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New trends in modeling applied to wastewater treatment and potable water

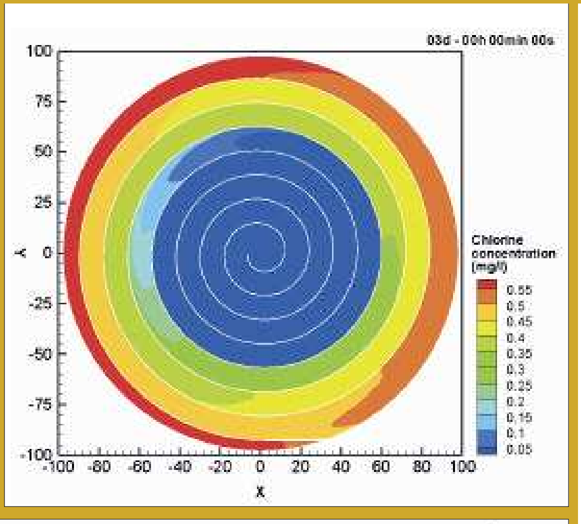
Hydrolink

NEW TRENDS IN MODELING APPLIED TO WASTEWATER TREATMENT AND POTABLE WATER

BY OLIVIER BERTRAND, JULIEN SCHAGUENE, BERNARD MAZAUDOU & PATRICK SAUVAGET

Modern and environmentally developed cities use large sewage network systems to collect and transport all types of wastewater from homes to wastewater treatment facilities. At the treatment plant, different processes are used to remove most of the pollutants from the wastewater. The efficiency of the treatment depends not only on the degree of purification applied to wastewaters, but also on the ability of the facilities to treat the effluent homogeneously and without temporal variations.

Artelia, as an independent engineering, project management and consulting group, operates in nine markets including industry, water, environment and urban development, providing services to private clients (industrial groups, developers, investors, building contractors, etc.) as well as to public clients (government departments, local authorities, international funding agencies, etc.). This article provides a brief overview of Artelia's use of modelling in support of the design of water storage, transfer structures, treatment installations and the development of solutions for decontaminating wastewater.



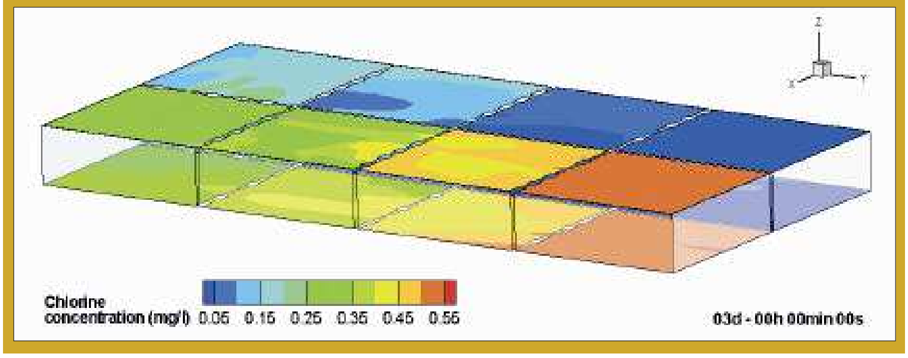


Figure 1. Simulation of water renewal within a circular/rectangular storage mega reservoir

From simple to more complex model

Most of the structures involved in water treatment or storage are large, but their performance is affected by small details in their design (orifices, distribution weirs, baffles, etc.) and is highly sensitive to the definition of the water surface, a few centimeters of water surface variation having significant influence.

This can be illustrated by the following project (Figure 1) the aim of which was to design an alternative back-up system (reservoirs, pumping stations and interconnection with the existing network) in order to secure continuous water supply. This involved a total storage capacity of 17 Mm^3 broken down into 5 storage sites. This system was susceptible to be used in case of sea water pollution or major power shortage for a country where water supply currently relies on desalinated water source plants. Mega Reservoirs structures were designed in order to achieve a 7-Day strategic water stock at any time within the network system. The dimensioning of the reservoirs was one of the main aspects of the project.

This objective was achieved thanks to a 3D non-hydrostatic numerical model with advection-diffusion of a conservative tracer to quantify the renewal time, elaborated on the basis of open source TELEMAC modelling system. The flow was free surface only. Various baffle geometries and positions of orifices were simulated and compared to minimize detention time in the water domain and to avoid recirculation or stagnant areas. Internal baffles were placed in the water storage tanks in order to direct and control the flow of water and to reduce water stagnation.

Interacting physical and numerical models

Physical and numerical modelling approaches are very complementary in the global study of the hydraulic structure of a water treatment plant and for many projects we performed comparison of both tools.

Physical scale models remain an incomparable resource when it comes to the analysis, communication and discussion of most complex development projects. Their experimental and practical nature provides guidance for engineers to understand various phenomena and help them determine high-performance solutions to manage projects in full compliance with specific requirements. They make it easier to explain phenomena by presenting the existing situation and changes to be expected once the project is implemented. Physical

models allow visualization and quantification of flow and solute transport by directly simulating these phenomena.
On the other hand, mathematical models replicate these physical processes through mathematical governing equations, boundary conditions, and initial conditions. Mathematical models and computer simulations are also essential to describe, predict and control the complicated interactions of the processes. The number of reactions and organism species involved in wastewater treatment may be very large. An accurate description of such systems can therefore result in highly complex models, which may not be very useful from an operational point of view. Numerical modelling has the advantage of allowing flexibility in selecting problem parameters, being this way better suited for predicting results under different scenarios.

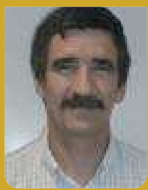
As an example of numerical application, water treatment plants are generally classified by implemented processes. Treatments could be physical (filters, settlers…) and/or chemical (coagulation, biological…). The use of ozone in waste water as chemical treatment is expanding. It is an accepted fact that drinking water is disinfected when a residual of ozone has been maintained for few minutes. The design of ozone generators and treatment chambers can be improved with the use of modeling.

In this application case (Figure 2), a model was set up and used to assess the behaviour of the ozonation tower. The entire tower was represented in the model and ozonated air diffusers positioned at the apron were included in the model. Two-phase modeling thus allowed simulating both the fluid phase and the gas phase. No exchange between the phases was considered. The rise of gas bubbles tended to block the water flow along the upstream walls of each compartment, but the whole mass of water was in contact with the gas phase. The ozonated air transfer to water to be treated was more important for the diffusers positioned upstream of the compartments.

Open source software and a distributed computer environment

With the explosive growth of mesh discretization there is a shift from the use of single desktop computers to using computer clusters. At the same time the use of Open Source software (as OpenFOAM) is gaining

After having obtained general training in fluid mechanics and transfers, *Olivier Bertrand* developed numerous computation codes in such varied fields as crystallogenesis, compression of petroleum fluids, oceanic and river modelling, transport of oil slicks.
As Project Manager/Director, he participates in particular in expert appraisal and complex hydraulic. He provides his experience in hydraulic development and its impact on the environment at different levels, from simple advisory services to design and innovative modelling studies. In particular, he runs and coordinates research and development projects associated with these problems.
In February 2015, he became Leader of the Numerical Hydraulic Modelling team and Project Director in the Maritime business unit.



***Bernard Mazaudou* participated in the development and maintenance of the CAREDAS computer model for simulating unsteady flows in urban sewerage networks, which constitutes the hydraulics module of the CANOE system that has been co-developed since 1992 by Artelia and INSA (engineering college in Lyons, France). He also manages complex hydraulic studies for major water and waste water transmission schemes and pumping facilities, covering both steady and unsteady flow conditions.**
He is currently a project manager for water and wastewater studies within the Water & Solid Waste - International Activities business unit of Artelia Ville & Trans*port.*

Following a general training in fluid mechanics, *Julien Schaguene* has specialised in numerical modelling applied to the mechanics of unconfined surface flows. Julien Schaguene is a hydraulic modelling project manager in the fields of maritime, river and structural engineering. In this framework he is developing particular skills in the implementation of three-dimensional numerical models, notably using the CFD OpenFOAM computation code.

***Patrick Sauvaget* has 36 years of professional experience in the field of numerical modeling applied to the water environment. After obtaining an engineering degree in Hydraulics (INPG, Grenoble, France), he passed a master's thesis in civil and environmental engineering (University of Iowa, USA) and a PhD thesis in fluid mechanics (INPG, Grenoble, France). He is presently head of the Hydraulics department of Artelia Eau & Environnement, Grenoble, France. He acted as project leader or project director of water and environmental studies in various domains: hydraulics and water quality in rivers, coastal hydrodynamics, flood risk management, water resources management, water distribution, etc.**

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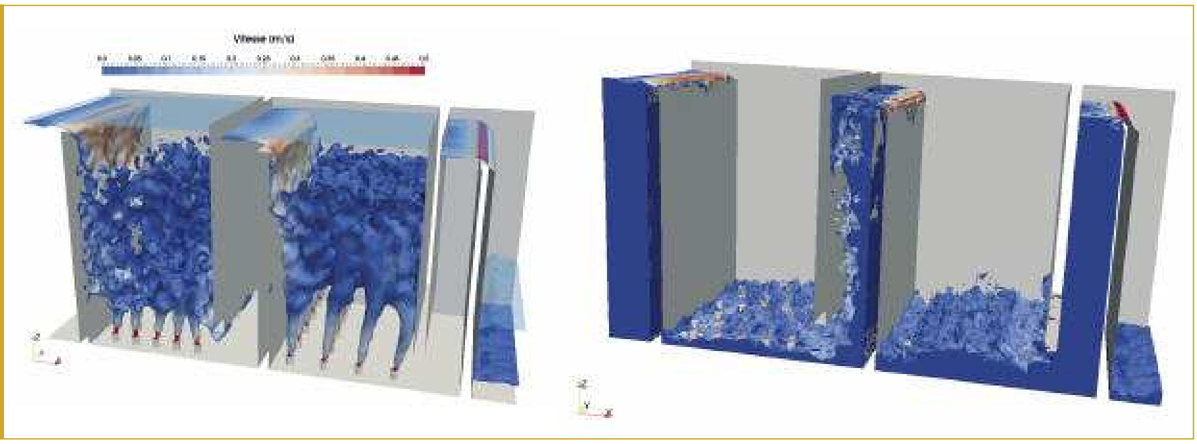
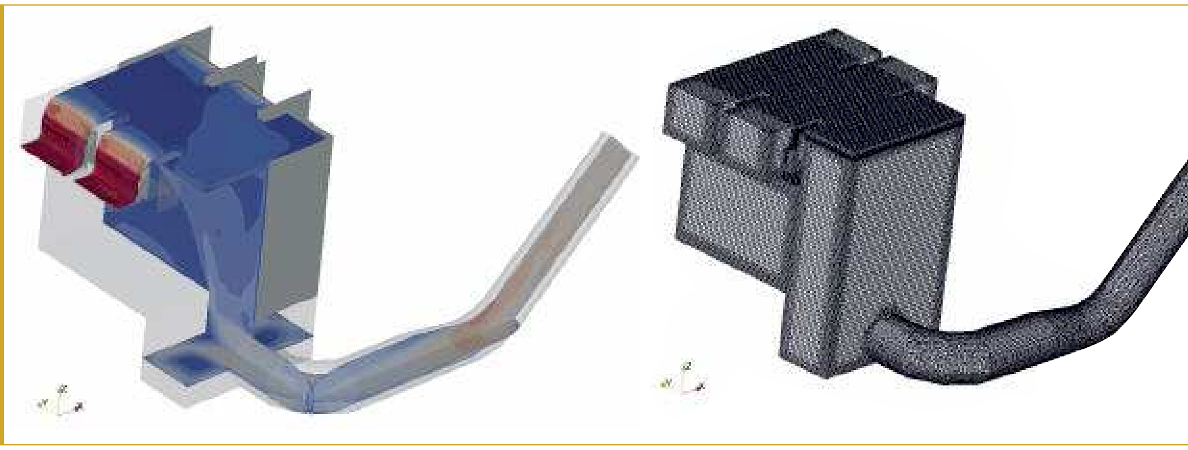


Figure 2. Analysis of the correct mixing in an ozonation tower (left: plume of water/ozonated air (99% water) and free surface; right: water volume out of contact with the ozonated air

Figure 3.
Flow analysis of an upstream distribution chamber



popularity as it provides free access to computer programming codes allowing experienced users to modify equations, to program new processes, or to optimize numerical solvers. These choices allow in the end to build numerical models totally adapted to the engineering problem to be solved.

These computational hardware and software facilities made it possible for instance to study the flow in a distribution chamber with weirs which is used to avoid unequal distribution (Figure 3). This kind of geometry required the computation of a mixed free surface and confined flow. The Volume Of Fluid (VOF) method that was used is simple, but it allows very complex free surface tracking. In this case the mesh (spatial discretization) was refined near the walls, at the free surface and in potentially highly turbulent areas.

For all these studies, expertise on core business and Computational Fluid Dynamics is extremely important, as well as improvements in the speed of scientific computations. They facilitate the use of more complex models, produce better designs by the multiplication of tests, reduce the time of the development phase and at the end the costs of new projects. ■

References

Bertrand O., Lavedrine A., Rebai A., David E., Pierrefeu G., Roumieu P. 2011 – Numerical modelling of the Vaugris reservoir on the Rhône with Telemac 3D. Proceeding of the XVIIIth Telemac & Mascaret User Club, Chatou, France, October 19–21.

Daou, M. P., Blayo, E., Rousseau, A., Bertrand, O., Tayachi, M., Coulet, C., & Goutal, N. 2015. Coupling 3-D Navier Stokes and 1-D Shallow Water. La Houille Blanche, (6), 29-33.

Loisel, P.E., Schaguene J., Bertrand O., Guilbaud C., 2015. Comparative study between numerical and physical hydraulic modelling of flood spillway structures. ICOLD 25th Congress, Stavanger, Norway, June 17-19, 2015.