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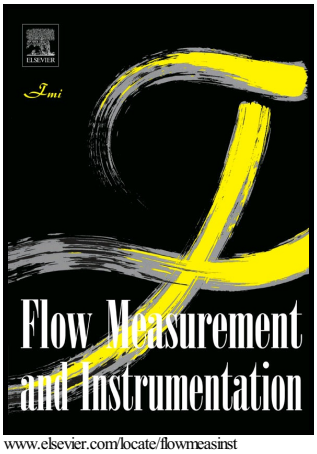


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Flow Measurement and Instrumentation



# Analysis of activated sludge aerated by membrane and monolithic spargers with ultrafast X-ray tomography

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## ABSTRACT

Up to 80 % of the total energy budget of wastewater treatment plants is consumed by the activated sludge process. Current optimizations are mostly based on limited instrumentation for single points of measurement which cannot express the complex hydrodynamic and biochemical processes. Therefore, the ultrafast electron beam X-ray tomography system ROFEX of HZDR is used as a new measurement technique to capture the temporal evolution of the multiphase flow in the opaque active sludge. A detailed study has been carried out in a vertical column of 3.5 m height at HZDR to obtain an improved understanding of the hydrodynamics of aerated sludge and an evaluation of different aerators. The target parameters are bubble size distribution, equivalent Sauter mean diameter of the bubbles, bubble rise velocity and local gas hold-up under the variation of sparger type (rubber, monolithic material), gas flow rate, rheology of the fluid (deionized water, salty water, sludge) and height in the liquid column. Therefore, in-house developed advanced image analysis algorithms were applied to the reconstructed tomographic images, which are also presented in the paper. The experiments showed that with ROFEX reliable measurement data of opaque multiphase flows is produced and is expected to be used in further investigations for the validation of computational fluid dynamics (CFD) models. The different sparger types showed comparable hydrodynamic performance.

**Keywords** Ultrafast X-ray tomography, activated sludge, aeration

## 1 INTRODUCTION

Wastewater treatment plants consume 20 % of the municipal energy in Germany. Thereof, the main part is required for the aeration of the activated sludge. Sludge aeration is necessary to feed microorganisms with oxygen. Therefore, compressed ambient air is injected into the aeration basins via large gas spargers at the bottom of basins. Power is required to overcome the hydrostatic pressure and for some membrane spargers to open the exit slits of the membranes [14, 24]. One possibility to decrease the energy consumption of the aeration process would be the reduction of the gas pressure drop of the diffuser. Hebrad et al. [14] showed that a membrane diffuser creates a pressure drop ten times larger than a perforated plate. Therefore, IWEB Institut für Wasser & Energie Bochum GmbH developed a novel cannula diffuser based on the idea of a perforated plate for the use in wastewater treatment plants. However, Hebrad et al. [14] also found out that the hydrodynamic parameters of the multiphase flow depend strongly on the used diffuser. The air once released to the sludge bubbles upwards in dense bubble swarms and transfer the oxygen into the liquid. The mass transfer depends on specific interfacial area (bubble size), bubble rise time (or gas residence time) and local liquid phase turbulence. Bischof et al. [7] found out that bubble sizes between 1.6 - 1.9 mm achieve the highest oxygen transfer into the liquid. The bubbly two-phase flow in the aeration basin is complex since bubble swarms develop their own dynamics and many details of it are unknown. Such are for example the exact bubble rise velocity and hence residence time since bubbles in a swarm rises with a different average velocity than single bubbles. Bubble size and interfacial area may change due to coalescence and break-up effects and rising bubbles themselves produce local turbulence, whose strength cannot be inferred from first principles. Moreover, it is known that certain types, configurations and arrangements of spargers can have positive or negative effects of mass transfer and back-mixing and hence process efficiency [6, 11, 16, 25, 27, 28]. A way to find optimal configurations for aerated basins with respect to geometry and spargers is the use of computational fluid dynamics (CFD) for