EFFLUENT TREATMENT AT FELIXTON MILL

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Abstract

The treatment of sugar mill effluent in biological trickling filters at Felixton mill is described. The performance of the plant over the past three seasons is discussed. Initial performance was poor and details are given of the steps taken to produce a consistently acceptable final effluent.

Introduction

Sugar mill effluents generally have a high carbohydrate content and can be classified as strong organic wastes. They do not normally contain any toxic materials and hence their polluting potential arises solely from the high concentrations of soluble carbohydrates, which provide a substrate for rapid biological growth in the receiving waters, with a consequent depletion of the dissolved oxygen due to bacterial respiration. In terms of the Water Act No. 54 of 1956, some form of pretreatment is necessary before such wastes can be discharged to a natural water-course. The local sugar industry has been granted exemption from compliance with certain sections of the Act, and as far as organic carbon is concerned, it is only required that the Chemical Oxygen Demand (COD) shall be less than 120 mg/ℓ. Since the waste comprises mainly organic compounds it should be amenable to controlled biological degradation.

In the treatment of organic wastes both aerobic and anaerobic organisms can be employed. Anaerobic systems are ideal for treating highly concentrated wastes but are not suitable for producing a high quality effluent.[1] This can be achieved by the use of an aerobic system and here both the activated sludge process and biological trickling filters (or biofilters) are widely used,[2] especially in sewage treatment.

During recent years a considerable amount of work has been done on the application of the activated sludge process to the treating of sugar mill wastes.[1, 3, 4] These studies have indicated that the process is sensitive to several parameters such as residence time, organic loadings, pH and nutrient balance and hence requires careful control. On the other hand the performance of biofilters is considerably less susceptible to shock changes in the composition of the waste or, at least, recovery is more rapid.[5] This factor coupled with their extreme simplicity of operation and lower power requirements led to the selection of a biofiltration plant at Felixton mill.[6]

Description of plant

A schematic layout of the overall treatment plant is depicted in Figure 1.

The integral parts of the plant are described in the relevant sections below.

Anaerobic surge pond

A 4 455 m^3 (or 1 million gallon) dam was situated ahead of the biofilters in order to provide buffer capacity against plant breakdowns and to iron out surges in the quantity/strength of the effluent. It was expected that a certain amount of anaerobic degradation would occur in this pond. The mean residence time in the pond was estimated at about 72 hours for an effluent flow of 1 500 m^3/d.

Biofilters

In view of the almost total lack of published information on the use of biofilters for treating sugar wastes, the plant was designed to provide a wide flexibility in mode of operation. The two filters can be operated in series or in parallel, with or without recirculation and/or intermediate solids removal. Standard practice is series operation with 1 : 1 recirculation. Each filter is 23 m in diameter and contains a nominal 920 m^3 of crushed stone having a size grading of 100-150 mm and a specific surface area of around 40 m^2/m^3. The incoming feed is sprinkled across the stone surface via a rotary head and four reaction-driven distributor arms.

At a total feed rate of 30 ℓ/sec (including 100% recirculation), the design hydraulic loading is 6,2 m^3/m^2d, which is at the top end of the scale for conventional low rate filtration.[7] When coupled with an estimated feed COD of 1 500 mg/ℓ, the

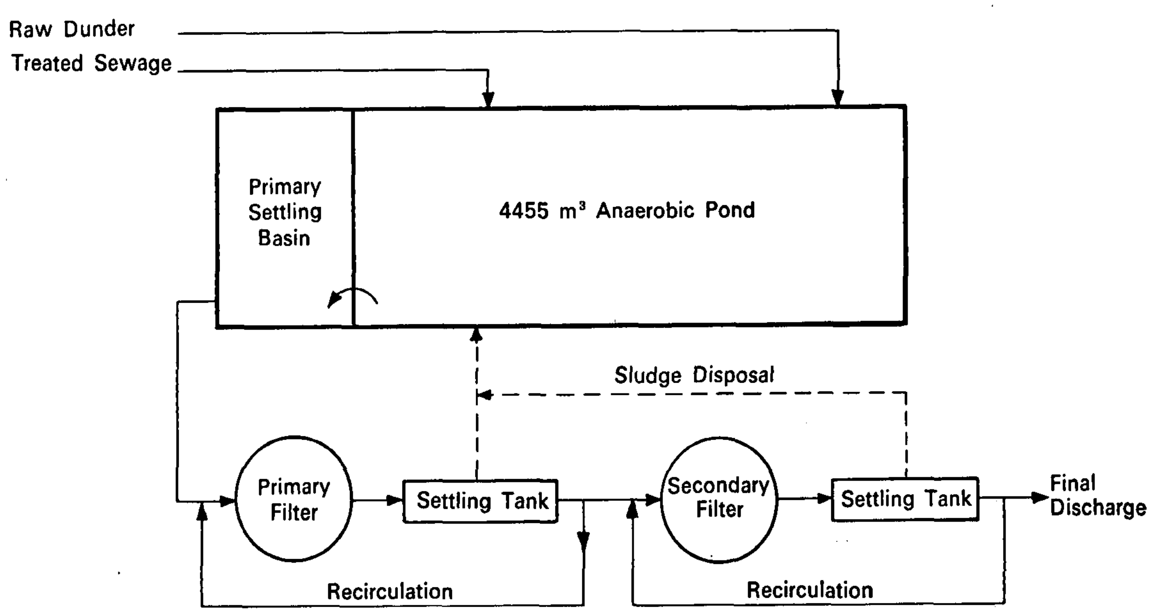

FIGURE 1 Schematic layout of plant.

overall design organic loading is approximately 1 kg COD/m^{3}d. This is getting up into the range of high rate filtration. This particular factor influenced the selection of the coarse 100-150 mm stone aggregate so as to provide large interstitial spaces which would prevent clogging and ponding of the bed as a result of heavy bacterial growth rates at these high organic loadings.

Settling tanks

Two sets of four rectangular settling tanks were provided. The individual dimensions of each tank are 7 620 × 3 048 mm with a peripheral weir length of 18 288 mm. For a maximum design flow rate of 30ℓ/sec to each filter (including 100% recirculation), the surface overflow rate to each set of tanks is 1,16 m^3/m^2 hr with a weir loading of 1,48 m^3/hr per lineal metre of weir length. Both these factors are well within the bounds of conservative design practice.[7]

Sludge disposal

Approximately 200 m^2 of conventional sludge drying bed capacity was provided. However it was recognised from the outset that solar drying of an unstabilised sludge was likely to prove problematical, as indeed it did.

Measurement and control

The total effluent flow rate from the mill is recorded continuously at a Parshall flume located just ahead of the anaerobic pond. The feed flow rate from the dam to the plant is set by altering the position of an adjustable weir and is measured through a 90° V-notch. Recirculation rates are adjusted manually using butterfly valves, whilst the combined flow to each filter as well as the final effluent discharge are measured across separate 90° V-notch weirs in the distribution box.

A number of regular routine tests are undertaken in order to monitor plant performance. Full details of the methods of sampling and analysis are given in the Appendix.

Plant operation

1973/74 *Season*

The plant was completed and taken into operation in September, 1973. The balance of the crushing season was spent in testing the plant hydraulically and ironing out the inevitable teething problems. The initial performance of the plant was disappointing as can be seen from the set of typical results shown in Table 1.

TABLE 1
Initial operating results (all figures in mg/ℓ except for pH)

	Factory Effluent	Anaerobic Pond Effluent	Final Effluent
pH	11,8*	4,5	7,4
Permanganate Value (O.A.)	364	324	44
Chemical Oxygen Demand (COD)	3 344	2 986	544
Free and Saline Ammonia, as N	2,1	Nil	Nil
Phosphate, as P	Trace	6	—

* due to lime addition

These results revealed a number of interesting factors:

(*a*) the final effluent COD was still a lot higher than the required level of 120 mg/ℓ, whilst the feed was also a lot stronger than had originally been anticipated.

(*b*) the raw effluent was obviously nutrient deficient in terms of N and P.

(*c*) very little anaerobic degradation was occurring in the pond, based on the COD values tabulated.

(*d*) the pH of the pond effluent was too low despite the addition of lime to the inflow.

(*e*) despite the low feed pH conditions, the COD removal across the biofilters was good, amounting to some 1,6 kg COD/m^{3}d. This was no doubt largely due to the very high organic loadings applied.

1974/75 *Season*

Early in the 1974/75 season the responsibility for operating the plant passed from the construction crew to the mill staff. Plant performance was still unsatisfactory with final effluent quality well outside the required standards. A number of changes were instituted in order to improve the situation.

Due to the poor dewatering characteristics of the waste sludge produced, the available drying bed area was inadequate. It was decided instead to route the sludge direct into the anaerobic pond where it would hopefully undergo anaerobic fermentation and stabilisation. It was recognised that this would result in an accumulation of sludge in the pond which would eventually necessitate having to clean out the pond. However to date this has not been necessary.

The total flow (2-3 ℓ/sec) of purified sewage effluent from an adjacent small activated sludge plant was introduced into the anaerobic pond in order to improve the nutrient supply.

A small primary sedimentation basin was installed just after the anaerobic pond in order to remove the fairly high levels of settleable solids (e.g. leaves, bagacillo, etc.) from the effluent. It had been found that some of this material was carrying right through to the biofilter feed.

A concerted campaign was mounted throughout the mill to reduce both the quantity and the organic contamination of the mill effluent.

Lastly a schedule of regular routine analyses was instituted in order to monitor plant performance and the possible effects of the various modifications mentioned above. The results obtained are depicted graphically in Figure 2 which indicates the marked improvement which was achieved.

It can be seen that from mid December, 1974 onwards the final effluent COD was consistently below 120 mg/ℓ.

1975/76 *Season*

No additional modifications were undertaken during the 1975/76 season but a series of tests were performed to assess the effect of recirculation on plant performance. As can be seen from Figure 2, final effluent quality was quite acceptable except for a very short period at the start of the season.

During the offcrop the plant was kept in operation by recirculating the final effluent back to the anaerobic pond. This was done in order to preserve the culture of microflora which had been established on the stone media, but of course resulted in a progressive purification of the pond contents. Hence on start-up the normal mill effluent constituted a shock load to the system and it took a week or two to settle down again and become acclimatised.

Discussion

Anaerobic pond performance

From the data in Figure 2 it is evident that the performance of the anaerobic pond improved very markedly during the 1974/75 season. The average results for three consecutive periods over the past 18 months are listed in Table 2.

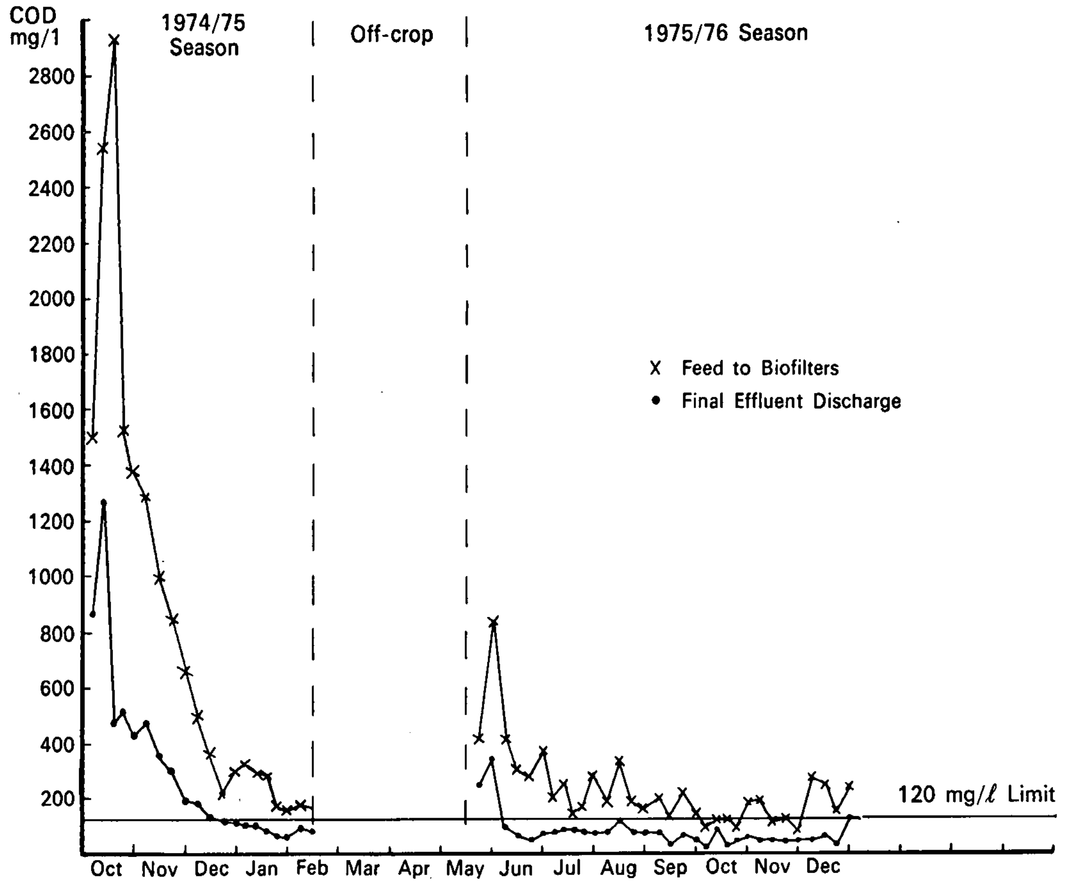

FIGURE 2 Biofilter performance.

TABLE 2

Anaerobic pond performance

	Sept. 1974 to Nov. 1974	Dec. 1974 to Feb. 1975	May, 1975 to Jan. 1976
Inlet pH	8,2	7,9	7,1
Outlet pH	5,5	6,9	6,8
Inlet COD (average) mg/ℓ .	2 512	1 919	1 527
Outlet COD (average) mg/ℓ	1 539	266	212
COD removal % . . .	38,7	86,1	86,1

These results indicate the significant changes which have taken place in the pH and COD of the pond effluent as a result of improved anaerobic degradation. This is probably due to the additional nutrients introduced with the purified sewage effluent, coupled with a progressively decreasing COD level in the factory effluent. When it is operating satisfactorily the pond becomes covered by a thick scum and ceases to emit the characteristic foul odours.

Role of nutrients

Earlier tests by an independent consultant during the 1973/74 season showed the effluent to be deficient in nutrients. It is well known that both anaerobic and aerobic systems require nitrogen and phosphorus. Previous workers[1] have recommended a minimum COD : N : P ratio for the activated sludge treatment of sugar mill wastes of 100 : 2 : 0,4 whilst for biofilters[2] a suitable ratio is 100 : 4 : 0,8.

Following the introduction of purified sewage into the dam the nutrient balance on the pond effluent was determined on a number of occasions. These results are presented in Table 3.

TABLE 3

Nutrient Balances

Date	COD pond effluent (mg/ℓ)	Kjeldahl N as N (mg/ℓ)	Phosphates as P (mg/ℓ)	COD : N : P
4.12.1974	502	24	13	100 : 4,8 : 2,6
12.12.1974	262	20	not done	100 : 7,6 : –
18.12.1974	216	18	13	100 : 8,3 : 6,0
8.1.1975	287	16	11	100 : 5,6 : 3,8
14.1.1975	252	11	8	100 : 4,4 : 3,2
21.1.1975	247	12	not done	100 : 4,9 : –
28.5.1975	1 381	not done	48	100 : – : 3,5
4.6.1975	365	4	not done	100 : 1,1 : –
21.1.1976	111	12	not done	100 : 10,8 : –

It is readily apparent that, at the relatively low COD levels in the pond effluent, the nutrient values are on the high side for a biofiltration process.

Biofilter performance

The biologically oxidisable fraction of the dissolved organic matter is normally characterised by the BOD analysis (Biological Oxygen Demand), whilst the COD figure also includes other oxidisable materials which are not readily degraded by micro-organisms. The removal kinetics of oxidisable organic matter in a biofilter generally approximate closely to those of a first-order reaction.[5, 8] Unfortunately during the present study only the more rapid COD figures were determined and hence it is not possible to subject these results to a more rigorous theoretical treatment.

A highly significant correlation was found to exist between the applied load and the overall COD removal. This is illustrated in Figure 3 which is based on the combined results for the 1974/75 and 1975/76 seasons.

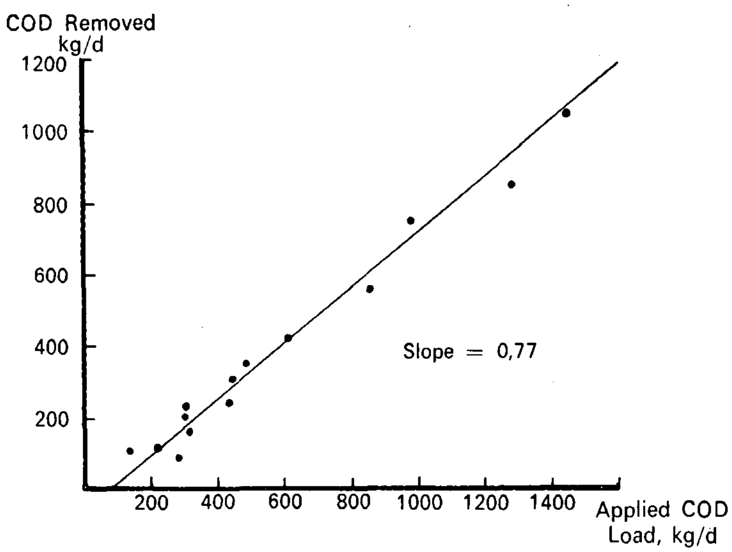

FIGURE 3 COD removal.

This graph represents a constant COD removal efficiency of about 77 % based on the COD of the incoming feed, although there were indications that the removal tends to decrease with increasing organic load.

With an overall COD removal of 77 %, it can readily be shown that the limiting COD value for the incoming feed is 520 mg/ℓ, if a final effluent COD of less than 120 mg/ℓ is to be produced. This is confirmed by the results depicted in Figure 2.

At the design feed rate of 15ℓ/sec this limiting COD of 520 mg/ℓ is equivalent to an organic loading of 0,37 kg COD/m^3d. This figure is considerably lower than the design loading of 1 kg COD/m^3d and confirms that it is not possible to produce an acceptable effluent while operating at organic loadings which are consistent with high rate filtration. For the treatment of domestic sewage, Bruce[5] quotes a limiting load of about 0,1 kg BOD/m^3d. Assuming a COD/BOD ratio of 2 : 1,[1] this agrees fairly well with the above conclusions.

Effect of recirculation

During the 1975/76 season a number of tests were undertaken in an attempt to establish the effect of varying the individual recirculation ratios. It is generally accepted that an increase in the recycle ratio results in improved performance, particularly in the treatment of strong wastes.[5]

No changes were detected in plant performance for recycle ratios of zero, 1 to 1 and 2 to 1. Physical limitations on the settling tanks precluded the use of higher recycle ratios.

Acknowledgements

The authors' thanks are due to the Felixton mill staff, particularly Mr G. Welman, for the considerable assistance which was rendered and for the bulk of the analytical results, to Mr L. L. Rennie for many helpful discussions and suggestions and finally to the Board of Directors of Huletts Sugar Ltd. for permission to publish this paper.

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APPENDIX

Sampling

Nutrient analyses were performed on snap samples taken as required. Composite hourly samples over a period of seven days were used for all COD analyses. These samples were preserved by the addition of 2 ml concentrated sulphuric acid per litre followed by refrigeration at 4°C.

Analysis

Full details of the methods used for the analysis of chemical oxygen demand (COD), free and saline ammonia and nitrates/nitrites are given in the relevant *Government Gazette*.[9] The initial ammonia removal step was omitted from the Kjeldahl determination[10] and hence the nitrogen figures quoted in the text include free and saline ammonia. Phosphates were determined by persulphate digestion followed by the vanado-molybdophosphoric acid colorimetric method.[10]