OPERATING EXPERIENCE OF AN ACTIVATED SLUDGE EFFLUENT DISPOSAL SYSTEM

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Abstract

The historical background to the installation of the system is outlined. The laboratory analyses required to determine the desirable operating parameters are described. The normal values of these operating parameters and reasons for their choice are outlined. Practical experience of COD removal efficiency, operating costs and problems are discussed.

Introduction

Today effluent disposal has become an integral part of the production process; its costs having to be incorporated into the selling price of the product. The most desirable form of effluent disposal is to prevent the formation of effluent, but this is probably an unattainable goal in many industries. For this reason the sugar industry aims at a total re-use system.

If the concept is accepted that effluent disposal is part of the production process, then it follows that the disposal system must be managed as effectively as the rest of the operation. It cannot be added at the end and left to run itself, because it will neither effectively dispose of effluent nor operate at minimum cost.

Historical Background

Initially the Union Co-operative system started as a containment and ponding operation. Two ponds were constructed, two more were added and finally two small dams on the waterway draining away from the factory. Further developments were a spray irrigation system to deal with overflow problems.

By the early 1970's the operation had become difficult and expensive to continue. The main problems were limited availability of dam sites and space for the required quantity of irrigation. Consequently in conjunction with consultants it was decided that an activated sludge disposal system should be built to treat effluent to an acceptable standard for disposal into a watercourse.

The contract was awarded to Ames Crosta for completion by factory start-up in 1975. It comprised the pump station at the ponds, aeration basin, 2 Simplex S.A. 50 aerators and a final settling tank as well as all associated pumps and switchgear. Total capital cost which included all civil engineering works was R130 000. The aerators were driven by 37kW motors via Flender gearboxes. These gearboxes have subsequently been changed for Radicon ones due to their poor performance and lack of spares. The design oxygenation efficiency was 2,05kg oxygen/kwH giving a volumetric oxygen loading of the basin of 1,75 kg O^2 /m^3/day.

Initial problems included very severe corrosion of the activated sludge plant supply pumps, due to the low pH of water from the ponds. Bulking of the sludge in aeration basin was extremely severe, producing a poor quality final effluent and a high loss of suspended solids from the basin. Original recommendations suggested dosing urea and trisodium phosphate at 100 and 50 kg per day respectively, to obtain a BOD : N : P ratio of 160 : 4 : 1. At today's prices this would add some 22 c/m^3 to the costs.

In 1976 the National Institute for Water Research (N.I.W.R.) became involved in monitoring the performance of the plant. Simpson and Hemens[1] established in the laboratory trials that the nutrient requirements of the system were a soluble COD : N : P ratio of 100 : 2 : 0,4. The actual operating ratio had been found to be 100 : 0,26 : 0,07. Once this problem had been corrected the plant operated to produce an acceptably low soluble Chemical Oxygen Demand (COD) level, but with an unacceptably high suspended solids level. The N.I.W.R. programme operated until 1977 when it was discontinued. In order to reduce the suspended solids problem a candle filter was installed prior to the final effluent buffer tank.

The final effluent was used as make up water for the injection cooling tower as circulating water from this tower was used as make up for boiler scrubbers. Any excess was allowed to overflow to dams for storage and re-use.

With the severe drought conditions of 1981, facilities for the dosing of flocculants were installed in order to improve the quality of the clear effluent. This water was then used as make up for the Wattle Bark Factory extraction well. The sugar factory was also piped up to receive the same water for use in plant washing instead of using domestic water.

Present System

The present system comprises four anaerobic lagoons operated two in parallel followed by two in series. The outflow from the last lagoon is pumped to the activated sludge plant. Clear effluent is either used in the factory or is overflowed to the holding dams for maturation and re-use. Rainwater run off is also directed to these dams as dilution and to prevent hydraulic overloads of the anaerobic lagoons.

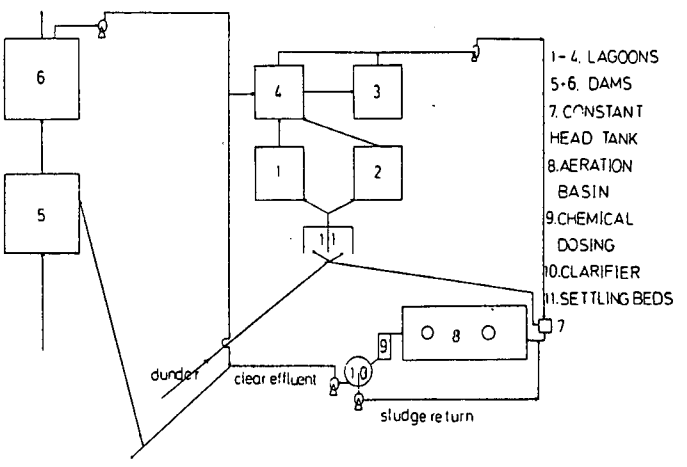

FIGURE 1 Union Co-operative effluent disposal scheme

Analysis Scheme

UCL.41

THE UNION CO-OPERATIVE BARK & SUGAR CO. LTD.

EFFLUENT ANALYSIS

DATE							
RAW EFFLUENT m³/day							
p.H							
COD							
Cond							
D.O.							
MIXED LIQUOR pH							
S/Solids							
D.O.							
S.V.							
S.V.							
Urea Kg/day							
Phosphate Kg/day							
CLEAR EFFLUENT pH							
Cond							
COD							
D.O.							
SLUDGE RETURN pH							
S/solids							

WEEKLY COMPOSITES

	DATE	COD	PO_4	NH_3-N	No_3-N	T.I.N	S/SOLIDS
LAGOON FEED							
RAW EFFLUENT							
CLEAR EFFLUENT							

REMARKS: .....

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FIGURE 2 Analytical report sheet

Because effluent disposal requires effective management and is a delicate microbiological process, the scheme of analysis as shown in Figure 2 was arrived at by Union Co-operative. The majority of these analyses are conducted on a daily basis for routine operational control. The weekly composite analyses provide a guide to the nutritional status on which supplemental N + P addition is based. These composites are made up of catch samples collected daily and preserved with 2% Sulphuric Acid.

Methods of analyses are as follows:

For COD + Suspended Solids – SASTA Laboratory Manual[2]
For Conductivity, pH + Dissolved Oxygen – Instrument Manufacturers Instructions

For Phosphate – as reduced phosphomolybdate blue complex in SASTA Laboratory Manual[2]

For Nitrogen – Ammonia and/or Total Inorganic N after reduction of Nitrate with Devarda's alloy are distilled from a strongly alkaline solution into 2% Boric Acid and titrated with standard acid.

If solutions being distilled froth badly, about 2 g candle wax added prior to distillation acts as an efficient defoamer. The procedure is based on that described by the American Water Works Assocation.[3]

Nitrate N is calculated from the difference in total Inorganic N and Ammonia N

ie Nitrate N = Total Inorganic N – Ammonia N

For Settling Volume and Sludge Volume Index (SVI), calculations are according to Hammer.[4]

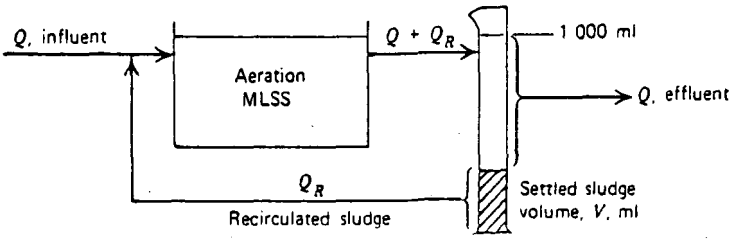

FIGURE 3 SVI relationship

$$SVI = \frac{V \times 1000}{MLSS} \qquad \text{Equation 1}$$

Where SVI = Sludge Volumetric Index in mℓ/g
V = Volume of Settled Solids in 1ℓ measuring cylinder after 30 minutes in mℓ/ℓ.
MLSS = Mixed Liquor Suspended Solids in mg/ℓ.

From Figure 3 – $\frac{Q_R}{Q + Q_R} = \frac{V}{1000}$ rearranges as

$$Q_R = \frac{V \times Q}{1000 - V} \qquad \text{Equation 2}$$

Further parameters as described by Hammer[4] are calculated on a monthly basis. These comprise the COD loading of the basin and the Food to Micro-organism Ratio (F:M Ratio).

$$\text{COD Loading} = \frac{\text{kg COD in Feed/day}}{\text{m}^3 \text{ of Mixed Liquor}} \qquad \text{Equation 3}$$

$$\text{F:M Ratio} = \frac{Q \times COD}{V \times VMLSS} \qquad \text{Equation 4}$$

Where Q = Flow to Plant in m³/day
COD = COD in mg/ℓ
V = Volume of Mixed Liquor in m³
VMLSS = Volatile Suspended Solids in Mixed Liquor in mg/ℓ

It is important to note that a correction should be made for the inert suspended solids by determining the loss on ignition of sludge from basin. This is normally in the range of 25 to 35% in the plant at Union Co-operative (ie approximately 30% of Suspended Solids are Active).

Operating Parameters

Efficient anaerobic lagoon operation requires that the exit pH be maintained in the range of 6,5 to 7,0. This is done by addition of lime to the constant head return from the aeration basin. The point of addition should be as far back from the lagoons as possible to provide good mixing. Poor mixing results in the lime settling out in the lagoon and a continuing low exit pH. The range of feed rates is 150 to 450 kg of lime per day.

Provided good pH control is maintained there is little or no "Sour Acid Smell" from the lagoons and a COD removal efficiency of about 70% is achieved. A floating scum cover over the whole surface of the lagoons and a high rate of bubble evolution indicate a good COD removal rate. Within limits, the higher the COD inlet concentration the higher the removal efficiency.

Provided that the anaerobic lagoons are operating efficiently then the activated sludge operation is almost trouble-free. Nutrient status must be checked regularly (once per

month) to maintain the required 100:2,0:0,4 ratio of COD:N:P. Should signs of bulking/foaming become evident then the nutritional status must be checked more often than once a month.

Additional nutritional requirements are calculated as follows:

$$\text{for N} \quad \frac{\left[\frac{\text{COD} \times 2}{100} - \text{mg/ℓ N Incoming}\right] \times Q}{1000 \times \%\ \text{N in Supplement}/100} = \text{kg Supplement per day} \qquad \text{Equation 5}$$

$$\text{for P} \quad \frac{\left[\frac{\text{COD} \times 0{,}4}{100} - \text{mg/ℓ P Incoming}\right] \times Q}{1000 \times \%\ \text{P in Supplement}/100} = \text{kg Supplement per day} \qquad \text{Equation 6}$$

Generally urea and 10,5% P single superphosphate are the cheapest nutrient supplements. A further advantage is that the superphosphate also provides sulphur which is required for growth. The exact sulphur nutrition requirements are not certain.

Mixed Liquor Suspended Solids (MLSS) is generally run in the range of 7 000 to 10 000 mg/ℓ, together with a Sludge Volume Index (SVI) of not more than 150 mℓ/g. These conditions in the basin will generally produce a clear effluent with low suspended solids and COD.

A higher SVI than 150 mℓ/g indicates a bulking sludge condition, which will lead to increase clear effluent suspended solids and a loss of activated sludge from the plant. As activated sludge is lost, the F:M ratio increases leading to an increase in growth rate and development of non-settling sludge making the problem worse. Sludge should be checked regularly (once a month) under a microscope at 30 to 50 times magnification for the presence of excess filamentous growth. Some filamentous growth is required to bridge together smaller bacterial flocs. Experience will soon show when this growth becomes excessive.

Reasons for bulking are numerous and can include any sudden change in:-
COD input
Temperature
Type of effluent
Nutrient status
pH
Dissolved oxygen

Solutions to the problem are to restore system conditions if possible, or dose the sludge with chlorine either as calcium hypochlorite or gas. Dosing[5] should be at the rate of 5 to 15 g Cl_2/kg solids in mixed liquor/day. Split dose chlorine into clarifier feed and return sludge so as not to exceed 10 to 15 mg/ℓ concentration. The chlorine attacks all organisms but filamentous ones are preferentially destroyed due to their greater surface area. The clear effluent may go cloudy during dosing due to destruction of biological growth. Treatment should continue until the SVI reverts to normal. This may take anything from one to six weeks or possibly longer. Each problem is unique and variation in length, quantity and concentration of chlorine treatment may be required.

The desirable level of suspended solids in the sludge return depends on how excess sludge is to be treated. For disposal via drying beds it should obviously be as high as is practically possible, probably in the 60 000 to 100 000 mg/ℓ range. Drying beds have the disadvantage of being labour intensive and taking up a lot of space. Consequently the excess sludge is returned to the anaerobic lagoons, where it is digested in the normal way. In this case the suspended solids level in sludge return is maintained in the 30 000 to 40 000 mg/ℓ range. This level produces the correct recirculation rate to the basin and a highly mobile liquor that is not prone to blockages in the clarifier under flow, as is the much less mobile liquor required for drying bed disposal. Recycle rate is generally in the range of 50 to 60% of input flow. This figure may be checked by the relationships of Equations 1 and 2.

Equation 2 may be re-written as:

$$\frac{Q_R}{Q} = \frac{V}{1000 - V} \qquad \text{Equation 7}$$

For a normal value of V of 350 mℓ

$$\frac{Q_R \times 100}{Q} = 53{,}85\%$$

Results

The analytical results for each month of the sugar seasons of 1984 and 1985 are represented graphically in Figures 4 and 5.

It can be seen that the activated sludge plant can tolerate a fairly wide range of COD feed rates, provided that the F:M ratio remains relatively low. Higher F:M ratios encourage a logarithmic growth phase of sludge leading to a bulking problem. In other words "starve" the activated sludge in order to obtain a maximum COD reduction and best settling characteristics from that sludge.

However, in order to produce a consistently clear final effluent it is essential to dose flocculants prior to the sludge clarifier. Use is made of alum, 61D16A (now 4166) an anionic polymer plus cationic polymers such as Lt 31, Bubond 65 and D8100.

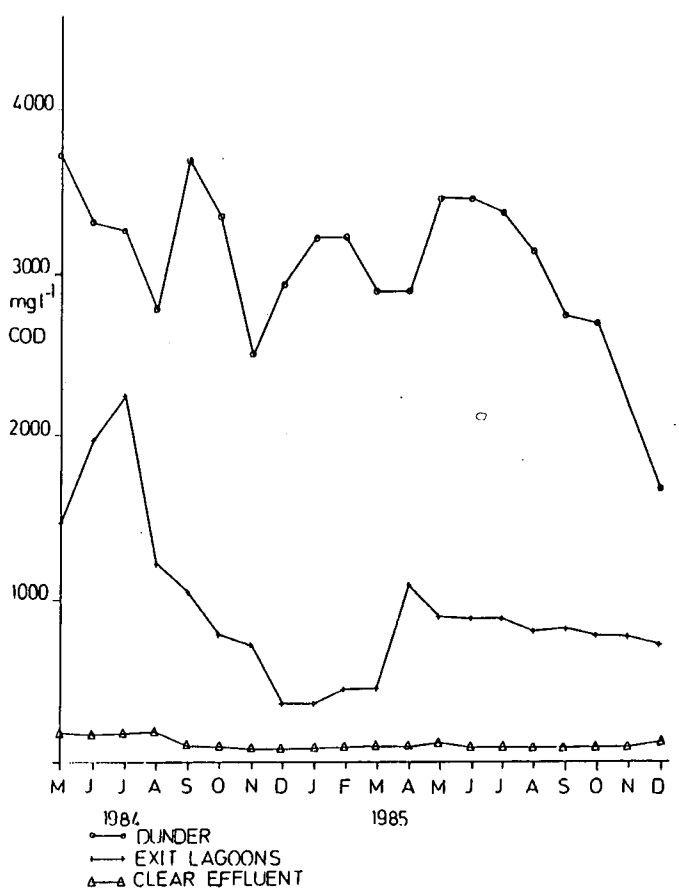

FIGURE 4 COD levels

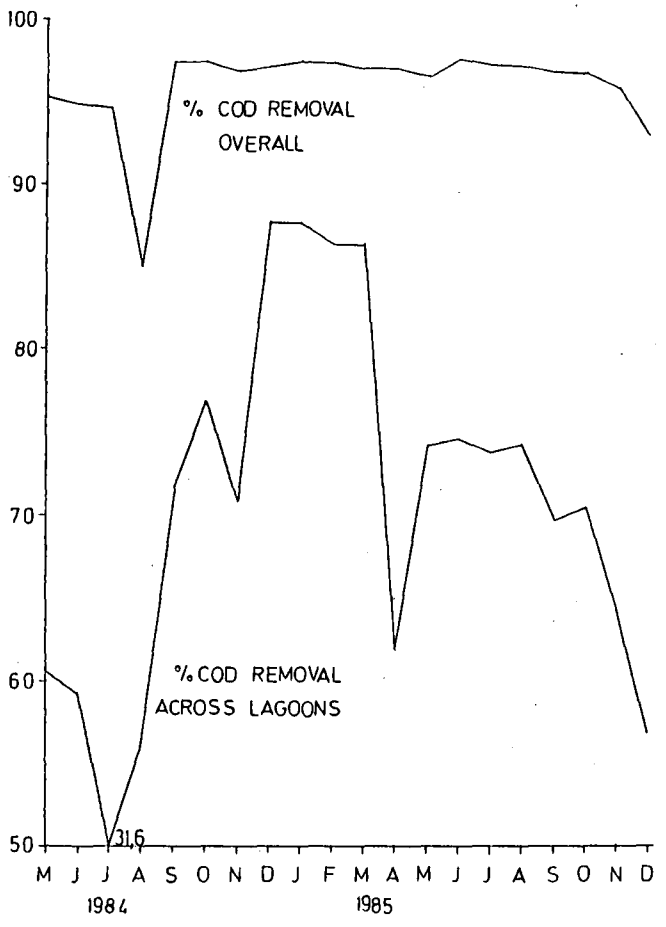

FIGURE 5 COD removal

It is essential to carry out jar flocculation tests using a combination of alum, with cationic and anionic polymers to establish dosing rates. The order of addition can also affect the results achieved so facilities to vary point of addition are desirable on the plant. Generally, alum is first in the 20 to 40 mg/ℓ range followed by Anikem 4166 in the 2 to 4 mg/ℓ range. Addition of cationic polymers may be required at various times if the sludge exhibits poor settling characteristics. The alum/anionic combination seems to provide the most cost effective treatment.

Costs

Chemical dosing costs are monitored on a monthly basis for control and budget purposes.

1985 costs were 8,98 c/m³ of effluent treated at the clarifier. This figure however, includes a recycle flow of about 55%. If this flow is removed the figure changes to 13,92 c/m³ pumped to the activated sludge plant.

Power consumption is 70 kW × 24 = 1680 kwH/day at a cost of 7,38 c/kwH = R123,98/day. Average sugar season flow rate is 450 m³/day which means the costs are 27,55 c/m³.

Labour and maintenance costs are estimated at 4,26 c/m³.

Consequently, Total Costs are:-

Chemicals	13,92 c/m³	30,44 %
Power	27,55 c/m³	60,24 %
Labour & Maintenance	4,26 c/m³	9,32 %
Total	45,73 c/m³	100,00 %

Conclusion

This cost figure is still considerably lower than the approximately 70 c/m³ average purchase price for municipal water although it is much higher than the approximate cost of 17 c/m³ for domestic water purification. However, if effluent water is not re-used then the present domestic treatment plant would have to be doubled in size in order to cope with demand and a further equivalent volume of effluent treated.

Acknowledgement

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4. Hammer MJ *Water and Waste Water Technology*, Wiley, New York, 1977 pp 387–390.
5. Anon. *SA Water Bulletin* August 1983 pp 11–14.