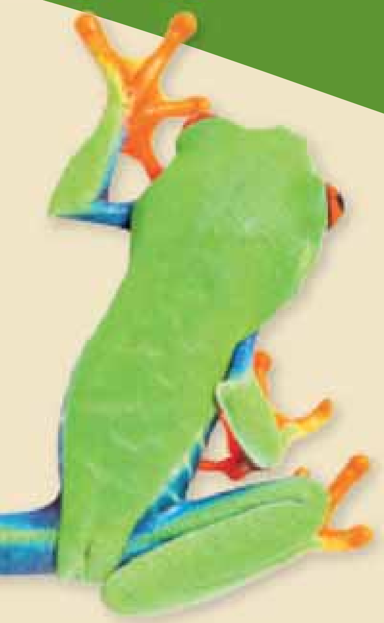
Specialist **Conferences**

First Announcement and
Call for Abstracts

13th International Conference

Wetland Systems for Water Pollution Control

25-29 November 2012



The biennial meeting of the IWA Specialist Group on the Use of Macrophytes in Water Pollution Control

Hosted and Organised by Murdoch University Perth, Western Australia
in collaboration with IWA and AWA

Murdoch UNIVERSITY

Supported by

AWA australian water association

PERTH CONVENTION BUREAU

The Organisers

The Environmental Technology Centre (ETC) at Murdoch University is the lead organiser behind this conference.

Background and purpose

The use of constructed wetlands in water pollution control has been a matter of considerable interest and research from the early eighties. While most of the work has focused on the use of wetlands as polishing systems and on removal of nutrients, metals and pathogens, research has also revealed their application for primary wastewater treatment ("French systems") and sludge stabilisation.

Reuse of wastewater and stormwater for non-potable purposes has become necessary due to increasing demand on high quality water. Wetlands have proven to reliably achieve efficient treatment processes, satisfying non-potable reuse requirements. This is of extreme importance in the Australian context, where most of the water is used in agriculture. Besides, population pressure and declining rainfall patterns in some areas have led to degradation of natural wetlands and groundwater dependent ecosystems.

Treatment wetlands are now a well established technology. There are several thousand wetland systems treating municipal, agricultural and industrial wastewaters in North America and Europe and a rising number of systems treating point source and non-point source pollution globally. These wetland systems have a wide variety of engineering designs, wetted areas, flow rates, influent and effluent quality, hydraulic properties and monitoring requirements. The information from this operational treatment experience can be used to form design guidelines for wetland systems. Further research is necessary in areas of system longevity, pollutant removal process dynamics and system modelling.

The major aim of the Conference is to bring together researchers and professionals to discuss new developments and exchange experiences in the field of constructed wetland systems. The Conference will highlight the latest improvements and achievements in the treatment of urban stormwater runoff, domestic and municipal wastewaters, agricultural and industrial effluents.

The success of several IWA Conferences organised by the ETC demonstrates our capacity to organise the 13th International Conference on Wetlands Systems for Water Pollution Control. We have long been encouraging and disseminating research on treatment wetlands. Murdoch organised an International Workshop on Wetland Systems for Wastewater Treatment in 1996. We have published papers in the field of Constructed Wetlands, Decentralised Systems and Environmental Technologies.

Conference date

Considering the date of previous conferences in the series, and in the hope of ensuring that participants have a pleasant stay, we have chosen the week from 25-29 November 2012. This period is a non-teaching time at the University and all the facilities of the University will be available. Weather-wise November is an excellent period to organise a conference, as the weather is generally consistently warm and pleasant.

Conference venue

The Conference will take place at Murdoch University. There are modern lecture theatres available at the University. The Environmental Technology Centre will display sustainable technologies at their location on the University campus. The participants of the conference will have the privilege to visit the centre.

Conference language

The official language of the conference will be English. There will be oral and poster presentations, with pre-printed abstracts of conference papers.

Technical Tours

A technical tour is proposed for the Tuesday 27 November 2012. The tour is an integral part of the conference. The tour will include the following wetlands systems: CSBP Ltd. Kwinana – Industrial effluent; Point Fraser (CBD) – Stormwater treatment, Wharf + Liege Street (Cannington) – Stormwater treatment; Peppermint Grove Library – Stormwater (rainwater use, urine separation) and other wetland facilities in Perth.

An additional pre/post conference tour highlighting natural and constructed wetland systems in the scenic Margaret River Region in South Western WA is also being proposed.

http://www.promaco.com.au/events/wetlandsystems2012.html

Conference Topics

- Process Dynamics
- Management and Control
- Case studies
- Design criteria
- Economics
- Environmental issues and operation policies
- CW Components
- Modelling of wetland treatment processes
- Systems with enhanced/active aeration
- Floating emergent macrophyte wetlands
- Suitability of treatment wetlands for developing countries
- Removal of pharmaceuticals, heavy metals, surfactants and other emerging pollutants
- Stormwater and industrial wastewater treatment
- Mine water treatment
- Combined algal systems
- Wetland and waterway restoration
- Non point source pollution control
- Limitations and lessons to be learned

Conference Planning Schedule

Our organisation schedule is as follows:

First Announcement and Call for Abstracts	**July 2011**
Deadline for Abstracts	**May 2012**
Date for notifying successful authors	**June 2012**
Date for full written papers to be received	**Sept 2012**
Web Hot Registration Fee Before	**31 Jul 2012**
Early Registration Fee Before	**30 Sept 2012**
Conference takes place	**Nov 2012**

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Registration Fees

Web Hot Registration Fee (before 31 July 2012)	
Au$800	IWA Members
Au$900	IWA Non Members
Au$500	Students/Retired
Early Registration Fee (before 30 September 2012)	
Au$900	IWA Members
Au$1,000	IWA Non Members
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Regular Registration Fee	
Au$1,100	IWA Members
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Keynote speakers

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MESSAGE FROM IWA

IWA Membership

Thank you for renewing!

Thank you to the many members that have already renewed their membership for 2012!

If you also wish to renew now and make sure you do not miss out on IWA information, updates and benefits, you may do it online: https://www.portlandpress.com/iwa/membership/ind/default.cfm.

Corporate members can renew your membership online https://www.portlandpress.com/iwa/membership/corp/default.cfm or by contacting our Member Relations Officer: Roselyn Chang at roselyn.chang@iwahq.org

A membership renewal invoice, for both individual and corporate members, has also been sent out. For any questions about your membership renewal do not hesitate to contact IWA membership team.

Are you not an IWA member yet? It is not too late!
If you are not a member of IWA and would like to benefit from a range of opportunities to connect with water professionals from around the world and participate in IWA's programmes and related events now is the time to join! New Members who join for 2012 between October and December will receive the last three months of 2011 for free!

For more information please visit IWA website: www.iwahq.org or email membership at members@iwahq.org.

IWA World Water Congress and Exhibition, September 2012, Busan Korea: plan now to attend the conference

The IWA World Water Congress and Exhibition is a high-profile international event that attracts 5,000 water professionals, companies and institutions from across the globe. It is the only truly global event of its kind and covers every aspect of the water cycle. The event presents global best practice, innovative research and policy developments in the global water sector and provides direction and solutions to challenges faced by water professionals worldwide. It also engages with the dynamics of the water sector and its interfaces, including urbanisation, climate change and energy.

The key themes and topics that will be discussed are the following:

- Science and application of water management
- Water, climate and energy
- Cities of the future
- Managing utilities and their assets
- Securing new and traditional water resources for the future
- Water, ecosystems and catchments
- Water and health

Call for papers: closed.
Submission of full papers: 31 May 2012
Website: www.iwa2012busan.org

As a city, Busan, Korea, rivals the cities that the IWA World Water Congress & Exhibition has previously been held in: Montreal, Vienna, Beijing, Marrakech, Melbourne, Berlin and Paris.

Busan, a busy beachside metropolis, is less than three hours from Seoul Station and packed with attractions. It boasts amazing seaside cliffs; seven white sandy beaches; lighthouses; inspiring heritage and historical sites and temples; vibrant nightlife; a massive shopping district; art galleries and museums; fine beachside restaurants, bars and cafes; and festivals.

It is served by luxurious hotels, and an extensive ferry, subway and rail system for transport. Join 5,000 water professionals from across the globe for this inspiring and influential congress, set in a perfect place.

There is a full programme of business networking and social events and tours. The gala dinner—highlight of the congress—usually attended by about 2000 people, will completely round out your congress experience.

For more information please visit the congress website at www.iwa2012busan.org.

New from IWA – the IWA Water Wiki!

Invitation to Participate

www.iwawaterwiki.org

The **WaterWiki** is a website providing a place for the water community to interact, share knowledge and disseminate information online.

Since the site was launched, we have been working with IWA Specialist Groups, offering them the opportunity to set up their own group work spaces on the WaterWiki – we now have over **20** Groups using the site to communicate and network online.

Want to get involved? We would like to invite members of **The Use of Macrophytes in Water Pollution Control** Specialist Group to access their own dedicated private Group Space on the Wiki.

WaterWiki Group Spaces – Why participate?

Working in a Group Space on the WaterWiki is excellent way to share information within your group. You can:

- Include contact details of key members in the group
- Upload PDFS, Word documents, presentations etc.
- Circulate minutes from meetings, events, conferences etc.
- Plan up coming events and webinars
- Discuss research developments and group activities

With your own private group space on the Wiki, members can add, remove, or edit content at anytime – and we have a dedicated support team on hand to answer any technical queries.

If you are a member of the **The Use of Macrophytes in Water Pollution Control** IWA Specialist Group and would like more information on how to make the most out of your dedicated group space, please contact Chloe Parker (cparker@iwap.co.uk).

New Contributions

Feel free to use the wiki as your online reference point for all things water-related! Some of the material that may be of interest to you can be found here:

The New IWA Benchmarking Framework, Water Pollution, The Role of Water Policy Entrepreneurs in Adaptation to Change in the Water Sector, Monitoring of Micropollutants, etc.

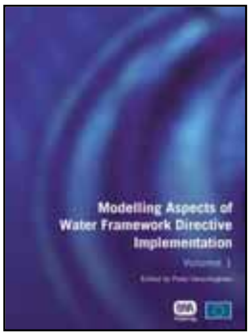
We are always looking to add new material to the WaterWiki in your subject area. If you are able to write on any of the above subjects (about 600-1000 words), please do submit an article.

To see how other IWA Specialist Groups have been using the wiki, visit the Specialist Groups home page.

Chloe Parker
IWA WaterWiki Community Manager
cparker@iwap.co.uk

NEW FROM IWA PUBLISHING

Water Framework Directive Series Set



Peter A Vanrolleghem, Fred Hattermann and Zbigniew W Kundzewicz

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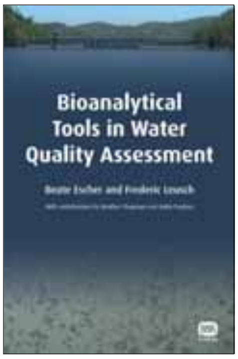
Bioanalytical Tools in Water Quality Assessment



Beate Escher and Frederic Leusch

ISBN: 9781843393689 • December 2011 • 272 pages • Paperback
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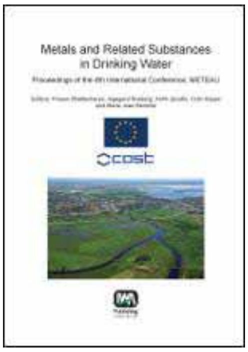
Bioanalytical Tools in Water Quality Assessment reviews the application of bioanalytical tools for assessment of water quality including surveillance monitoring. The types of water included range from wastewater to drinking water, including recycled water, as well as treatment processes and advanced water treatment. Bioanalytical Tools in Water Quality Assessment not only demonstrates applications but also fills in the background knowledge in toxicology/ecotoxicology needed to appreciate these applications. Each chapter summarises fundamental material in a targeted way so that information can be applied to better understand the use of bioanalytical tools in water quality assessment.

Metals and Related Substances in Drinking Water - *Proceedings of the 4th International Conference, METEAU*



Prosun Bhattacharya, Ingegerd Rosborg, Arifin Sandhi, Colin Hayes, and Maria Joao Benoliel
ISBN: 9781780400358 • November 2011• 292 pages • Paperback
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A comprehensive resource on contaminated sediments, this book opens with discussions of the contamination of sediments resulting from discharge of pollutants, excessive nutrients, and other hazardous substances from anthropogenic activities. It examines impacts observed as a result of these discharges, including the presence of hazardous materials and the phenomenon of eutrophication, and elucidates the remediation techniques developed to restore the health of sediments and how to evaluate the remediation technologies using indicators. The text highlights the problems inherent when dealing with contaminated sediments in rivers, lakes, and estuaries and includes numerous case studies that illustrate key concepts.

Cause and Prevention of Clogging of Wells Abstracting Groundwater from Unconsolidated Aquifers

C.G.E.M. (Kees) van Beek

ISBN: 9781780400242 • October 2011•192 pages • Paperback
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This title belongs to **[KWR Watercycle Research Institute Series]**

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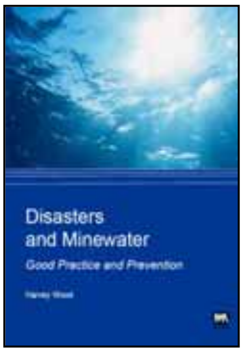
Groundwater serves many purposes. It is a source of public and private drinking water, it is utilized as an industrial feedstock and it is used in agriculture for irrigation and cattle watering. The abstraction of groundwater also serves many civil engineering purposes such as structures, construction pit dewatering and remediation of polluted groundwater. Furthermore, groundwater is increasingly used for supply and storage of energy for the cooling and heating of buildings.

Many wells abstracting groundwater suffer from impaired performance as a result of clogging by mechanical or biogeochemical processes. This represents a significant economic loss due to volume reductions, cost of well rehabilitations or construction of new wells. **Cause and Prevention of Clogging of Wells Abstracting Groundwater from Unconsolidated Aquifers** provides a comprehensive description of the various causes and processes associated with well clogging in addition to describing methodologies for diagnosis and prevention.

Disasters and Minewater- *Good Practice and Prevention*



Harvey Wood

ISBN: 9781780400068 • January 2012• 160 pages • Hardback
IWA members price: £ 59.25 / US$ 106.65 / € 79.99

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Disasters and Minewater: Good Practice and Prevention draws together all of the major minewater catastrophes that have occurred over the last half century. It examines incidents to find useful and positive information of great value that could prevent future disasters. Practical experience provides many lessons in respect of the causes of minewater incidents where lack of adhesion to good practice is principally to blame.

SELECTED RESEARCH REPORTS

Concentration Dynamics of Fecal Indicators in Hawaiian Coastal and Inland Sand, Soil, and Water during Rainfall Events
WERF Report PATH6R09
Authors: Tao Yan
Publication Date: June 2011 • ISBN: 9781843395492
Pages: 60
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Diagnostic Tools to Evaluate Impacts of Trace Organic Compounds
WERF Report CEC5R08

Author(s): Jerry Diamond
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