Issue 1, March 2008

NEWSLETTER EU Project Neptune

Sponsored by the European Commission Sixth Framework Programme Priority

Project coordination
Prof. Dr. Hansruedi Siegrist
Eawag, Switzerland

Contact
Marjoleine Weemaes
marjoleine.weemaes@aquafin.be
Dijkstraat 8
B-2630 Aartselaar
Belgium
Phone: +32 3 450 4537
Fax: +32 3 450 4444

www.eu-neptune.org

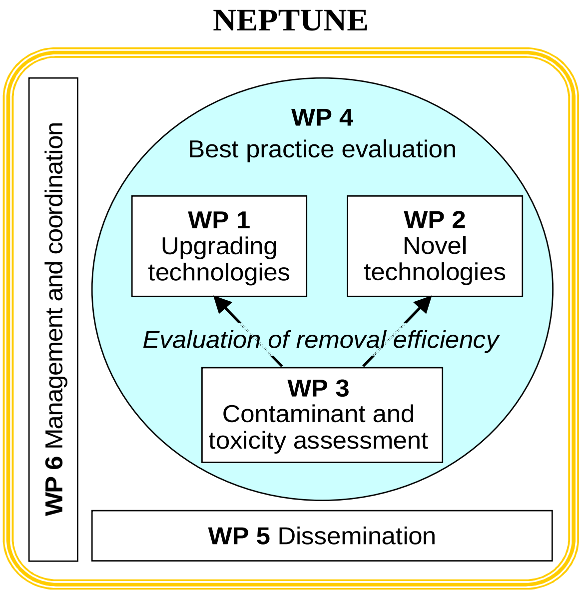
This issue

Foreword from the coordinator, H. Siegrist
Eawag, Switzerland

Dear Reader,

The scope of sewage treatment is changing: today municipal WWTP are seen as end-of-pipe treatment before discharge to avoid eutrophication, toxic effects and hygienic health hazard in surface water. Due to global demographic trends, climate change and new legislations, the future focus is put on resource recycling and on improving quality of products, e.g. reuse of effluent and sludge.

The focus of EU project Neptune is put on removal and recycling of nutrients, micropollutant and ecotoxicity removal, energy optimization and production, sludge inertisation as well as reuse of sludge and of its resources. The structure of Neptune is described in the figure (right). It consists of two technical work packages: WP1 investigates the upgrading of existing technologies, WP2 deals with novel technologies mainly at laboratory scale, WP3 assesses the effluent quality of the processes investigated in WP1 and WP2 while in WP4 these processes are evaluated with Life Cycle Assessment (LCA).



The EU-projects Neptune and Innowatech were the only two projects supported by the EU commission within subtopic II.3.2 “New concepts and processes in wastewater treatment” of the 4th Call in the 6th EU-Framework ,"GLOBAL CHANGE AND ECOSYSTEMS" Area II: Water cycle, including soil related aspects.
Whereas Innowatech concentrates on industrial wastewater Neptune is dealing with municipal wastewater treatment.
Both projects have started in November 2006 and have a good cooperation (combined LCA methodology, project meetings, midterm workshop and enduser conference). To inform stakeholders and partners from both projects about the project results of the first 18 months, a combined workshop will be organized on Tuesday, 6th May 2008 at Eawag, Dübendorf, Switzerland, where you are warmly welcome (see next page).

Hansruedi Siegrist, EAWAG, Switzerland
Hansruedi.Siegrist@eawag.ch

Workshop on priority compounds and water reuse

The sixth IWA specialist conference on wastewater reclamation and re-use was held in ocotober 2007 in Antwerp. Neptune organized a dedicated workshop on priority compounds and water re-use. The workshop was led by **Adriano Joss** (EAWAG) and **Thomas Ternes** (BfG). **Marie-Laure Janex-Habibi** (Suez-Environment France)) and **Harald Mückter** (Ludwig-Maximilans University, Germany) were invited as guest speakers.
The workshop resulted in the following conclusions:
Organic micropollutants found in the aquatic environment as well as in drinking water are currently being intensively discussed. Some environmental impacts have been documented (e.g. endocrine disruption, specific organ damage, interference with neural signaling) but a comprehensive understanding of the relevance of this heterogeneous compound group is currently missing. In drinking water no evidence for a direct relevance to human health has been found but their presence clearly represents a challenge to customer trust. Advanced micropollutant removal is feasible by implementing ozonation or activated carbon filtration as post treatment in centralized wastewater treatment with acceptable additional costs estimated between 5 - 30 € per person and year. Since in urbanized areas, wastewater represents a significant amount of the total fresh water resources, the estimated cost/benefit ratio may justify applying advanced treatment based on the precautionary principle. While this measure may be implemented quite fast at sensitive locations, it must be complemented by source control measures on longer term. For compounds being disposed with water we propose basing registration and use restriction on environmental aspects (persistency, bioaccumulation and toxicity) as well as on removability with standard advanced treatment processes applicable in wastewater and drinking water treatment. Compound and product labeling as well as treatment at the source (e.g. hospital wastewater) are seen as further important complementing measures.

Authors: A. Joss, N. Miladinovic, EAWAG, Switzerland
Adriano.Joss@eawag.ch

Invitation to end user workshop in Zürich, 6 May 2008

As the result of the cooperation between project Neptune with EU Project Innowatech, a midterm workshop will be organized on 6 May 2008 in Dübendorf, Zurich.

The morning session of the workshop will cover the topics dealing with industrial wastewater treatment, which are part of the project Innowatech:

- Aerobic granulation (WP1)
- Coupling advanced oxidation processes with biological treatment (WP2)
- Membrane based intensification of wastewater treatment processes (WP3)
- Tailor made solutions for end-users (WP4)

The following topics, all covering the area of domestic wastewater treatment, will be presented in the afternoon as part of the Neptune section:

- Introduction to EU project Neptune
- Up-scaling of supernatant treatment with nitritation anammox process (WP1)
- Full scale ozonation in Regensdorf: Operation experience and Micropollutants removal (WP1)
- Fuel cells: electricity from wastewater (WP2)
- Biopolymers from sewage sludge (WP2)
- Micropollutants: selection and fate to assess advanced processes (WP3)
- LCA overview: a tool to evaluate processes (WP4)

The invitations with detailed program will be sent to Neptune stakeholders. All others, interested in the mentioned topics please contact the Neptune coordination team (*Natalija.Miladinovic@eawag.ch*).

Sustainable treatment of municipal wastewater: Neptune uses LCA for performance ranking (WP4)

Reducing environmental problems related to wastewater effluents require resources in terms of energy, chemicals, infrastructure, installations for wastewater treatment, thus, involves advantages as well as disadvantages to the environment and society. But how does one chose among different waste water treatments? Which ones are most beneficial in a holistic perspective? Here, the life cycle assessment (LCA) approach as a decision supporting tool may help because its goal is to allow quantification and direct comparison of characteristics as diverse as energy consumption, CO_2-emission, toxicity impacts, nutrient enrichment and consumption of various resources.

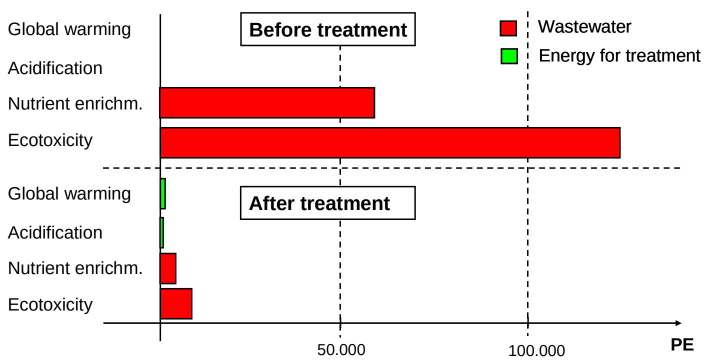
Deciding upon advanced wastewater treatment options implicitly means weighing various aspects against each other (e.g. energy consumption, by-product formation, process chemicals requirements, feasibility of water and sludge reuse). LCA explicitly quantifies the positive and negative value of each aspect in a standardized unit, allowing their direct comparison.

Very essential focus points of the EU Water Framework Directive and the EU Bathing Water Directive are micropollutants with relatively newly discovered impacts (like endocrine disruption) and pathogens, respectively. These elements have hitherto not been included in LCA. However, including these aspects is actually one of the goals of the NEPTUNE project.

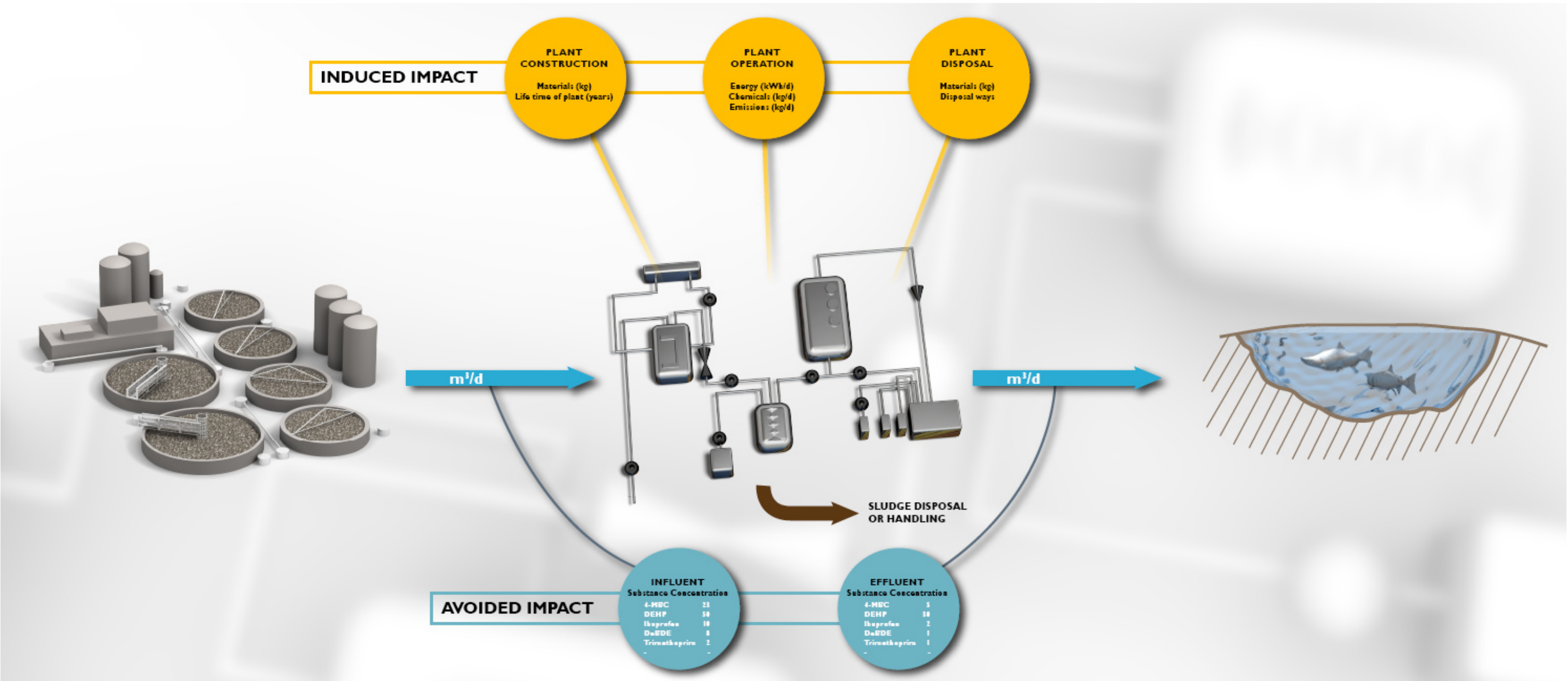
The main goal of the sustainable approach in NEPTUNE is to carry out a holistic environmental performance ranking (optimisation) of different waste water treatment technologies (WWTTs). These WWTTs include end-of-line technologies involving, i.e. membrane bioreactors, sand filters, ozonation, wetlands, activated carbon, supernatant treatment and for sludge handling: disintegration, inertisation and separate treatment of primary and secondary sludge. The objective is to assess post-treatment of municipal wastewaters to remove focus micropollutants and pathogens. Furthermore, use of in-line sensors and maybe microbial fuel cells focusing on nutrient removal (and energy production) are included.

The performance ranking is based on comparative LCAs, i.e. induced impacts as compared to avoided impacts, see figure below. In this way it becomes possible to assess whether or not more environmental impact is induced by introducing the "new" WWTT than avoided by the resulting cleaning of the water.

LCA impact profile before and after treatment at a municipal waste water treatment plan



Author: H.F. Larsen, DTU, Denmark
hfl@ipl.dtu.dk



Neptune FP6 Project

NEWSLETTER EU Project Neptune

Going full scale with autotrophic deammonification (WP1)

Partial nitritation and autotrophic anoxic ammonium oxidation in a single stage sequencing batch reactor is suitable for the N-removal of ammonium rich digester liquid: the start-up of two full scale plants (1400 and 300 m^3 reactor volume) on municipal wastewater treatment plants confirm the process as simple and robust (see also Wett, 2003). In a single reactor one part of the ammonium is oxidized with oxygen to nitrite (partial nitritation) and the remaining ammonium is oxidized with this nitrite to molecular nitrogen. Key control parameters are:

a) oxygen concentration being kept ≤0.7 mgO_2/L,

b) accumulation of NH_4^+ and NO_2^- and depletion of NH_4^+ is to be avoided by regular supervision

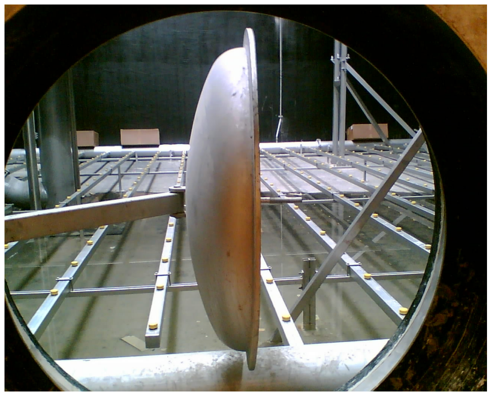
c) to prevent accumulation of nitrite oxidizing bacteria.

Stable long-term operation has been achieved at a net activity of 350 g NH_4^+ removed $m^3_{reactor}/d$, but short term experiments (one month duration) indicate that doubling this activity is feasible.

Compared to the alternative process (aerobic oxidation of ammonia followed

by heterotrophic denitrification with an organic substrate, mostly methanol) this process sticks out as significantly more efficient: this process requires less primary energy (2.2 kg methanol/kg NH_4^+-$N_{removed}$ corresponding to 12 $kWh_{primary}/kgN_{removed}$) and less electrical energy for the aeration (1.5 $kWh_{electrical}$ /kg $N_{removed}$). With stable operation now being demonstrated on several full scale locations, and the key control parameters being identified, it is expected that the last hurdle impeding wide application has now been taken.

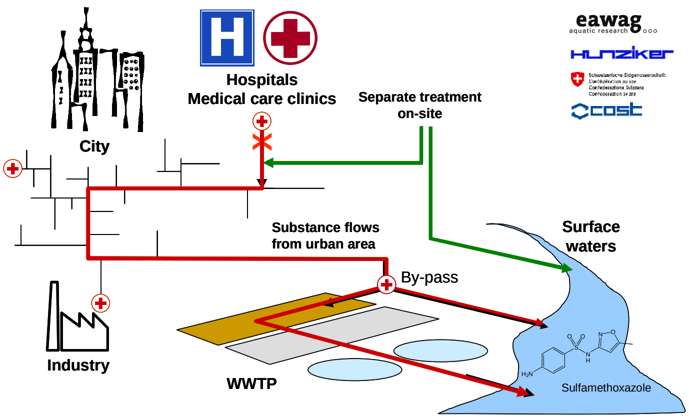
Offering the possibility of energy efficient N-removal from ammonia rich wastewater, this process has an important influence on the feasibility and profitability of anaerobic treatment (generating biogas) for a wide variety of highly loaded wastewaters. For the case of centralized municipal wastewater treatment, it allows extending the hydraulic retention time in the primary clarifier to 2-3 hours to remove more primary sludge, resulting in improved biogas production at the same nitrogen removal level (Siegrist et al., 2007).



Authors: D. Salzgeber, J. Eugster, K. Rottermann, A. Joss, H. Siegrist
Eawag, Switzerland
David.Salzgeber@eawag.ch

Potential of separate treatment of hospital wastewater to reduce pharmaceutical and biocides in urban wastewater (WP1)

Hospitals contribute to a significant extent to the total urban wastewater load of compounds such as X-ray contrast media, cytostatic agents and antibiotics. About 20% of the sold pharmaceuticals in Switzerland are given out in hospitals. The objective of this study is to model the input of pharmaceuticals and biocides from hospitals into surface waters. Input data will be based on statistics about the consumption of pharmaceuticals and biocides in the hospitals, their excretion and transfer rate into wastewater, their fate in the WWTP. For selected compounds the model results will be validated with measurements in Swiss hospitals. The information gained in this study regarding input loads of pharmaceuticals from hospitals will enable the risk assessment of these point sources.



This assessment is required for deciding whether dedicated treatment of hospital effluents (e.g. ozonation or membrane processes) are advantageous for urban water management.

In a medium-size Swiss city we will investigate the feasibility of urine separation installation, separate wastewater treatment and water reuse for toilet flushing in the normal renovation cycle of the hospital and nursing home sanitation.

These activities are in cooperation with projects funded by the Swiss State Secretariat for Education and Research (SER)/COST and the Swiss EPA.

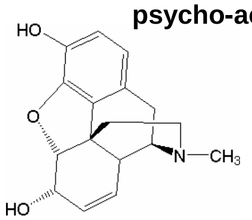
Authors: C.S. McArdell, H. Siegrist, D. Weissbrodt, L. Kovalova, Eawag, Switzerland
R. Moser, Gebrüder Hunziker AG, Winterthur, Switzerland
Christa.McArdell@eawag.ch

Neptune predicts the biological removal of betablockers and psycho-active drugs in wastewater treatment plants (WP3)

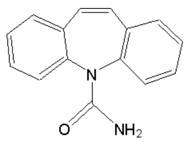
Betablockers and psycho-active drugs such as opium alkaloids, tranquilizers and antidepressants are highly consumed world-wide, either via prescription or as ingredients of illicit drugs (cp. figure with chemical structures). Since an appreciable quantity is excreted unchanged, they are known to be discharged with treated wastewater into rivers and streams after passing wastewater treatment plants (WWTP). Ecotoxicological studies indicate a potential hazard for aquatic ecosystems due to a continuous discharge of these substances.

Neptune´s approach is to quantify and to predict the elimination of betablockers and psycho-active drugs by differentiation of biological degradation and sorption in municipal WWTPs. Hence, the elimination of betablockers and psycho-active drugs was determined in a conventional German WWTP by full-scale measurements along the treatment processes. A WWTP was selected serving 1,350 000 population equivalents (PE) and consists of two activated sludge units including denitrification and nitrification with a sludge retention time (SRT) up to 18 d. In the Neptune study the biological treatment with the elevated SRT of 18 d was the only process which led to a significant removal of certain pharmaceuticals. The elimination efficiency was below 60% for all substances except for the natural opium alkaloids Codeine and Morphine being removed by about 80 and 90%, respectively. Many substances, predominantly from the group of psycho-active drugs, were not reduced at all or by less than 20%.

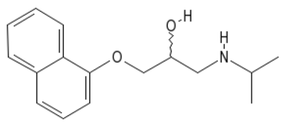
psycho-active drugs | **betablocker**



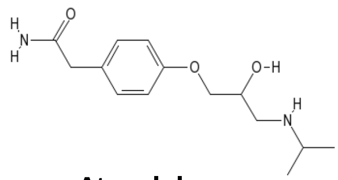
Morphine



Carbamazepine



Propranolol



Atenolol

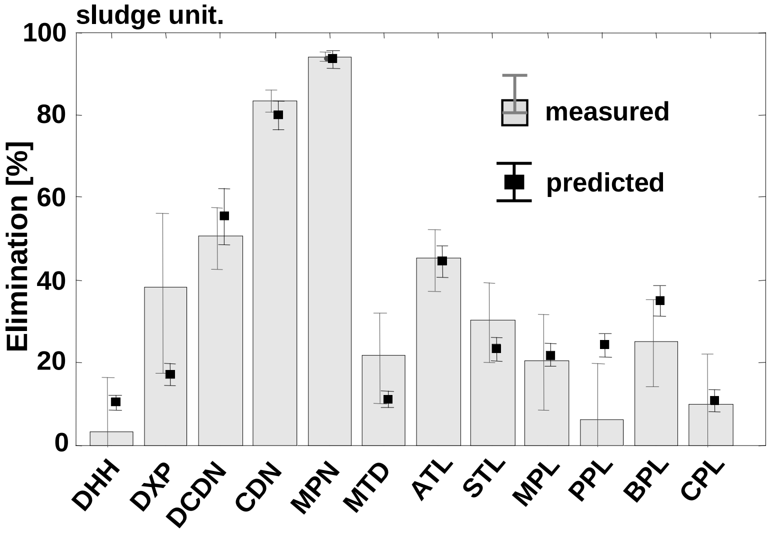
Biodegradation and sorption onto sludge as the main elimination mechanisms were examined in lab-scale batch experiments (cp. picture), in order to predict the removal in WWTPs by modelling. The results of the lab-scale experiments (sludge-water partition coefficients K_d, biological degradation rate constants k_{biol}) were used to predict the elimination of the selected pharmaceuticals in the activated sludge unit (SRT 18 d) using a model considering additionally the reactor configuration and the temperature effect on biodegradation. For most of the target pharmaceuticals the predicted elimination was in good agreement with the elimination measured in the full-scale WWTP (cp. figure).

Thus, the behaviour of the selected betablockers and psycho-active drugs during activated sludge treatment, and probably of many other organic pollutants as already indicated in the former EU project POSEIDON, can be quite well predicted by results from batch experiments. Most of the tested substances could be classified as not or only partly removable. Consequently, conventional biological treatment schemes are an insufficient barrier to prevent a continuous emission of betablockers and psycho-active drugs into the aquatic environment even at high sludge age.

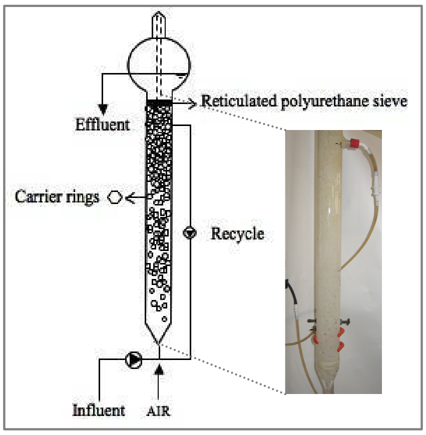
Abbreviations: DHH: 10,11-Dihydro-10,11-dihydroxycarbamazepine, DXP: Doxepin, DCDN: Dihydrocodeine, CDN: Codeine, MPN: Morphine, MTD: Methadone, ATL: Atenolol, STL: Sotalol, MPL: Metoprolol, PPL: Propranolol, BPL: Bisoprolol, CPL: Celiprolol.

Authors: A. Wick and T. A. Ternes
BfG, Germany
Wick@bafg.de

Measured vs. predicted elimination [%] of selected betablockers and psycho-active drugs in an activated sludge unit.



Retro-fitting bioreactor for the removal of EDCs (WP2)

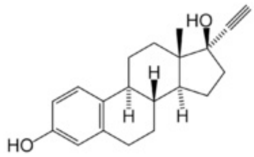


Shortage of resources in the future will probably increase the indirect reuse of treated wastewater for drinking water production. To guarantee safe drinking water supply, advanced treatment for hygienization and removal of the micropollutants still present in effluents is required. Endocrine disrupting compounds (EDCs) are a group of micropollutants, which are known to exert negative effects on the aquatic life, and they are also considered a possible treat for human health because they mimic the hormonal effects.

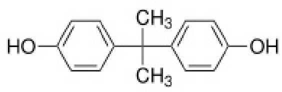
An aerated bioreactor was developed to remove EDCs in a simple and biological way *(Figure)*. More than 96% of the synthetic hormone 17α-ethinylestradiol (EE2), used as the main ingredient in the contraceptive pill, is degraded at initial µg/L levels. At a hydraulic residence time of 8 hours, removal is maintained at 75%. The bioreactor contains a biofilm with highly active bacteria degrading EE2 as a sole substrate. It has been shown that metabolism of EE2 during nitrification is the main removal mechanism during biological treatment of sewage. In this bioreactor, removal of EE2 is maintained even without addition of ammonium. Ammonia-oxidizing bacteria (AOB) are known to remain active for a long time even without the presence of growth substrate.

It has been recently proven that the enzyme responsible for the first step in nitrification (ammonium monooxygenase, AMO) is also capable to attack other EDCs with similar structures as EE2. These EDCs include bisphenol A, used as a plasticizer and widely present in the environment, and nonylphenol, which is a breakdown product of detergents (*Table*).

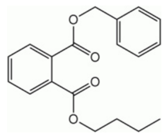
In a retro-fitting approach, such as a fast contact aerated bioreactor with nitrification could be used as a post-treatment step of the secondary effluent of industrial or domestic wastewater treatment plants.



17α-ethinylestradiol

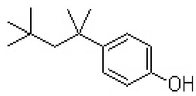


bisphenol A



n-butyl benzyl phthalate

p-nonylphenol



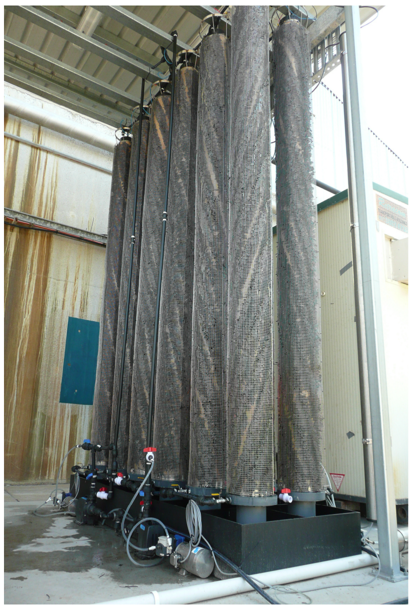
p-tert-octylphenol

Authors: I. Forrez, W. Verstraete, LabMET, Belgium
Ilse.Forrez@UGent.be

Microbial Fuel Cells: electricity generation from sludge hydrolysate (WP2)

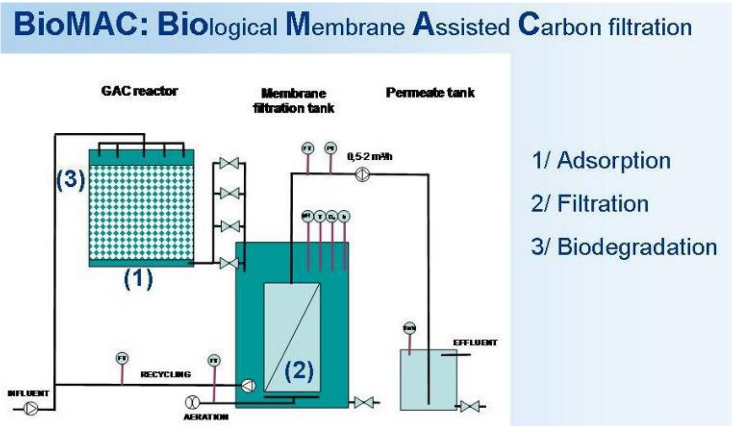
Microbial fuel cells (MFCs) are a novel technology that allows to directly generate electricity from organic and inorganic electron donors, such as organics or sulfides in wastewater. MFCs rely on bacteria to perform the role of catalysts that oxidize the waste constituents using an electrode as electron acceptor. Recent breakthroughs in the microbiology and the technology have led to a rapid emergence of MFCs on the international research scene. More importantly, MFC pilot plants are now being established already as well, and a collaboration between the NEPTUNE partners Advanced Water Management Centre (AWMC), University of Queensland (Australia) and LabMET, Gent University (Belgium) has already lead to a 1m3 plant, which was started up in Sept 2007 (see picture). Full scale applications are therefore conceivable in the coming years.

Within the Neptune project, the AWMC is investigating the possibility to directly generate electricity from a fermented waste activated sludge hydrolysate. Initial testing will determine the MFC performance using a range of major compounds present in this hydrolysate separately and in combinations to assess the utilisation rates and the attainable power. The data from this will be used to optimise the fermentation process to maximise the desirable feed compounds. This optimised fermentation effluent will then be directly applied to MFCs to determine short and long-term performance. The concept can be further expanded to use nitrate as cathodic electron acceptor (instead of air/oxygen), which allows simultaneous nitrogen and carbon removal by the MFC, while still generating useful power. At present, pure compound studies are underway, with results expected by mid 2008.



Authors: J. Keller, K. Rabaey, AWMC, University of Queensland, Australia
j.keller@awmc.uq.edu.au

Advanced treatment of municipal WWTP effluent and membrane concentrates: upscaling of the BioMAC concept (WP1)



Many pollutants passing a biological wastewater treatment step are poorly biodegradable and therefore end up in the receiving surface waters. Furthermore, the presence of pathogens in WWTP effluent involves a threat if the receiving water is used for bathing or recreational purposes. Neptune investigates several potential effluent treatment technologies to minimize the overall discharge of micropollutants and pathogens.

One such treatment process is the BioMAC process. The patented BioMAC (Biological Membrane Assisted Carbon filtration) technology uses a combination of GAC (Granular Activated Carbon) and micro/ultrafiltration for enhanced treatment of WWTP effluent or for the treatment of concentrate streams.

The combination of activated carbon sorption and membrane filtration has been extensively documented in literature. The novelty of the BioMAC however is situated in:

✓the concentration of developed specialist organisms by recirculating the biomass retained by the membranes over the activated carbon, which serves as a carrier material

✓only partial submersion of the activated carbon to increase the activity of the developed biofilm.

The concept has been developed by Aquafin and was tested at laboratory scale at Ghent University (Van Hege *et al.* 2002). Within the framework of the European project Reclaim Water, the BioMAC was scaled up to a 0.5-2.0 m^3h^{-1} pilot plant. The BioMAC pilot was evaluated for the removal of 'classic' compounds (BOD, COD, N, P etc…) and a selection of micropollutants and pathogens . It was found that a number of pollutants could be removed by a high degree, whereas some other compounds were characterised by a medium to low removal. The results are summarized in Table 1.

Within Neptune, the research will be continued and will focuss on the optimisation of the reliablilty, complexity and flexibility for the treatment of WWTP effluent.

Furthermore, the concept will be evaluated for the removal of a new set of micropollutants, complementary to the ones investigated within Reclaim Water.

Authors: W. De Wilde, M. Weemaes
Aquafin nv, Belgium
wouter.dewilde@aquafin.be

Removal efficiency	Basic parameters	Micropollutants
70-100%	BOD, NH_4-N, Fe-sol, Fe-tot, Mn	Anionic detergents, Fe-total, Fe-soluble, Mn, Atrazine, Simazine, Diuron, Total coliforms, Enterococcus
40-70%	COD, KjN, NO_2-N, Org-P	As, Cr, E. Coli, Total germ count
20-40%	COD filtrated, TOC, DOC, SS, Ash content, Org-N, PO_4-P, TP	-
≤ 20%	Dry solids, NO_3-N, TN, Cl, Conductivity, FOG, Hardness, Ca, Mg	Cu, Ni, Zn, $CHBrCl_2$, $CHBr_2Cl$, chloroform

Sponsored by the European Commission Sixth Framework Programme Priority

Project coordination
Prof. Dr. Hansruedi Siegrist
Eawag, Switzerland

Contact
Marjoleine Weemaes
marjoleine.weemaes@aquafin.be
Dijkstraat 8
B-2630 Aartselaar
Belgium
Phone: +32 3 450 4537
Fax: +32 3 450 4444

www.eu-neptune.org

Let us know your opinion!

The goal of this newsletter is to inform our readers of the progress of our project, adressing New Sustainable Concepts and Processes for Optimization and Upgrading Municipal Wastewater and Sludge treatment

Since we appreciate very much your opinion, please send us your feedback, comments and questions!

List of Partners

- **Eawag** Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz, Switzerland
Prof. Dr. Hansruedi Siegrist, Dr. Adriano Joss, Dr. Natalija Miladinovic Hansruedi.Siegrist@eawag.ch; Adriano.Joss@eawag.ch; Natalija.Miladinovic@eawag.ch

- **BfG** Bundesanstalt für Gewässerkunde, Germany
Christine Lachmund, Dr. Thomas Ternes lachmund@bafg.de; ternes@bafg.de

- **LabMET** Laboratory of Microbial Ecology and Technolgy, University of Gent, Belgium
Prof. Dr. Willy Verstraete, Ilse Forrez Willy.Verstraete@UGent.be; ilse.forrez@ugent.be

- **IRSA** Consiglio Nazionale delle Richerche (CNR), Italy
Dr. Giuseppe Mininni, Dr. Giuseppe Mascolo MININNI@IRSA.CNR.IT; giuseppe.mascolo@ba.irsa.cnr.it

- **UniFra** University of Frankfurt, Germany
Prof. Dr. Joerg Oehlmann oehlmann@bio.uni-frankfurt.de

- **DTU** Technical University of Denmark, Denmark
Dr. Michael Hauschild mic@ipl.dtu.dk

- **INCDTIM** National Institute of Research and Development for Isotopic and Molecular Technology, Romania
Dr. Zaharie Moldovan zaha@oc1.itim-cj.ro

- **Aquafin** Aquafin nv, Belgium
Marjoleine Weemaes Marjoleine.weemaes@aquafin.be

- **DPU** Deutsche Projekt Union Ltd., Germany
Sandra Ante, Stephan Ellerhorst Sandra.Ante@grontmij.de; stephan.ellerhorst@grontmij.de

- **IPU** Institute for Product Development, Denmark
Dr. Henrik Fred Larsen hfl@ipu.dk

- **Siluet B** Siluet B, Bulgaria
Dipl. Eng. Plamen Petrov pl_at_petrov@abv.bg;

- **Pyromex** Pyromex PLC, United Kingdom
Peter Jeney mail@pyromex.com

- **Hunziker** Gebrüder Hunziker AG, Switzerland
Ruedi Moser rm@hunzikerwater.ch

- **S::can** SCAN Messtechnik GmbH, Austria
Wolfgang Lettl wlettl@s-can.at

- **CAMBI** CAMBI A/S, Norway
Thomas Seyffarth thomas.seyffarth@cambi.no

- **AnoxKaldnes** AnoxKaldnes, Sweden
Dr. Alan Werker alan.werker@anoxkaldnes.com

- **model*EAU*** Université Laval, Canada
Dr. Leiv Rieger, Prof. Dr. Peter Vanrolleghem leiv.rieger@gci.ulaval.ca; peter.vanrolleghem@gci.ulaval.ca;

- **AWMC** Advanced Wastewater Management, Center, The University of Queenland, Australia
Prof. Dr. Jurg Keller j.keller@uq.edu.au;