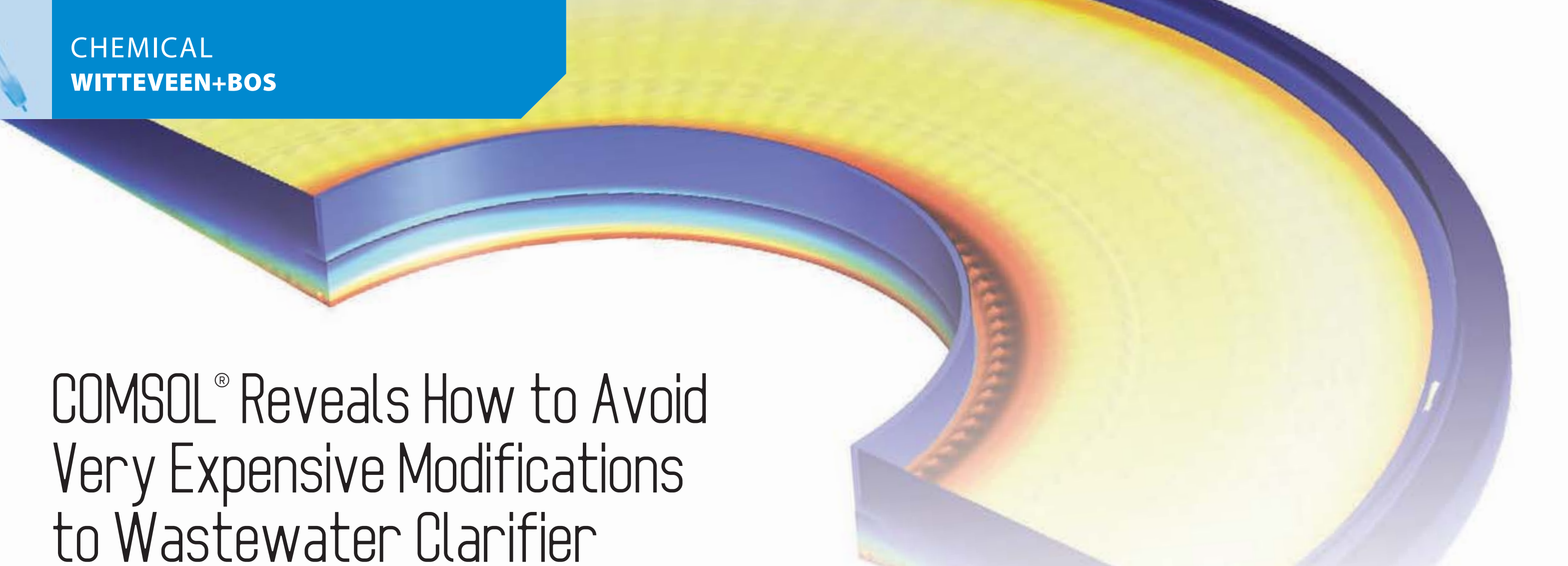

COMSOL® Reveals How to Avoid Very Expensive Modifications to Wastewater Clarifier

A wastewater treatment plant encountered a problem with one of its redesigned clarifier tanks. A group of consulting engineers used COMSOL Multiphysics® and the Mixture Model application mode to determine that there was no need to make physical modifications that could have cost in the range of 1,000,000 in Euros; instead, adding a certain chemical to improve flock (flocculent) formation cost only 100,000 Euros — and thus modeling saved the company 90% of the costs.

BY ARIE C. DE NIET, WITTEVEEN+BOS, DEVENTER, THE NETHERLANDS

In municipal wastewater treatment, clarifiers are a central component. In these large circular tanks (Figure 1), activated sludge that consists of biological microcultures removes nitrogen and phosphorous from the waste; at the end of the treatment process, the activated sludge must be separated before the clear water flows into the environment. The heavier sludge flocs settle to the bottom of the tank where it flows through a return conduit and is removed for reuse (bottom left of Figure 2); the clear water floats over the top at the tank's outer boundaries (upper right of Figure 2). A number of deflector plates promote proper circulation so the sludge has an opportunity to settle to the bottom of the tank and work its way out the return conduit.

Problems Surfaced After Reconstruction

A local wastewater authority in the Netherlands was experiencing trouble with one of its clarifiers after having reconstructed it to divide it into an inner part and an outer part. After reconstruction only the outer part was used for sedimentation. They found that too much sludge was leaving with what should have been clear water at the top, and at the bottom the exiting sludge contained too much water. The water authority struggled for 18 months to find a way to get the outer part working properly. Then, to help them find out what the problem was and how to correct it, they turned to the consulting firm Witteveen+Bos (www.witteveenbos.com). This company, which employs roughly 800 engineers and had sales in 2007 of more than 91 million Euros, offers its clients advice and designs in the areas of water, infrastructure, the environment, spatial development and construction.

Figure 1: The modeled clarifier tank in the wastewater treatment facility. *Photo courtesy of Witteveen+Bos.*

The first step was to model the flow in the clarifier. While many of our mechanical engineers use specialized modeling software, I was looking for a package that could handle the multiple linked physics of this problem. I had encountered COMSOL on the web and read in Dutch magazines targeted at environmental engineers how other water authorities had already used COMSOL for such studies. In a trial, I found that COMSOL was very easy to use, especially for coupling the various physics, the geometry modeling was quite good, and I also found the many example models quite useful.

In particular, the Mixture Model application mode in the Chemical Engineering Module proved invaluable. It can compute the flow for a mixture of two liquids or a liquid and a solid. The predefined physics

"In particular, the Mixture Model application mode in the Chemical Engineering Module proved invaluable."

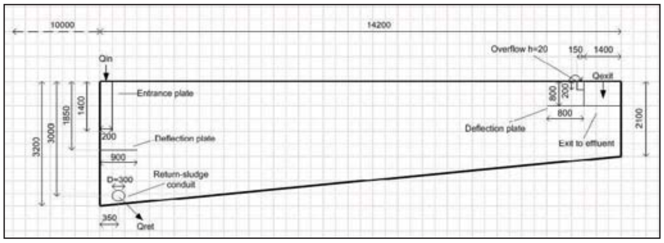

Figure 2: A cross section of a clarifier from the center (left) to the outer ring (right). The wastewater enters at the upper left and exits from the upper right; the sludge collects on the bottom surface and is then pumped from the return-sludge conduit on the lower left.

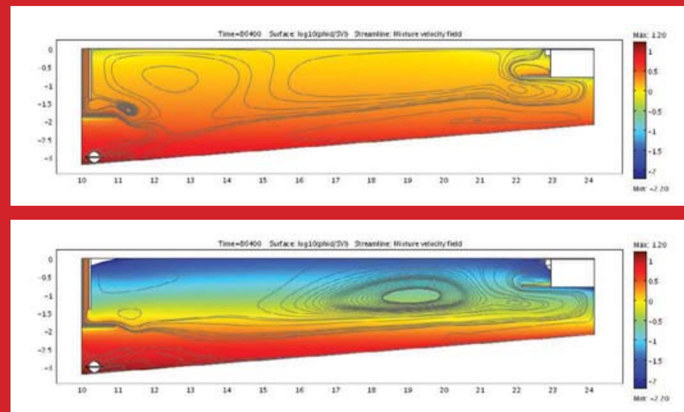

Figure 3: In the original configuration (top), some wastewater can follow a short-circuit route from the input (upper left) to the sludge exit (lower left) without the particles having an opportunity to settle. An additive changed the flock diameter, which eliminated the short-circuit flow and allows the sludge particles to settle (bottom).

setting implements a multiphysics connection between the κ-ε turbulence model for the main flow with equations for the transport of the dispersed phase and the relative velocities of both phases.

When we ran our model of the existing clarifier tank, we noticed that after it reaches equilibrium, the streamlines show a short-circuit flow (Figure 3, top). In other words, part of the incoming flow goes straight to the return sludge conduit at the lower left, and there is no time for the sludge particles to settle. We surmised that the short-circuit flow was caused by the tank's shape. But even though it would likely be very effective to modify the shape or change the position of the return sludge conduit, doing so would be an extremely expensive proposition, costing more than a million euros. Thus, we searched for less expensive ways to change the flow pattern.

Modeling Finds the Cost-Effective Solution

Naturally our thoughts turned to the deflection plates. With the COMSOL model it was easy to study the effects of changing their horizontal and vertical positions as well as their length and slopes. We discovered, though, that there was no significant reduction in the amount of sludge at the water outflow.

Fortunately, we found that two other measures appeared to be effective in the model: an increase of the sludge density or an increase of the flock diameter. With the model, we determined that the most effective choice was the latter. Best of all, there are available means to change the properties of the sludge; flock formation can be altered by adding certain chemicals to the mixture before it enters the clarifier. Better packing of sludge particles in this way results in higher densities, and stimulation of flock growths leads to an increase in the flock diameter. Figure 3 (bottom) shows model results for some new values of sludge density and flock size that we achieved with the proper chemical mix, and note that the flow is more stable and the short-circuit flow has disappeared. The particles have time to settle on the bottom and there is better transport of the sludge particles to the return conduit at the bottom left.

Our client has since implemented the chemistry changes we recommended and found that these measures did solve the problem and the clarifier functions far better than before. And rather than spend perhaps more than a million euros to restore the tank's shape to the previous geometry, they spent only 10% of that for the necessary chemicals to stimulate flock growth and also to replace the pumps in the sludge return conduits. ■

READ THE RESEARCH PAPER AT:
www.comsol.com/papers/5310/

About the Author

Arie de Niet is an advisor on statistics and applied mathematics at Witteveen+Bos consulting engineers in Deventer, the Netherlands, and has been working with COMSOL Multiphysics for almost two years. He studied applied mathematics at the University of Groningen, and his previous employment was at the university developing improved algorithms to solve ocean models. (website: **www.witteveenbos.nl**, email: A.dNiet@witteveenbos.nl, phone: +31 570 69 7307)