Mixing studies in an Orbal activated sludge system

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Abstract

Orbal multi-channel oxidation ditches have received relatively little attention and thus knowledge of their characteristics is not as highly advanced as for other oxidation ditch systems. Dye tracer and dissolved oxygen measurements have been undertaken to elucidate the mixing characteristics of a three-channel Orbal system treating 80 Ml/d. The dissolved oxygen concentrations showed a complex variation in space due to the input, approximating a continuous line source, non-uniform distribution of turbulence and secondary flows caused by channel configuration. Consideration of the DO measurements and the dye tracing results suggest that the flow could be treated as 2 CSTRs in the outer channel and a single CSTR in each of the two inner channels.

Nomenclature

BOD_5	=	5 d biochemical oxygen demand (mg/l)
COD	=	chemical oxygen demand (mg/l)
DO	=	dissolved oxygen (mg/l)
S_{NH}	=	concentration of ammoniacal-nitrogen (NH_4-N)(mg/l)
S_{BOD5}	=	concentration of soluble BOD_5 (mg/l)
RAS	=	return activated sludge (mg/l)
TBOD	=	total BOD (mg/l)
TSS	=	total suspended solids (mg/l)
X_{BOD5}	=	concentration particulate BOD (mg/l)
X_{NVSS}	=	concentration of non-volatile solids (mg/l)
X_{VSS}	=	concentration of volatile solids (mg/l)

Introduction

Since its introduction in 1959, the oxidation ditch has been used very widely throughout the world for the treatment of both domestic and industrial wastewaters. Its original design has been modified to accommodate greater loads, thus creating the Carrousel and the Mammoth systems (Koot and Zeper, 1972; Von der Emde, 1971), and the design expectations have changed so that, as well as removing carbonaceous BOD, an oxidation ditch can be configured to nitrify, denitrify and to even remove phosphorus (Rachwal et al., 1983; Sen et al., 1992). As such, their design and performance characteristics have received considerable attention. One mode of operation which has not been subjected to very much scrutiny is the multi-channel Orbal system. Two decades ago it was reported as being able to provide a reliable form of treatment, both for the removal of carbonaceous and nitrogenous pollutants (Drews and Greeff, 1973; Applegate et al., 1980) and a recent study (Daigger and Littleton, 1999) of six Orbal processes has confirmed this. Nevertheless, the knowledge about its overall characteristics for a wide range of operating conditions is not highly advanced.

The behaviour of wastewater treatment systems is increasingly being examined by mathematical models. These range over a wide variety of sophistication with a comparable range of data requirements. Most of the models which are in use need the mixing characteristics within the aeration tank to be specified, usually in terms of the equivalent number of continuously stirred tank reactors (CSTR) in series. In a traditional activated sludge plant a reasonable estimate of this can be made. In a traditional oxidation ditch a similar philosophy could prevail, and certainly one modeller has assumed that 20 tanks in series would be reasonable to describe an oxidation ditch 100 m long and 10 m wide (Stamou, 1994). What is not known is whether a similar approach would apply to an Orbal configuration. It is known that the mixing characteristics in a single-channel ditch, a Carrousel system, may be viewed in two ways. Over the time scale of one or two hours there is a high degree of plug flow but, viewed over a mean hydraulic retention time, the tank must be considered as being completely mixed (Koot and Zeper, 1972). Recently, four Orbal systems have been built for United Utilities plc, UK and mathematical modelling studies of these systems were required for performance predictions. There are no reported examples of Orbal tracer studies in the literature. It is known that one such study was carried out on the Orbal plant in Paris, Texas, USA in 1974, and this showed that the system could be considered as three completely mixed tanks operating in series (Envirex, personal communication). However, the Orbals at the Paris plant were designed with a depth of 1.5 m compared with 3.65 m for the UK plants.

This paper reports the results of tracer studies carried out at one of the plants operated by North West Water Ltd., UK and discusses the implications of the data for future studies.

Materials and methods

The Orbal treatment plant

The treatment plant, which treats a dry weather flow of 80 Ml/d, consists of conventional preliminary and primary treatment followed by two Orbal units. Each one consists of three concentric oval ditches. The mixed liquor flows around the outer channel, then through one of two ports into the central channel and finally into the inner channel, before passing into the final settlement tank. (Fig. 1). Aeration is achieved by four banks of disks which rotate around horizontal shafts. The number of disks on each section of the shaft may be altered to adjust the oxygen transfer, which can also be changed by varying the depth of submergence. The DO concentrations in the three channels are controlled by DO electrodes

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