The Effect of Flow Splitting and Aeration on Treatment Works Modelling

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ABSTRACT

Treatment works modelling for UPM studies often assumes that there is an equal flow split between parallel aeration tanks or trickling filters. A recent study has shown that this can be a dangerous assumption. This study showed that a reduction in the dissolved oxygen concentration and a 30% flow imbalance can cause a 20 fold increase in the peak effluent ammonia concentration. The verified model showed that if the lanes were under-aerated and unevenly loaded, a plant that normally met its ammonia consent comfortably, could possibly violate this same consent.

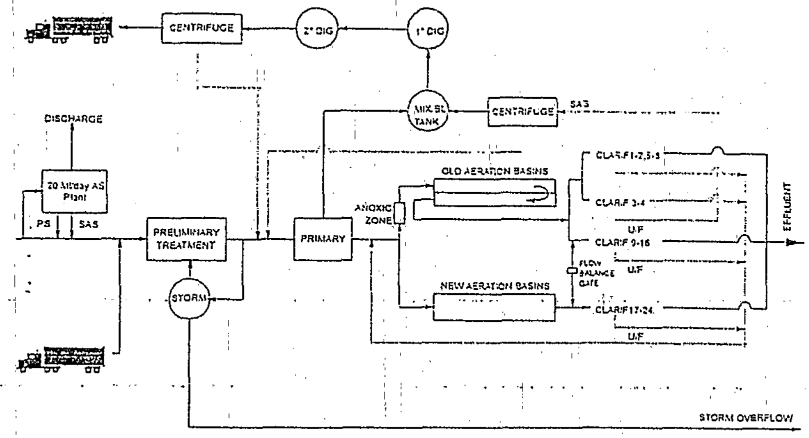
1 Introduction

The London Wastewater Optimisation Group of Thames Water Utilities and Reid Crowther Consulting Limited worked together to optimise the operation of a 140 Ml/day nitrifying activated sludge plant in the London area. The project proceeded in four phases:

1. Data Collection and Site Visits: Two Reid Crowther specialists visited the site and reviewed the drawings and historical data.
2. Diurnal Sampling: Thames Water Utilities collected diurnal data on the works. These data were used to conduct a mass balance and calibrate the computer model.
3. Preliminary Analysis: A series of one page, Value Engineering type proposals for improvements were prepared and discussed at a meeting attended by everyone involved with the plant. The feasible proposals were assigned to the appropriate people for further investigation.
4. Detailed Analysis: Reid Crowther built and calibrated a BioWin computer model and investigated the existing process configuration and various upgrading options.

This paper discusses the computer model calibration and the investigation into the existing process configuration.

2 Works Description



PROCESS FLOW SHEET

Figure 1: Works Layout

Figure 1 shows the layout of the treatment works.

The return activated sludge (RAS) from all the secondary clarifiers is mixed together before being split between the new and old aeration basins. All process modelling therefore included both the new and old aeration basins because a modification to one side would affect the performance of the other side.

The flow to the old side passes through an anoxic selector and is then split among 11 two-pass aeration lanes which feed clarifiers 1 through 16. The flow to the new side is split among 8 single pass aeration lanes which in turn feed clarifiers 17 through 24.

3 Theory

The capacity of an activated sludge system to oxidise the influent carbonaceous material (measured as BOD_5 or COD) and ammonia depends on

- The number of organisms in the system that can oxidise BOD_5 and ammonia
- The time that BOD_5 and ammonia in the wastewater is in contact with these organisms in the system

An activated sludge system consists of a liquid and solid phase. The solid phase consists of particulate and colloidal matter and the activated sludge floc.

The activated sludge floc is a complex eco-system consisting of micro-organisms, inert material and organic matter.

The liquid phase carries oxygen and other soluble nutrients such as soluble BOD_5 and ammonia to the organisms in the floc. The floc organisms readily oxidise the soluble BOD_5 in the first sections of the aeration basin.

Because a large fraction of the viable micro-organisms in the activated sludge system can utilise soluble BOD_5, the effluent BOD_5 is almost completely related to activated sludge flocs not settled out in the final clarifier.

This is not the case with nitrogen because in a typical nitrifying activated sludge plant only 5% to 6% of the sludge mass would be nitrifiers. This mass of nitrifiers is dependent on the sludge retention time and the nitrifier growth rate. The nitrifier growth rate decreases with a decrease in temperature, an excursion out of a pH range between 6 and 8 units, a drop in dissolved oxygen concentration below 2 mg/l and the presence of inhibitors (usually entering the collection system with trade wastes).

As the ammonia passes through a plug flow aeration tank, the specific rate of oxidation depends on the availability of oxygen and the ammonia concentration. The mass of ammonia oxidised depends on the flow through the aeration lane (i.e. hydraulic retention time), the mass of nitrifiers in the aeration tank and the specific oxidation rate.

Because the ammonia oxidation rate is much slower than that of the soluble BOD_5, consent violations at nitrifying activated sludge plants are usually related to either an increase in solids concentration or ammonia concentration in the final effluent.

Under normal operating conditions, an increase in final effluent ammonia concentration is usually related to problems with flow splits to individual aeration lanes or inadequate air supply during peak loading periods.

4 Choice of model

Reid Crowther constructed, calibrated and verified a computer model of the activated sludge basins. The process model that was used was a modified version of the IAWPRC Activated Sludge Model No. 1 incorporated in the BioWin wastewater treatment plant simulator software package. BioWin was developed by EnviroSim Associates Ltd. of Oakville, Canada in association with Reid Crowther. This model is mass conservative and incorporates a complete nitrogen balance. Ammonia and BOD_5 based models were not considered because they cannot achieve the level of accuracy necessary for process optimisation or design.

5 Model Calibration

The model was verified using data collected on May 22 and on July 31.

5.1 22 May 1995 Data

5.1.1 Simulation 1

We started with ideal flow split and aeration conditions. We used the measured data to give the flow to each side of the plant but assumed that these flows were split equally among the aeration lanes. We also assumed that the dissolved oxygen concentration was maintained at 2 mg/l.

The model successfully predicted the effluent COD, phosphorus, and nitrate concentrations but the measured ammonia concentrations were significantly larger than the simulated values (Figure 2-Simulation 1).

5.1.2 Simulation 2

There was additional data available as the dissolved oxygen profile had been measured in one lane on each side and the SCADA system also measured the flows leaving each lane, not just the flow to the two sides of the plant. This data showed that the first lane on the new side of the plant received approximately 30% more flow than the other lanes on the new side. We therefore re-ran the simulation with this flow split.

This increased the peak ammonia concentration on the new side by 18% (Figure 2- Simulation 2). Because the two sides share a common RAS, the peak effluent ammonia concentration also increased slightly on the old side.

5.1.3 Simulation 3

The simulation was then repeated using the dissolved oxygen profiles measured in one lane on each side. This almost doubled the median and peak effluent ammonia concentration on the new side (Figure 2- Simulation 3). The median and peak effluent ammonia concentration on the old side increased from 0.2 and 0.3 mg/l-N to 1.2 and 2.0 mg/l-N respectively. This simulation matched the observed data except for a short period during the night. During this period the observed effluent ammonia concentrations were much higher than those simulated.

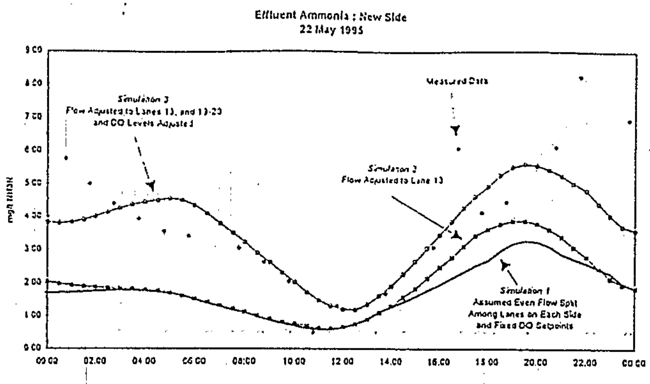


Figure 2: New Side Final Effluent - 22 May 1995

5.2 31 July 1995 Data

The SCADA data collected on July 31 was much more extensive.

5.2.1 Simulation 1

The model split the 11 lanes on the old side into three models components. Each lane on the new side was modelled as one component. The wastewater temperature was 19°C, suggesting that nitrification should not be a problem.

5.2.2 Simulation 2

When the SCADA flow data was used, the model predicted that the median ammonia concentration increased from 0.2 to 1.2 mg/l and the peak concentration from 1.0 to 1.9 mg/l (Figure 3 - Simulation 1). When the measured dissolved oxygen profile was used as well, the median effluent ammonia concentration on the new side increased to 1.9 mg/l-N and the peak to 2.8 mg/l-N respectively (Figure 3 - Simulation 2). The measured data on the old side was consistently higher than that which was predicted by the model.

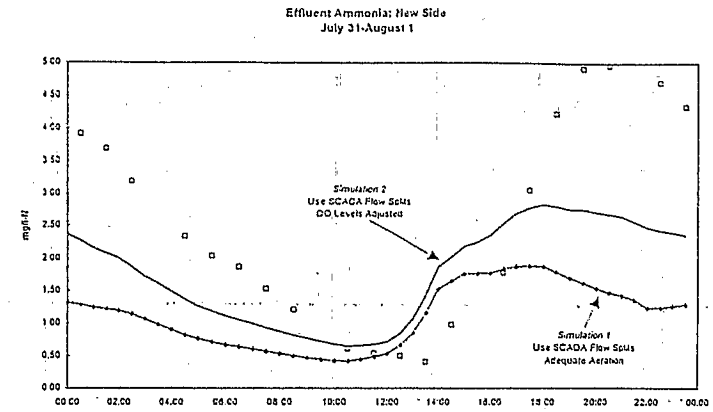


Figure 3: New Side Final Effluent - 31 July 1995

For the second simulation, we assumed that the dissolved oxygen profiles in each lane was similar to that which was monitored in one lane on each side. The model showed that as the flow increased into lane 13, nitrification failed (Figure 4). The flow to lane 13 was only 30% higher than the flow to the other

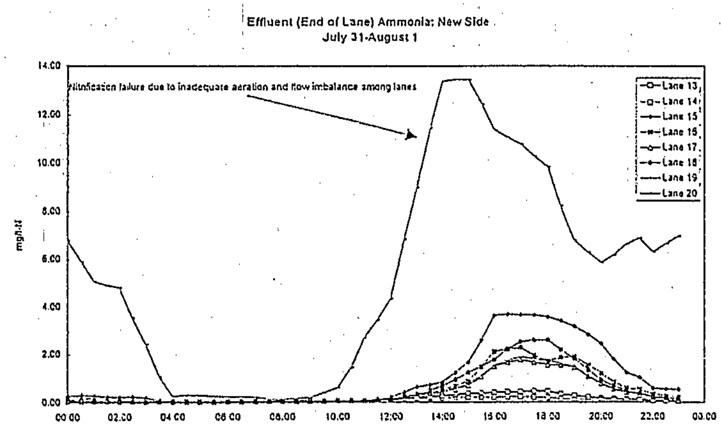


Figure 4: New Side - Effluent Ammonia Concentrations

lanes on the new side. The predicted peak effluent ammonia concentration was about 14 mg/l. The model also showed that the nitrification started to fail in lane 2 as well. This failure was probably much more severe as the model assumed that the dissolved oxygen profile in lane 2 was identical to the rest of the lanes on the old side.

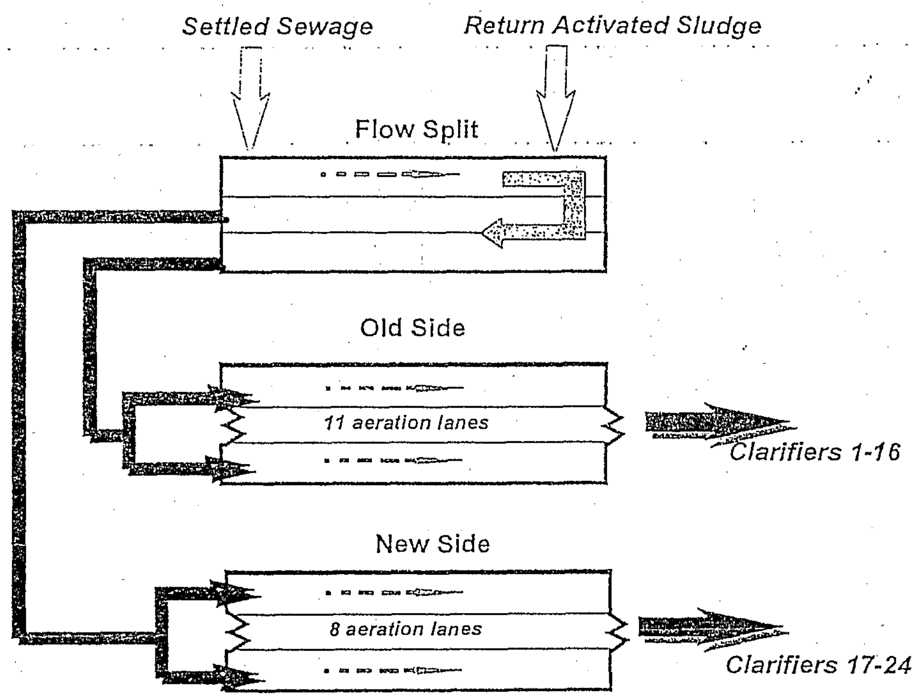
6 Conclusions

Unlike the effluent BOD_5, COD and phosphorus concentrations, a nitrifying activated sludge plant's effluent ammonia concentration is very sensitive to under aeration and unequal flow splits.

UPM studies examining the performance of nitrifying activated sludge plants under wet weather must be concerned about the dissolved oxygen profiles and flow split among aeration lanes.

7 Acknowledgement

Reid Crowther Consulting Limited acknowledges that the work discussed in this paper is the result of the co-operation and effort of all members of the Optimisation team including the employees of Thames Water Utilities. However the opinions expressed this paper are the those of the authors alone.



Session 2- Chairman Nick Martin Thames Water

The Effect of Flow Splitting and Aeration on Treatment Works Modelling

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Question Norman Walker Leeds City Council

How did you resolve the problem of the unequal flow split ?

Answer

We put forward a case to improve the control algorithms.

Like a lot of plants quite a lot of head is provided for flow splitting but unfortunately not at the units themselves.

Question Ian Noble Montgomery Watson

Would balancing the diurnal profile in the sewer system have given any benefit ?

You mentioned sludge return liquors as containing heavy slugs of load do these have bad effects ? and how are such returns dealt with in UPM ?

Answer

The diurnal profile was pretty flat so no real benefit in balancing ?

Mass balance showed that 33% was from the sludge dewatering plant ?

I believe that they can be accommodated in the UPM procedures.

Question Jon Farrer Bullen Barber Ltd

What level of data collection did you need or would you advise for monitoring an element of a plant with 11 aeration lanes.

Answer

The ammonia graph profiles for each lane were generated from by the model. The data collection monitored the ammonia in the effluents from the new and old sides not each part of each treatment unit.

Monitoring is always a balance with the cost.

On the subject of monitoring far more attention should be paid to organic nitrogen, you should do a total nitrogen test when modelling a nitrifying process. You always have a problem if you do not.

1. Get total nitrogen numbers

2. Use COD rather than BOD because BOD models cannot satisfy mass balance between the oxygen demand in the raw wastewater, the oxygen consumed and the biomass produced. The ratio of COD to biomass does not vary significantly while the ratio of BOD5 to biomass can vary anywhere between 0.2 to 1.0 (or more).