modelEAU: modeling, monitoring and control of water quality

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model*EAU* is the research team that is in development around the new Canadian Research Chair on Water Quality Modeling that was granted to Dr. Peter Vanrolleghem on February 1, 2006. This Chair fits within the new water engineering program at Université Laval and is embedded in the Environment and Water section of the civil engineering department (www.gci.ulaval.ca).

The overall objective of the research conducted at model*EAU* is to improve water quality in the following environmental systems (in order of spatial scale): (i) treatment plants (industrial and municipal), both focusing on bioreactors (activated sludge, MBR) and (ii) considering the many aspects of the whole plant, (iii) the urban wastewater system (sewer, treatment plant and urban river) and (iv) river basins (integrated river basin management). With this objective in mind, multifaceted studies are conducted in which models are the central ingredient. The research approach is mainly methodological, looking at experimental data collection, data quality assessment, development of new models and improved modeling approaches, instrumentation-control-automation (ICA), model-based optimization and supporting software for data quality assessment and modeling and simulation. The challenges that are being tackled with these methods in the environmental systems given above are (i) nutrients (nitrogen, phosphorous), (ii) micropollutants (heavy metals, endocrine disruptors) and pathogens, and (iii) energy consumption and greenhouse gas emissions.

model*EAU*'s research strategy is summarized in this three-dimensional diagram with the three axes methods, systems and challenges (see Figure 1). The fact that the methodology is at the front is not without reason: research at model*EAU* is mainly methodological, as it allows transferring these methods from one to the other system or from one to the other challenge.

The group is active within professional organizations such as WEF (Water Environment Federation) with its Québec representative Réseau Environnement, and IWA (International Water Association) with its Canadian affiliate CAWQ. Within IWA, members of the group play an active role in its Strategic Council and in three Task Groups: Leiv Rieger is chairing the Task Group on 'Good Modeling Practice - Guidelines for the use of Activated Sludge Models' (*www.modeleau.org/GMP_TG/*) and Peter Vanrolleghem is vice-chair of the Task Group on 'Benchmarking of Control Systems for Wastewater Treatment Plants' (*www.benchmark-wwtp.org*), and also of the recently initiated Task Group on 'Uncertainty Evaluations in WWTP Design and Operations' (www.iwahq.org/templates/ld_templates/layout_633184.aspx?ObjectId=679607).

model*EAU* is also very active within WEF, more particularly in the Automation and Information Technology Committee and, especially, the Modeling Expert Group of the Americas (MEGA), a sub-committee of WEF's Municipal Wastewater Treatment Design Committee. Among others, the latter organizes the upcoming second Wastewater Treatment Modeling Seminar in Mont-Sainte-Anne, March 28-30, 2010. This is a sequel to the very successful WWTmod2008 held in June last year. The development of vision and the in-depth discussion of the state-of-the-art and the future of modeling at this seminar are reported concisely in *Rieger et al. (2008)*.

The multi-cultural team of, currently, three post-docs and 10 undergraduate and graduate students works on a wide range of NSERC, FQRNT, European Union and industrially funded projects. The following three examples are of investigations being conducted at model*EAU* in relation to wastewater treatment plants.

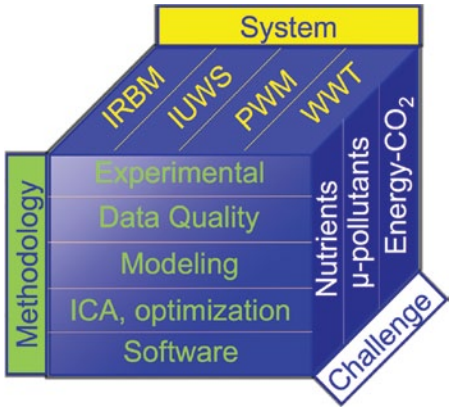

FIGURE 1 modelEAU's research strategy

monEAU measuring station

Huge amounts of data are now created by continuous monitoring of water quality. Therefore, new concepts are needed to guarantee the desired high data quality and to prevent the development of increasingly large data graveyards. Automatic monitoring stations now used in practice suffer from insufficient flexibility and a lack of standardization, i.e., even though most monitoring tasks are the same and robust and powerful platforms could, therefore, be expected to exist already, most current monitoring stations are the result of a case-specific development.

model*EAU* is actively involved in the development of the mon*EAU* concept, a new generation of water quality monitoring stations (see Figure 2). The flexibility of this new concept enables different monitoring tasks as well as different measurement locations (e.g., sewer, treatment plant and river). As the most commonly used data transmission protocols are provided, the user can select the best suited sensor for his application, independent of specific

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monitoring station capabilities. However, the most important step forward is mon*EAU*'s advanced data quality evaluation concept helping to relate the measurements to the processes under evaluation and not to guess about data meaning.

For more information, see *Rieger and Vanrolleghem (2008)* and *Nopens et al. (2007)*.

Fault-tolerant control

To deal with increasing environmental requirements for wastewater treatment, introduction of measuring and control concepts is a cost-saving and environmentally friendlier alternative to the extension of reactor volumes and is an excellent solution to adapt the plant to different loadings and to free already existing, but unused capacities. Real-time control concepts allow the plant to react on diurnal, weekly or seasonal variations and to deal with uncertainties in predicting future loading or changing treatment demands. A drawback is that a controlled plant is often driven to the limits of its capacity and, subsequently, equipment failures (sensors and actuators), unexpected changes in the influent or environmental conditions can cause severe effluent limit violations if unsuitable control concepts are used.

Due to the above, there is a strong need for new tools and new strategies to increase the reliability and fault-tolerance of control systems in wastewater treatment. To deal with these new challenges, model*EAU* is involved in an international and interdisciplinary research effort involving environmental and control engineers, as well as microbiologists and experts in data evaluation methods from Europe and Australia. In the ongoing research project, the available knowledge and experience from different disciplines is collected and translated into engineering practice. The project is the Canadian contribution to the European Union project NEPTUNE (*www.eu-neptune.org*).

More information will be available through our website. Published project results can be found in *Rosen et al. (2008)* and *Vanrolleghem et al. (2008)*.

FIGURE 2 monEAU concept

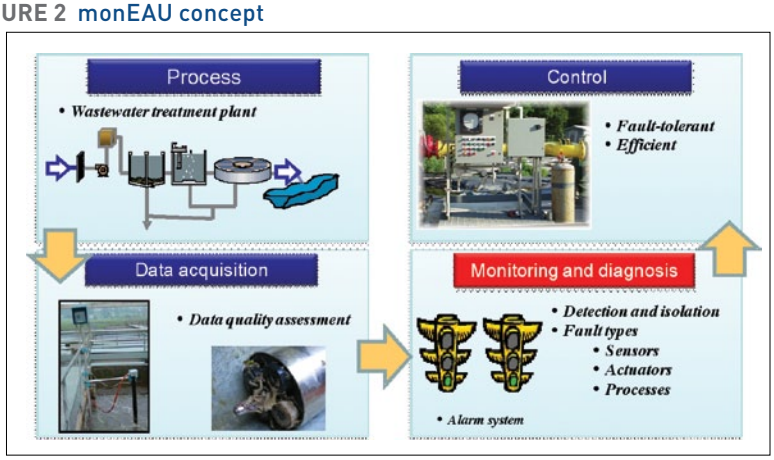
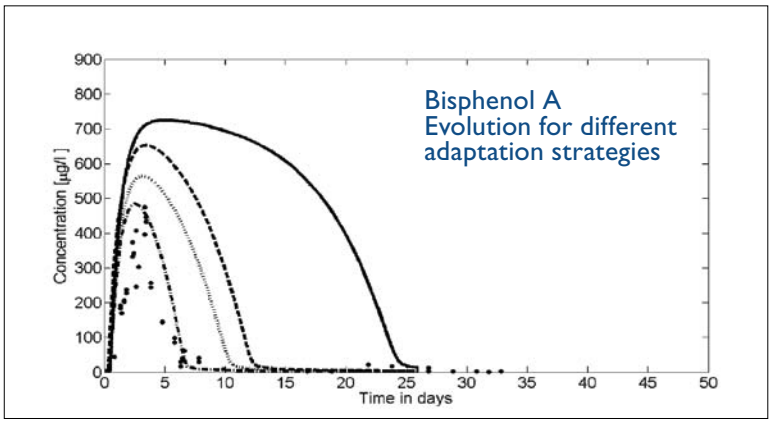


FIGURE 3 Observed and model results



Microconstituent modeling

The influent of WWTPs contains organic microconstituents originating from the chemical, pharmaceutical and hormonal products released by hospitals, industries and households. At the treatment plant, their concentration can be reduced significantly (but not completely) by biological degradation processes next to sorption/desorption and volatilization (e.g., perfumes). In addition, the wastewater contains heavy metals coming, for instance, from residues of galvanized steel (Zn), amalgam (Hg), and the wear and tear of car tires (Pb, Cd). Unfortunately, heavy metals cannot be degraded and are eliminated by adsorption to the waste sludge. Nevertheless, part of all these pollutants is rejected into the receiving waters and this in potentially toxic concentrations.

Various models are available to simulate the behaviour of wastewater treatment plants. However, they have mainly been developed to describe the removal of organic matter (COD, BOD), nitrogen and phosphorus, and, so far, little attention has been devoted to model the fate of such specific compounds. Thus, as its contribution within the EU ScorePP project (www.scorepp.eu), model*EAU* is developing a dynamic model that, at the same time, considers the fate of the microconstituents and of the traditional pollutants (COD, N, P) in wastewater treatment plants of different kinds. The work is based on experimental data sets collected at full-scale regarding, among others, Bisphenol-A and six heavy metals. In Figure 3, model predictions are compared with experimental data to illustrate how different operational strategies aimed at acclimating specialized biomass can limit the time of excessive Bisphenol A effluent concentrations under sudden Bisphenol A load increases.

More information on this microconstituent fate and behaviour modeling work can be found in *Vanrolleghem (2008)* and *Cloutier et al. (2009)*.

Concluding remarks

modelEAU's aim is to carry out methodology-oriented top level research and translate the results into practical applications. Close cooperation with private companies in the water sector guarantees smooth knowledge transfer. If you would like to know more about our projects and partners, please follow

the increasing information content of our newly-designed website (*http://modeleau.fsg.ulaval.ca*) or join one or more of the activities in which we are involved:

- WEF Distance Learning Webcast Series: Modeling 101 – How to use Simulators in the Design and Operation of Wastewater Treatment Facilities: February 25, 2009, *http://www.wef.org/ConferencesTraining/Webcasts/Modeling101/*
- IWA ICA2009, 10th IWA Conference on Instrumentation, Control & Automation: June 14-17, 2009, Cairns, Australia, *http://www.iwa-ica2009.org/*
- IWA Training Course on Modeling Activated Sludge Plants, in conjunction with the 2nd IWA specialized conference on nutrient management in wastewater treatment processes: September 6-9, 2009, Krakow, Poland, *http://www.bnr-iwa2009.pl/*
- Canadian dissemination workshop of the European Union 6th Framework project ScorePP (*www.scorepp.eu*): September 2009, Québec (QC), Canada.
- WEFTEC'09 workshop on Model Training Resources and the Application of a Calibrated Model: October 2009, Orlando (FL), USA
- Canadian dissemination workshop of the European Union 6th Framework project NEPTUNE (www.eu-neptune.org): March 25-26, 2010 in Québec (QC), Canada.
- 2nd IWA/WEF Wastewater Treatment Modeling Seminar: March 28-30, 2010 in Mont-Sainte-Anne (QC), Canada.
- IWA DIPCON2010, 14th International Diffuse Pollution Conference: September 11-17, 2010, in Mont-Sainte-Anne (QC), Canada.
- IWA World Water Congress 2010: September 19-24, 2010 in Montréal (QC), Canada.

model*EAU* is also providing excellence in training students in an international environment and has a special development program for postdoctoral researchers. If you are interested, contact us at:

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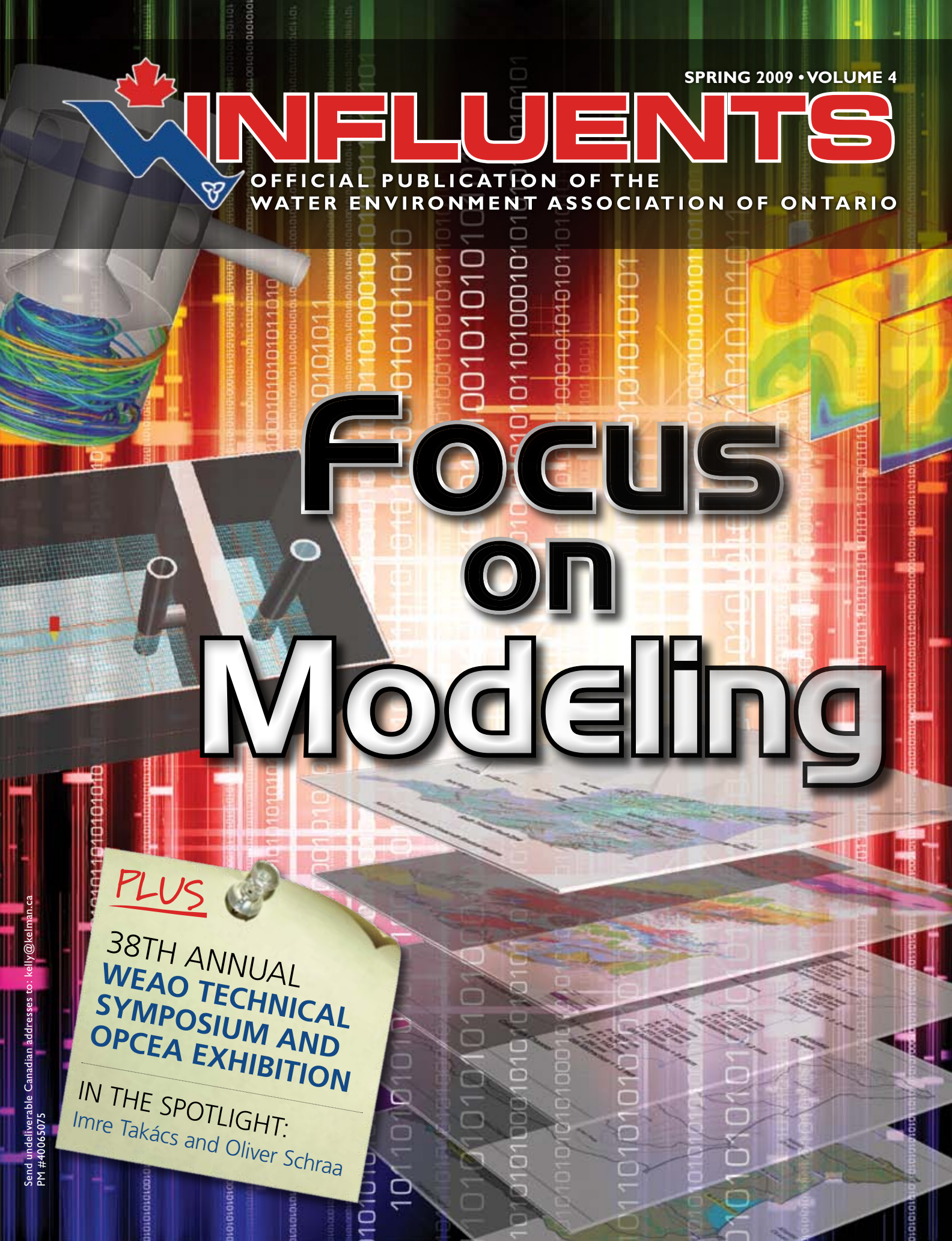

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