

Hydraulic Modelling of an Anaerobic Baffled Reactor (ABR)

Residence Time Distribution (RTD) studies conducted in Thailand allowed to describe and model the hydraulic behaviour of the ABR treating domestic wastewater. Yuttachai Sarathai¹ and Antoine Morel²

The ABR is successfully applied as treatment system for a variety of wastewaters. However, knowledge is restricted as regards its applicability to domestic wastewater exhibiting high qualitative and quantitative fluctuations. This PhD study investigates and models the hydraulic characteristics of the ABR treating domestic wastewater.

RTD studies

Residence time distribution (RTD) analyses (lithium chloride) were carried out in laboratory-scale ABR, comprising one sedimentation chamber and three upflow chambers in series (Fig. 1i). RTD curves were established using steady flow and non-steady flow tracer theories as described by [1]. These curves were used to quantify dead space, mean hydraulic retention time, short-circuiting effects, and mixing patterns in ABR operated at different peak flow factors (PFF 1–6), hydraulic retention times (HRT 24h, 36h, 48h) and influent COD concentrations (379, 911 and 1500 mg/L). RTD was further used to test the suitability of two non-ideal flow models (DPF and TIS) to characterise ABR's hydraulic behaviour.

Research findings

Dead space and short-circuits: RTD curves proved to be a good instrument to analyse the complex hydraulic patterns in ABR. Tracer response curves revealed rapid tracer breakthrough, indicative of prominent short-circuit channels and formation of circulation zones (dead zones). Highest short-circuit effects were observed at low nominal HRT (24h and 36h), with increased short-circuiting at increased peak flow factors. At a nominal HRT of 48h, peak flows had little impact on short-circuits. No clear trend could be observed between dead space and nominal HRT or biomass concentration. A substantial increase in dead space (15–25%) was observed at low nominal HRT (24h and 36h), when peak flows increased from 4 to 6 [2]. Dead space is assumed to increase mainly in the upflow chambers

due to increased upflow velocities of the fluid.

Hydraulic modelling

Two non-ideal single parameter models (tanks-in-series), were applied to the experimental data.

DPF model: The dispersion calculated in the experiments (0.10–0.19), corresponds to a large dispersion in the reactor with flow patterns far from plug-flow. The DPF model also simulated higher grades of symmetry compared to the observed RTD curves, underestimating the longitudinal dispersion (mixing) occurring in the ABR.

TIS model: At steady flow and non-steady flow (PFF 2–4), ABR's hydraulic behaviour can reasonably well be compared to a four tanks-in-series (TIS) model.

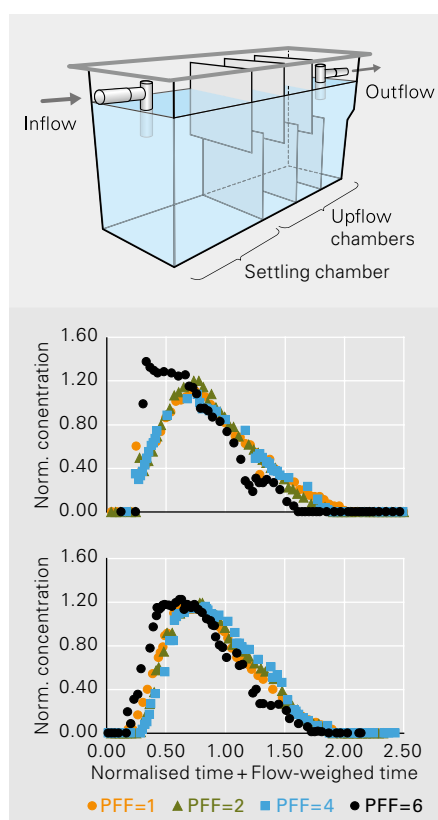


Figure 1i: Schematic diagram of the ABR model; ii and iii: RTD curves of the ABR operated at different peak flow factors (PFF) and HRT (ii: HRT = 12h; iii: HRT = 48h).

N was calculated based (1) on the variance of the RTD curve and (2) on the peak of the RTD curve. N values, calculated as a function of the variance of the RTD curve, were too high ($N=7-14$). The second method provided more accurate results, with N close to 4 (3.6). This number is equal to the number of compartments in the ABR, thus indicating that the ABR behaves like four continuously stirred tank reactors (CSTRs) operated in series.

Conclusions

Based on the RTD curves, it is possible to analyse the complex hydraulic patterns in ABR. The method allows rapid identification and quantification of short-circuiting effects, dead space and hydraulic efficiency.

The ABR is hydraulically very efficient at 24h–48h HRT and dead space below 15%. As high peak flow factors (PFF=6) strongly affect hydraulic efficiency of the ABR at low nominal HRT (12h–24h), a nominal HRT of 48h is recommended.

The TIS model with four tanks-in-series accurately reflects hydraulic behaviour of an ABR with one sedimentation and three upflow chambers operated at 12h, 24h and 48h HRT for steady flow and non-steady flow up to 4 peak flow factors.

Local RTD curves (for each ABR compartment) would localise areas with insufficient mixing and channelling in the system and allow to establish a more accurate hydraulic model for ABR.

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