

# Full-scale ANANOX<sup>®</sup> system performance

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## Abstract

This paper reports the results of the first experimental investigations carried out on the only existing full-scale plant that makes use of the biological treatment system known as ANANOX<sup>®</sup>. This system was first set up by the Italian research staff at ENEA (Agency for New Technologies, Energy and Environment) and consists of two biological stages in series: a two-section ABR and an anoxic section followed by an activated sludge process. The investigation aimed primarily to assess system performance under uncontrolled load conditions. In particular, system efficiency was assessed with regard to carbonaceous and nitrogen compounds in the anaerobic and anoxic phases, and the role of sulphides in the denitrification process was examined.

The results obtained show the system's ability to ensure efficiency levels that comply with stringent effluent regulations while also allowing considerable savings in running costs.

## Introduction

In the wastewater treatment field, systems based on anaerobic biological processes have traditionally been adopted to stabilise both primary and secondary waste sludge (Parkin and Owen, 1986), as this application is well-suited to the main requirements of anaerobic systems. These include:

- good removal ability of the biodegradable substrates;
- efficiency levels that are not excessively high;
- high production of biogas;
- and low running costs, mainly due to the lack of a forced aeration system.

However, over the last few years, the search for "sustainable" treatment systems capable of minimising energy consumption (Jetten et al., 1997) has encouraged the use of anaerobic biological systems even for intensive wastewater treatment, where the main goal is to eliminate the biodegradable dissolved fraction in carbonaceous substrates (Lettinga et al., 1979, Pfeiffer et al., 1986). Initially these applications were used for high-strength organic wastewaters (such as those produced by the food-processing industries, e.g. sugar refineries, distilleries, cheese factories, canning factories, etc.), as the effects of the intrinsically slow anaerobic processes are less serious (Malina and Pohland, 1992). Then, following the proposal of new and more efficient plant configurations, anaerobic systems were used also for the treatment of municipal wastewater, even though this contains a low organic substrate concentration, with a significantly high percentage of suspended and colloidal solids (Lettinga et al., 1981).

These innovative plant configurations are all characterised by a high substrate removal rate per unit reactor volume ( $\text{kg COD m}^{-3}\cdot\text{d}^{-1}$ ), obtained by retaining the biomass in the reactor

independently of the incoming wastewater (solids retention time, SRT, is higher than hydraulic residence time, HRT). High-rate anaerobic biological systems may be classified into three broad groups, depending on the mechanism used to achieve biomass detention. These are fixed film, suspended growth, and hybrid systems (Barber and Stuckey, 1999). The full-scale systems that have found a wider application are those based on the upflow anaerobic sludge blanket (UASB), which is a suspended growth system developed in the Netherlands in the early 1980s (Lettinga et al., 1980). Anaerobic biological systems arranged in series are called ABRs (anaerobic baffled reactors). The ABR uses a series of baffles to force wastewater containing organic pollutants to flow under and over (or through) the baffles as it passes from the inlet to the outlet (McCarty and Bachmann, 1992). The main advantage of the ABR stems from the ability to separate the two biological processes of acid formation and methane formation in which the anaerobic removal of carbonaceous substrate takes place (Eastman and Ferguson, 1981; Weiland and Rozzi, 1991).

Innovative anaerobic biological systems guarantee a fairly good removal of carbonaceous matter (which may even reach high efficiency levels in the case of rapidly biodegradable substrates), but are markedly inadequate to remove nitrogen and phosphorus compounds. Consequently, use of the anaerobic system alone cannot guarantee compliance with legal standards, a goal that could be reached by using the so-called integrated systems in which anaerobic biological systems constitute only one of the stages in the treatment flow-sheet (Lettinga and Hulshoff Pol, 1991).

The integrated systems developed over the last few years differ according to the various treatment systems that they consist of and the substrates that they eliminate. With specific reference to wastewater treatment in small communities, from as far back as 1988 the research staff at Italy's ENEA Institute (Ente per le Nuove tecnologie, l'Energia e l'Ambiente) proposed the two-stage biological integrated system known as ANANOX<sup>®</sup> (ANAerobic-ANoxic-OXic - Garuti et al., 1992). The schematic diagram of the ANANOX<sup>®</sup> system is represented in Fig. 1. The first stage uses an ABR comprising two floc sludge blanket sections; one anoxic sludge blanket section; and a sludge trap. The second stage is fed

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Received 3 May 2000; accepted in revised form 13 December 2000.