AEROBIC TREATMENT OF SUGAR MILL EFFLUENT WITH THE ADDITION OF NUTRIENTS

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Abstract

The suitability of the activated sludge process for the purification of sugar mill effluents was investigated, both on the laboratory and on the pilot scale. The process was found to be suitable provided additional nitrogen and phosphorus were added, and tentative design criteria for a full scale plant for a typical sugar mill are included.

Introduction

Sugar mill effluent containing dunder water has a high oxygen demand and may be classified as a strong organic waste. For this reason some form of pre-treatment is required before the waste is discharged to a local river or stream if the requirements of Water Act No. 54 of 1956 are to be met.

Mill effluents do not normally contain toxic materials and pollute only in the sense that the high concentrations of soluble carbohydrates in the waste provide a substrate for rapid biological growth in the receiving water body with consequent depletion of the dissolved oxygen due to bacterial respiration. The problem, therefore, is to reduce the concentration of oxidisable material in the waste to a low level before discharge. Since the waste primarily consists of organic compounds it should be amenable to biological degradation.

In the treatment of organic waste both aerobic and anaerobic organisms can be employed. With an anaerobic system dissolved oxygen is not required for the organisms and the degradable carbon is converted to carbon dioxide and methane as end products. In an aerobic system dissolved oxygen is required and the gaseous end product is carbon dioxide only.

Use of anaerobic degradation, usually by impoundment in lagoons, has been reported from India[2] and Puerto Rico[3] and a similar system has been tried in Northern Natal. The results obtained with these systems indicate that although substantial removals of oxygen demand can be obtained the final effluents will not meet three of the requirements of the General Standard for effluents, viz. a COD not exceeding 75 mg/l, suspended solids not exceeding 25 mg/l and a dissolved oxygen content not less than 75% of the air saturation value at the prevailing temperature, unless some form of final aerobic "polishing" of the anaerobic effluent is provided.

More recently work with aerobic activated sludge treatment has been reported from Australia[1]. The experiments were mainly of the batch feed type, concerned with determining the COD removed per unit of power consumption but the results indicated that the process would be capable of producing a high quality effluent. For this reason a research programme was undertaken using both laboratory and pilot scale equipment to determine whether the process could be used to produce a final effluent complying with the requirements of the Water Act and to establish the operating conditions that would be required.

Laboratory experiments

The aim of these experiments was to establish the permissible COD loading range and the influence of load factor on effluent quality and sludge settling characteristics, and also the effects of addition of supplementary nitrogen and phosphorus on these factors.

Materials

Dunder water obtained from a local mill three times a week was used for the study. Due to the very wide variation in COD concentration that occurred between batches (1 000 - 18 000 mg COD/l) a COD of 3 000 mg/l was adopted as an average value for experimental purposes, and dunder water supplies were adjusted to this value before use either by dilution with water or by addition of stronger dunder water or sucrose solution.

Analytical Methods

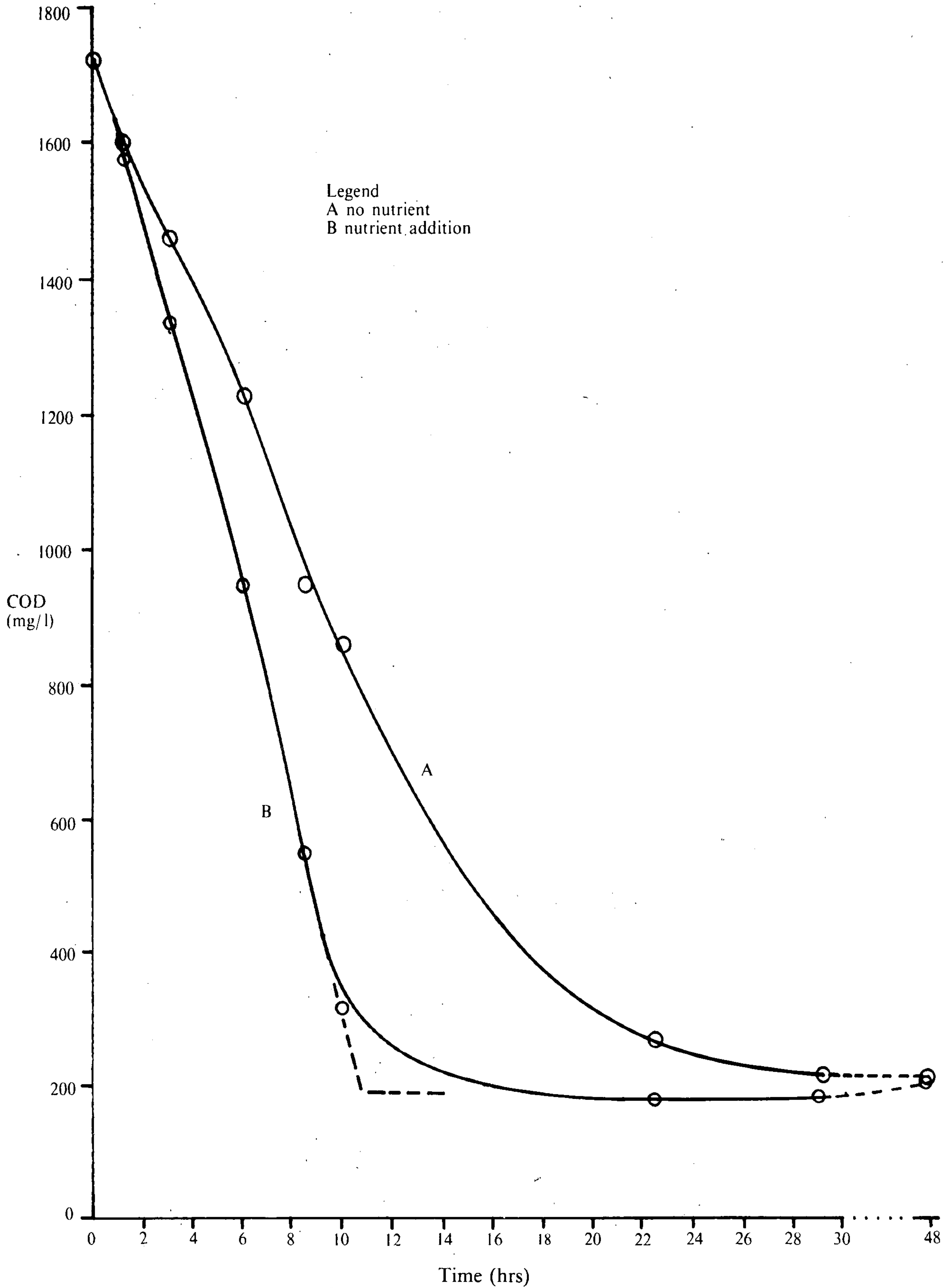
The analyses for Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Kjeldahl nitrogen were taken from Standard Methods [4], and for phosphorus and nitrogen from A Manual of Sea Water Analysis [5]. The Sludge Volume Index (SVI) was determined by settling for 1 hour in a 100 ml cylinder and noting the sludge volume: the suspended solids concentration was determined on the same sample and the SVI expressed as millilitres of sludge/g dry weight.

Batch feed experiments

Results and Discussion - To obtain an estimate of the optimum load factor and the effect, if any, of supplementary nutrient addition, batch feed tests using sludge pre-conditioned to dunder water substrate were carried out in aerated glass vessels. Equal volumes of dunder water were introduced to each vessel but extra nitrogen and phosphorus in the form of urea and potassium dihydrogen phosphate was added to one vessel to alter the COD:N:P ratio from 100:0,2:0,05 for dunder water alone to 100:4,2:0,8 in that with nutrients added.

Samples were withdrawn from each vessel at time intervals and clarified for analysis. This procedure was continued until the COD reached a minimum value and started to rise again due to autolysis of the sludge organisms.

Figure I



Batch feed tests with and without nutrients
Reduction of chemical oxygen demand with time

The decrease in soluble COD with time is shown in Fig. 1 and it is evident that the rate of COD removal with added nutrients was almost double that without nutrient addition, being approximately 150 and 80 mg COD/1 per hour on the linear portions of the curves. It is also evident that the COD removal curve with added nutrient was almost linear until a plateau was reached after 11 hours of aeration whereas the same plateau was only reached after 24 hours without nutrient addition.

The course of assimilation of nitrogen and phosphorus by the sludge organisms is shown in Figures 2 (a) and (b). In Fig. 2(a) with nutrient addition both Kjeldahl nitrogen and phosphorus concentrations decreased to low values within the first 10 hours and the rapid conversion of urea to ammonia and its subsequent assimilation by the sludge is evident. In Fig. 2(b) without nutrient addition there is little change in the initial low values. These results suggest that with nutrient addition, synthesis of new sludge becomes possible with incorporation of organic material (COD) whereas without nutrient addition synthesis is reduced and the rate of incorporation of oxidisable carbon compounds into new cellular material is limited.

From the curves shown in Fig. 1 it is possible to estimate the optimum load factor range from the expression

$$\text{Lf}_{\text{(optimum)}} = \frac{\text{Lf (Initial x 24)}}{\text{time to minimum COD}}$$

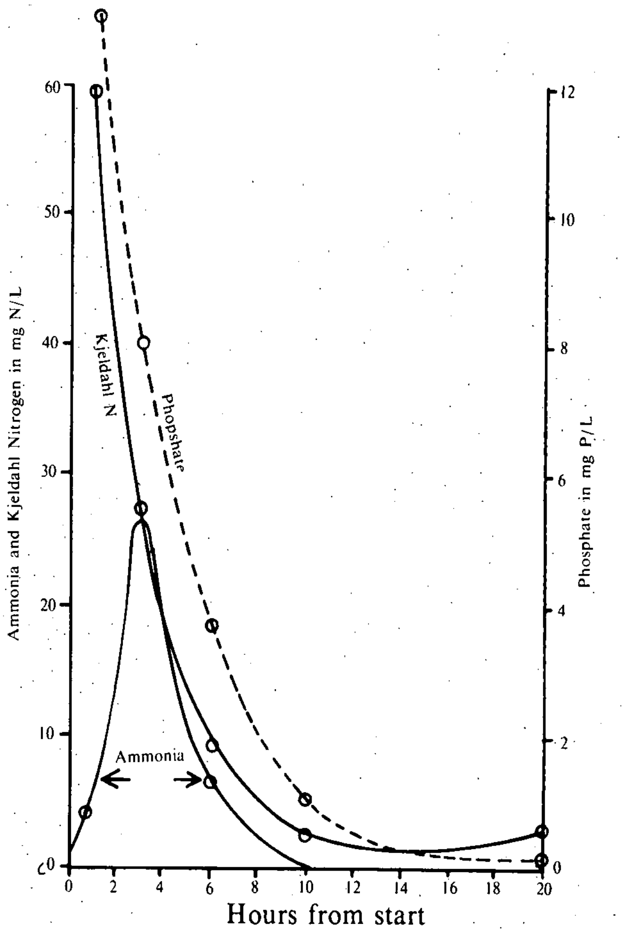


Figure 2 A: Batch tests with nutrient added changes in nutrient concentration with time

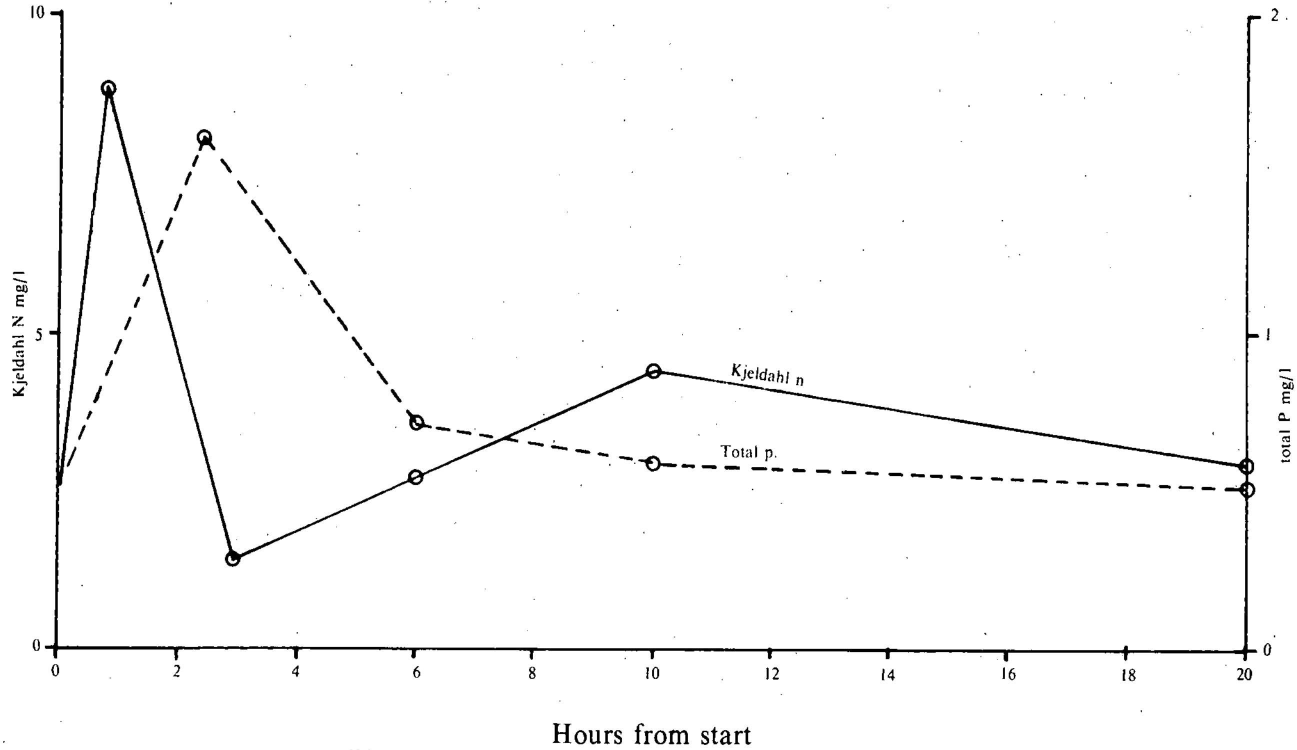


Figure 2 B: Batch tests with no nutrient added
Changes in nutrient concentration with time

with time in hours and Lf (load factor) in g COD/g MLSS/day.

(MLSS = mixed liquor suspended solids, i.e. sludge concentration) By assuming a zero order form of reaction and extrapolating the linear portion of the curve with added nutrients the following estimates were obtained:

	Lf (initial)	time to minimum COD(hrs)	Lf optimum
No nutrient addition	0,347	24—28	0,35—0,30
Nutrients added	0,347	11—16	0,76—0,52

To summarise, the batch feed experiments indicated that dunder water is not an ideal substrate for bacterial growth because it contains insufficient nitrogen and phophorus in relation to the quantity of biologically oxidisable organic compounds present. If this shortage is made good by nutrient addition then the rate of COD removal may be almost doubled.

Continuous Flow Laboratory Experiments

These experiments were conducted concurrently with a pilot scale unit at a local sugar mill (described later) in order to provide operational data for the pilot plant.

Apparatus

Two 6,5 litre aeration vessels were operated on a continuous feed basis, one of which was fitted with an effluent settlement and sludge return system as shown in Figure 3.

Adequate mixing and aeration of the sludge suspension was obtained using compressed air and sintered glass diffusers. Continuous dunder water input was obtained by time switch operated solenoid valves governing the supply from a constant head reservoir and dosing pipettes. The overflow from the aeration chamber was passed to a small settlement vessel from which the settled sludge was returned to the aeration chamber by periodic operation of a time switch controlled air lift system. A similar air lift system was used to

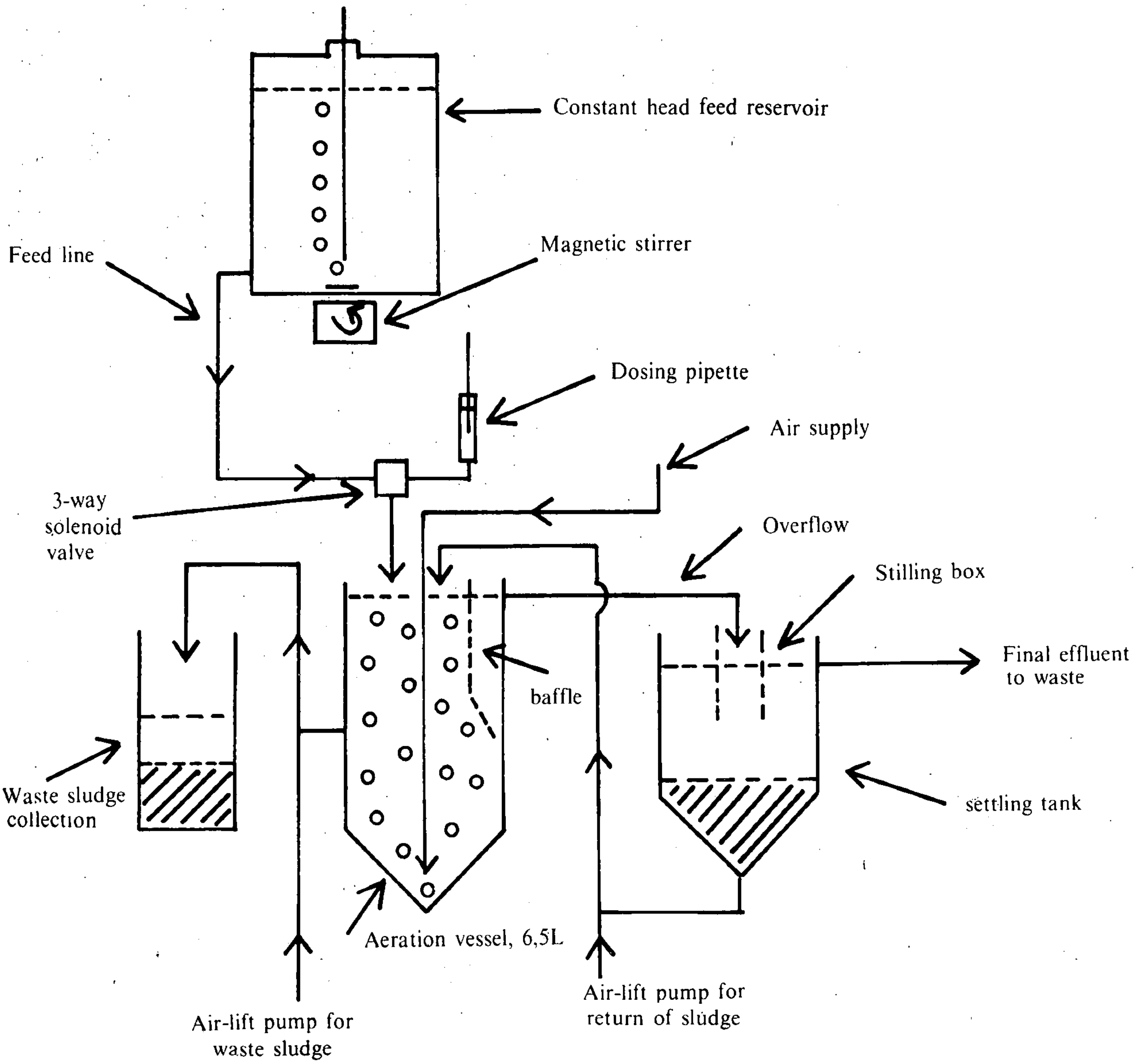


Figure 3 Diagram of laboratory apparatus.

remove a predetermined amount of excess sludge from the aeration vessel in order to maintain a constant sludge concentration of 4 000 mg/l during the experiments. This was particularly necessary at high loading rates in order to maintain a constant load factor.

Results

Operation without sludge return -

The purpose of this experiment was to determine the feasibility of waste treatment without return of settled sludge, but during 50 days of operation on an input of dunder water it was found that the sludge concentration in the aeration vessel could not be built up to more than 900 mg/l and tended to stabilise around 600 mg/l giving an effluent COD of 200 mg/l or more at load factors of 0,3 or above. Addition of nutrients in the latter stages of the experiment improved performance to some extent but it became obvious that the treatment capacity of the unit was limited by the inability to maintain a higher suspended solids concentration in the aeration vessel. The experiment was therefore terminated.

Operation with sludge return - Phase 1: Acclimation to Dunder Water Substrate, and Determination of Optimum Nutrient Ratio.

An initial mixed liquor suspended solids concentration of 3 000 mg/l obtained from a sewage treatment plant was acclimated to dunder water using a sewage/dunder water input with an increasing proportion of dunder water for 17 days at a load factor of 0,2 - 0,3. From the 18th day dunder water only, containing 3 000 mg COD/l was fed at load factors ranging from 0,3 - 0,5, a retention time of 2 days and a MLSS concentration maintained at 4 000 mg/l.

Soon after the addition of 100% dunder water the SVI rose rapidly (Fig. 4) and the sludge texture changed from a rapid-settling sludge to a suspension of fine particles that showed no evidence of settlement during the 1 hour period of the SVI determination. In consequence the effluent COD rose from less than 100 to more than 400 mg/l. Discontinuing the input for 1 day resulted in no improvement, whereupon, on the 25th day, nutrients were added to the dunder water input such that the COD:N:P ratio was 100:2,5:0,5. Within 2 days of resumption of the

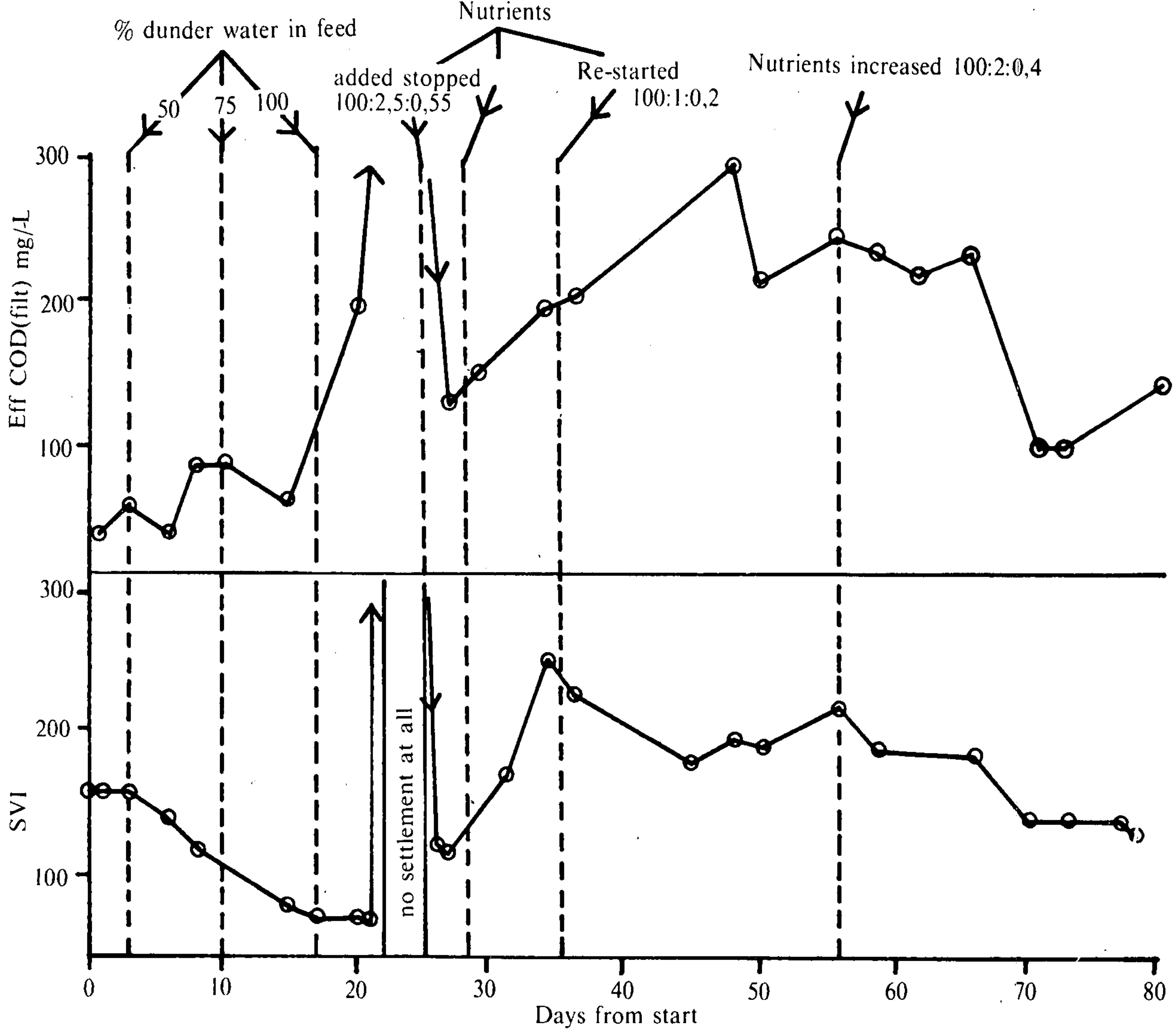


Figure 4 Variation of SVI and COD of effluent of laboratory unit from start

input the SVI had decreased to 120, sludge settlement was satisfactory and the effluent COD had fallen to 130 mg/l.

To confirm that the improvement was due to nutrient addition, no nutrients were added on the 28th day and the SVI immediately began to increase, reaching a value of 250 by the 34th day. During this period the nutrient ratios of the 2 batches of unsupplemented dunder water feed were

COD:N:P = 100:0,4:0,04
COD:N:P = 100:0,3:0,18

It was thus evident that the presence of adequate nitrogen and phosphorus was essential for the synthesis of a bacterial floc with satisfactory settling characteristics.

To determine the minimum nutrient requirements, nutrient addition was recommenced on the 35th day in the proportions:

COD:N:P = 100:1:0,2

As can be seen from Fig. 4 the SVI decreased to about 200 and the sludge settleability remained poor despite the fact that residual nitrogen and phosphorus was found in the effluent. On the 56th day the ratio was increased to 100:2:0,4 and soon afterwards a sharp decrease in both SVI and effluent COD was observed. From these results it appeared that the COD/nutrients ratio used was near to the optimum.

Operation of the unit was then continued for a period to confirm the stability of the system before use in the second phase of the investigation. During this time two air supply interruptions occurred and the sludge became anaerobic on both occasions. Recovery was achieved by discontinuing the input and aerating the sludge until the excess COD had been oxidised. By the 130th day of the operation the SVI and effluent COD had stabilised and the system was considered to be in a suitable condition for evaluation of the effects of changing load factor;

TABLE I

Average analytical and hydraulic data

						Effluent				% Reduction based on:			
Load Factor g COD /g MLSS/ d.	Temp. °C	Ret. time hrs.	No. ret. volumes	Feed mg/L		COD		BOD		COD		BOD	
				COD	BOD	Sett.	Filt.	Sett.	Filt.	Sett.	Filt.	Sett.	Filt.
0,38	23,9	45	11	3023	1479	—	80	—	8	—	97,4	—	99,5
0,59	23,5	31	16	2977	1700	97	75	13	8	96,7	97,5	99,2	99,5
0,83	24,4	22	15	2912	1696	107	82	17	9	96,3	97,2	99,0	99,5
1,13	26,2	16	15	2998	1798	108	77	14	4	96,4	97,4	99,2	99,8
1,43	25,8	12	16	3021	1680	97	85	14	8	96,8	97,2	99,2	99,5

TABLE II

Nutrient balance for periods of constant loading

Load factor g COD/g MLSS/d	Nutrients added to feed, mg/L		Average total in feed, mg/L		Filtered effluent mg/L			% Removal	
	N	P	N	P	Kjel-N	P	NO^3-N	N	P
0,38	60	12	70	18	5,0	7,0	12,0	76	61
0,59	60	12	70	18	3,5	6,2	1,0	94	66
0,83	60	12	70	18	2,2	4,8	0	97	73
1,13	90	18	100	24	19,0	5,5	1,2	80	77
1,13	90	18	100	24	6,0	2,3	0	94	90
1,43	90	18	100	24	2,5	1,2	0	97	95

Phase 2: Determination of Optimum Load Factor

During this experiment the load factor was varied from 0,4 to 1,4 and was held at each level for a period of time allowing at least II displacements of the aeration vessel volume to ensure establishment of equilibrium.

The effect of load factor on SVI, effluent COD and sludge growth is shown in Figure 5 and it is clear that the SVI is dependent upon the load since a minimum SVI of 53 was obtained at a load factor of 0,6 and the SVI subsequently increased with increasing load factor. From Table 1 it can be seen that the COD of the effluent changed very little despite the increase in load factor and that COD and BOD removals were not less than 96,3 and 99,0% respectively. The growth rate of the sludge expressed as a percentage rise per day from the base value of 4 000 mg/l increased with increasing load factor, as would be expected in view of the increasing amount of organic matter to be metabolised.

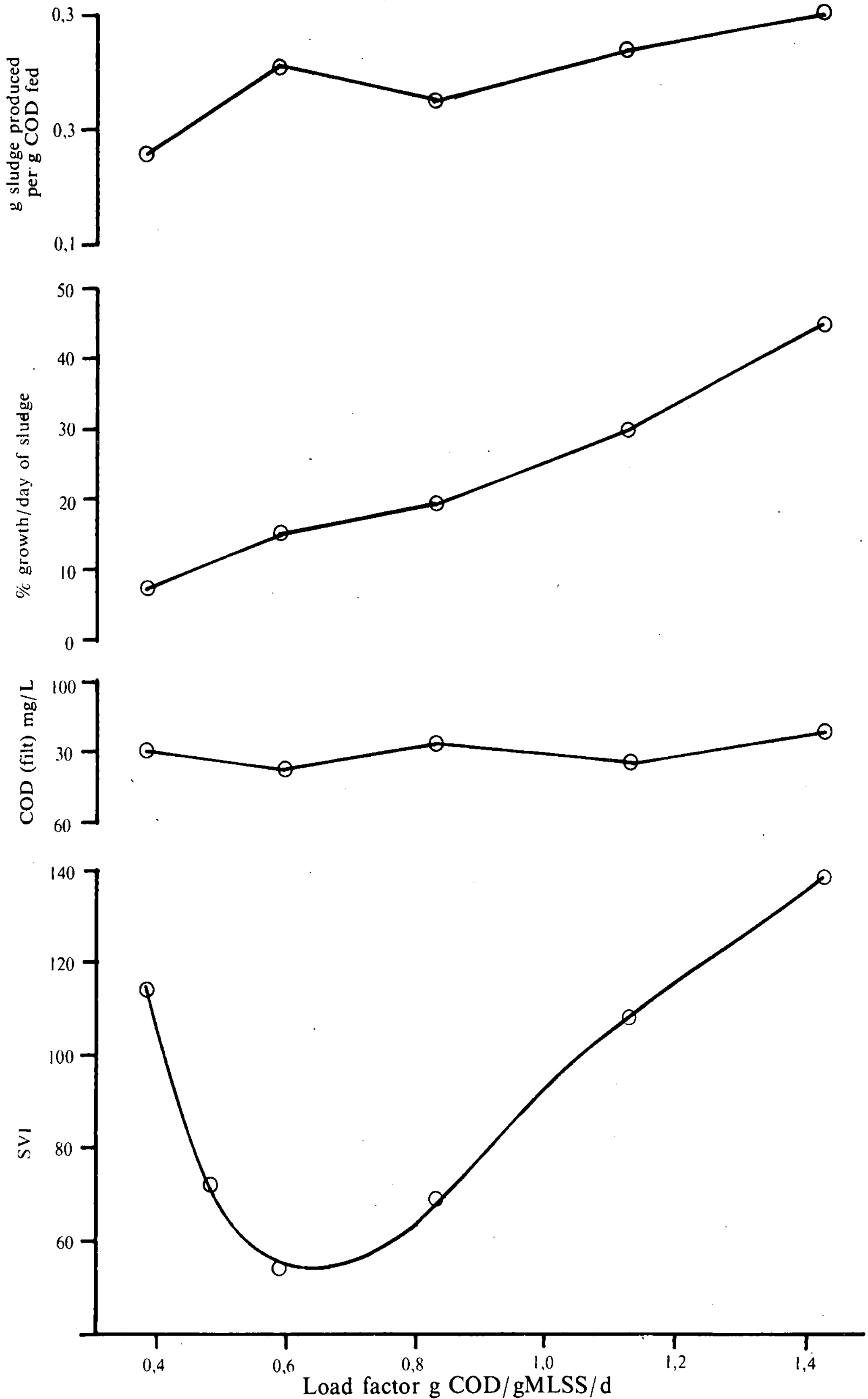


Figure 5 Variation of SVI, effluent COD and sludge growth with loading

The nutrient ratio COD:N:P of 100:2:0,4 used in the input was adequate up to a load factor of 0,83 but at this level 97% of the nitrogen was being taken up by the sludge growth (Table 2). For this reason the ratio was increased to 100:3:0,6 and this was shown to be justified since nutrient removals rose to the 90% level at load factors of 1,13 and 1,43

Variation of load factor, SVI and effluent COD during each run is given in Table 3. It may be seen that only at the lowest and highest loadings used did the upper limits of the SVI really represent a poor quality sludge. At mean load factors of 0,59 and 0,83 the spread of SVI values was not wide. The range of filtered COD values reported is considered to represent an effluent of acceptable quality.

Sludge Settlement

In Figure 6 are shown typical sludge settlement profiles at various load factors and a MLSS concentration of 4 000 mg/l. At a load factor of 0,6 the sludge compacted to 30% of the original volume in 10 minutes. At load factors of 1,1 or more the suspension of small sludge flocs produced settled much less rapidly.

COD:BOD Ratios -

The average COD:BOD ratio obtained from analysis of dunder water samples used in the experiments was 1,82:1 and this ratio can be used to calculate loadings in terms of BOD if required.

The COD:BOD ratio for the filtered final effluent was much higher, being 11:1. This ratio indicates that a high proportion of the chemically oxidisable material remaining in the effluent is not easily biodegradable.

TABLE III

Statistical data : Variation of loading, SVI and COD

Run	1	2	3	4	5
Load factor: mean	0,38	0,59	0,83	1,13	1,43
SD	0,022	0,024	0,024	0,28	0,118
n	21	21	13	10	7
90% limits	0,34-0,41	0,55-0,63	0,79-0,87	1,08-1,18	1,23-1,63
SVI : mean	114	53	68	109	137
SD	17	4,2	11	13	19
n	9	11	6	8	7
90% limits	86-142	46-60	50-86	87-131	117-175
Eff. COD : mean	80	75	82	77	85
(filt.) SD	28	25	7,2	9,7	16
n	8	8	6	7	7
90% limits	34-126	33-117	70-94	61-93	58-112

Note: 90% limits means that 90% of the results fall within the limits.

Discussion

From the results presented it was concluded that a dunder water input of 0,6 g COD/g MLSS/d is the optimum loading since settlement of the sludge from the treated effluent was most efficient at this level. Selection of this load factor would allow a safety margin in that a temporary overload should not effect performance, since a good effluent was produced at a load factor of 1,4 although sludge settlement was less satisfactory. A further reason for selecting this value is the fact that the experiments were made at temperatures ranging from 23 to 26°C. Outdoor operating temperatures might fall to 15°C during the winter months and, since a decrease of 10°C usually halves the rate of biochemical reactions, this would be equivalent to doubling the load factor to a value of about 1,2 which also lies within the range in which satisfactory operation is possible.

It has been shown that a settled effluent COD and BOD of the order of 96 and 13 mg/l respectively can be produced by aerobic treatment with nutrient addition. If the ultimate BOD of the effluent is conservatively assumed to be twice that of the 5 day BOD, this would represent a long term BOD of only 26 mg/l. It therefore follows that the difference between the COD, 97 and 26 mg/l, i.e.: 71 mg/l represents a biologically unoxidisable component of the total oxygen demand which would not be expected to cause any depletion of dissolved ovygen in a water body receiving the treated effluent.

Pilot Plant Operation

Description

The aeration basin had a water surface area of 58 ft (17,7 metres) x 56 ft (17,0 metres) sloping to a bottom area of 34 ft (10,4 metres) x 32 ft (9,8 metres) with an operating depth of 6 ft (1,9 metres) and an operating volume of 88 000 gallons (400 m^3). A 7½ hp (5,6 kw) Simplex aerator was centrally mounted and operated without a draught tube. The flow into the pond was controlled by adjustment of a 90° V-notch mounted in a constant head tank;the supply of dunder water came from a large concrete tank which, however, was not mixed in any way and consequently stratification of incoming waste

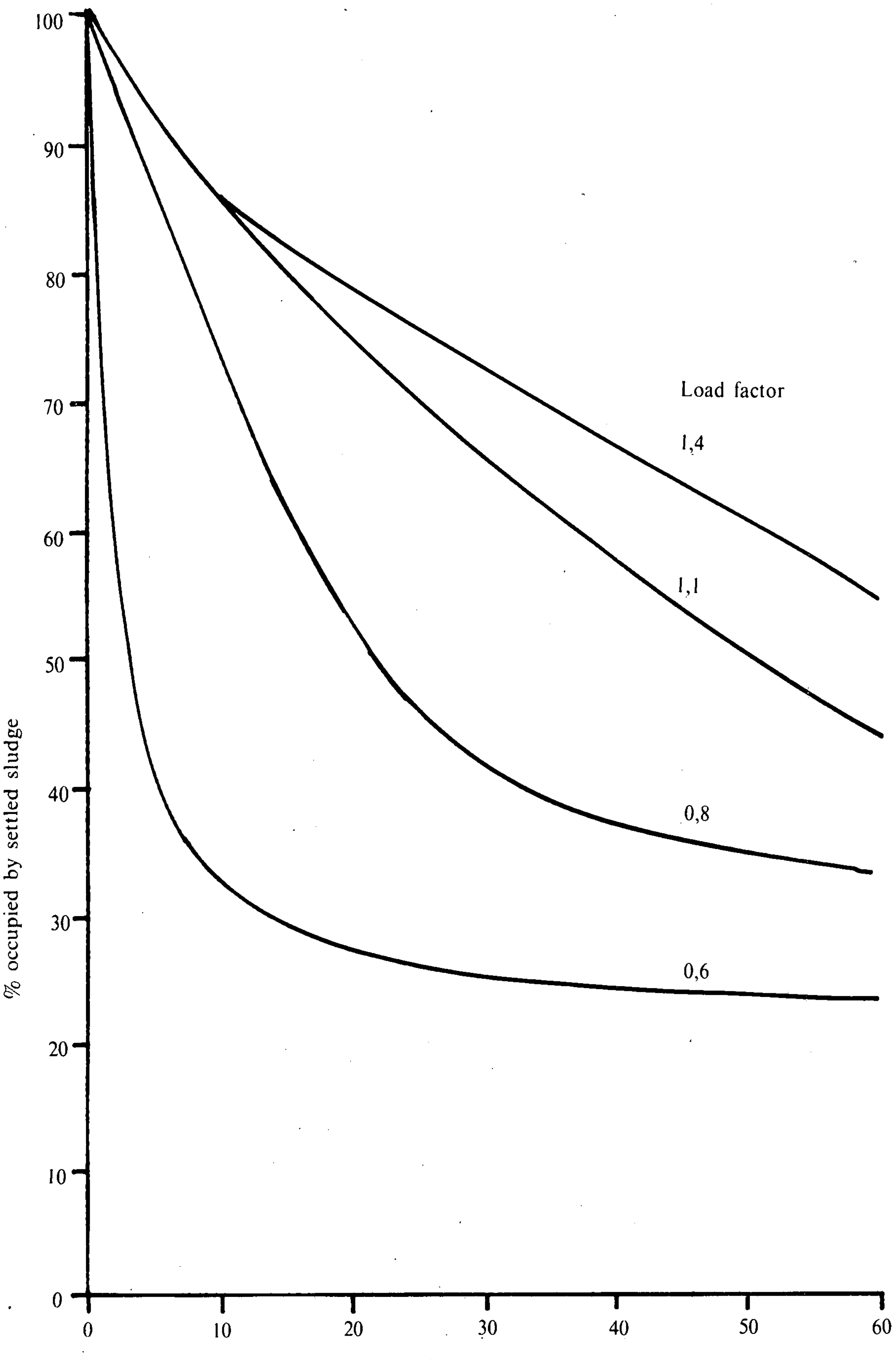


Figure 6 Comparison of settling profiles at different load factors

could occur. Two settling ponds were provided but initially there was no provision for continuous sludge return.

Results

For the first two weeks of the study the plant received sewage septic tank effluent and dunder water at a rate of 20 000 gallons (90,9 m^3)/d. Although the pond was innoculated with activated sludge from a sewage treatment works there was no appreciable build up of suspended solids above a level of 300 mg/l and the effluent produced had a COD of greater than 1 000 mg/l. A 10 000 gal (45,5 m^3) sludge settlement tank was therefore incorporated into the system which allowed sludge to be settled from the effluent and returned to the aeration basin.

After several weeks of operation with a dunder water input of 10 000 gals (45,5 m^3)/d, equivalent to a retention time of 8,8 days, the MLSS concentration in the aeration basin had risen to 3 000 mg/l and the investigation was then continued. Samples of the dunder water input were taken at hourly intervals and combined to give 24 hour composite samples for analysis. The fluctuation in the strength of the samples was very wide with COD values ranging from 1 000 - 10 000 mg/l or more. Figure 7 gives the average COD values for the different days of the week and maximum and minimum values; it is interesting to note that peak values occur on Mondays and Tuesdays, suggesting increased loss of oxidisable material from the mill during week-end operations. As a result the daily load on the pond was never constant and conditions for experimental studies were far from favourable.

During the first week of continued operation an effluent of satisfactory quality was produced since the filtered COD was less than 100 mg/l. During this period the daily load rose from 300 to 600 lb (136-272 kg) COD/d. When the loading further increased to 650 lb (295 kg) COD/d the effluent quality showed signs of deterioration by increasing in COD value. Unfortunately further observations during this period were precluded since it was noted during an inspection visit that the water level in the basin was higher than normal, due to a partial blockage in the outlet pipe. This resulted in partial submergence of the aerator rotor thus decreasing the efficiency of oxygen transfer. Despite a subsequent reduction in loading the effluent quality continued to deteriorate, becoming very turbid, and the contents of the basin became anaerobic and odorous a few days later. It is difficult to decide whether failure of the system should be attributed to simple overloading when 600 lb (272 kg) COD/d was exceeded or to reduced oxygen input by the aerator causing a build up of COD or a combination of both factors. A further complication was the high retention time of 8,8 days in the basin since this may have caused a time lag before the effects of overloading became detectable in the effluent quality.

Recovery of the system required 4 days but soon after feeding was resumed shock loads of 772 and 1 178 lbs. (350 and 534 kg) COD/d were passed to the basin which resulted in the return of anaerobic conditions. Although short periods of trouble free operation were subsequently obtained little data of any value was obtained except that an average load of 300 lb (136 kg) COD/d did not exceed the capacity of the aerator.

Nutrients in the form of urea and fertiliser grade superphosphate were added to the system from an early stage, in accordance with the information gained in the laboratory experiments, and the settleability of the sludge was always good during the relatively short periods of trouble free operation, as determined by the SVI test which gave values ranging from 50 to 90. This observation indicates that in a properly operated system settlement and return of solids should not present difficulties.

The load factor throughout the entire period ranged between 0,03 and 0,23 and since it was found in laboratory tests that much higher load factors could be maintained, it was concluded that the pond was never overloaded in this respect but that the aerator was too small to provide the oxygen required.

Oxygenation Capacity of Aerator;

As a result of the unfavourable experimental conditions the amount of usable data is limited but it appears reasonable to conclude that the oxygenation capacity of the aerator became a limiting factor in the region of 600 lb (272 kg) COD/d. Since the aerator was powered by a 7½ hp (5,6 kw) motor the treatment capacity of the unit is calculated to be 80 lb COD/hp/d (48,5 kg/kw/d).

A complication is the fact that at low loadings and long retention periods the suspended solids and colloidal material adsorbed onto the sludge floc undergoes extensive oxidation and, in consequence, the oxygen requirement may be more than 1 g O_2/g BOD removed. Conversely, at high load rates and low retention times the degree of oxidation is less compete and less than 1 g O_2/g BOD removed may be required. Using a table of load factor versus oxygen requirement in terms of BOD provided by Vosloo[6] for the activated sludge treatment of sewage and converting to COD using the COD:BOD ratio of 1,82:1 as determined for dunder water, it is calculated that at load factors of 0,18 g COD/g MLSS/d or less, as was usually the case in the aeration basin, the oxygen requirement will be 0,88 lb O_2/lb COD removed. It follows that to remove 80 lb COD the amount of oxygen required will be 80 x 0,88 = 70 lb O_2, and it is concluded that the 7½hp aerator was capable of supplying 70 lb O_2/hp/d.

The estimated oxygenation capacity of the aerator in de-oxygenated water at 10°C is given as 3,5 lb O_2/hp/hr (2,1 kg O_2/kw/hr) or 84 lb O_2/hp/d (51 kg O_2/kw/d) by the supplier. Bearing

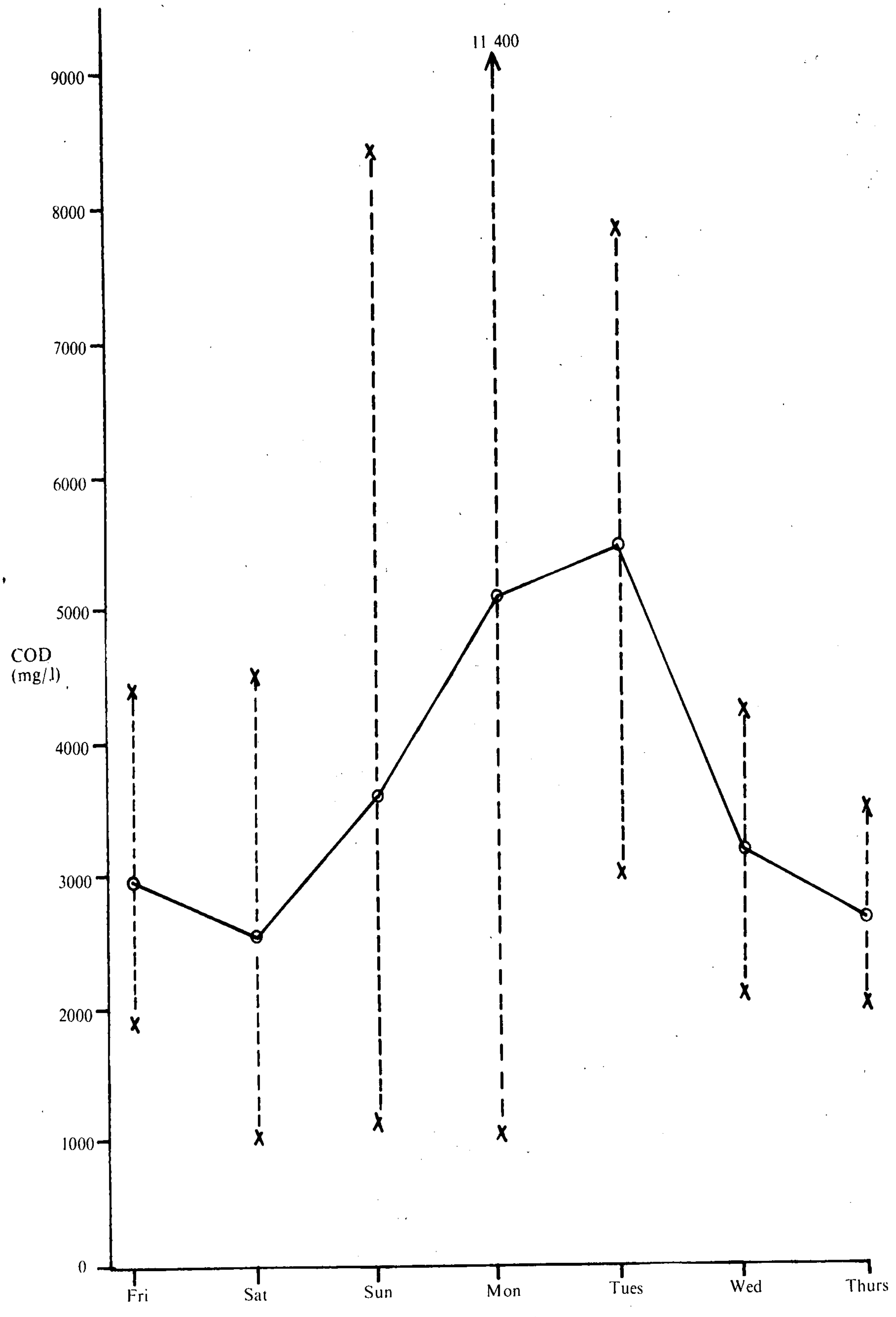


Figure 7 Average COD of dunder water for days of the week

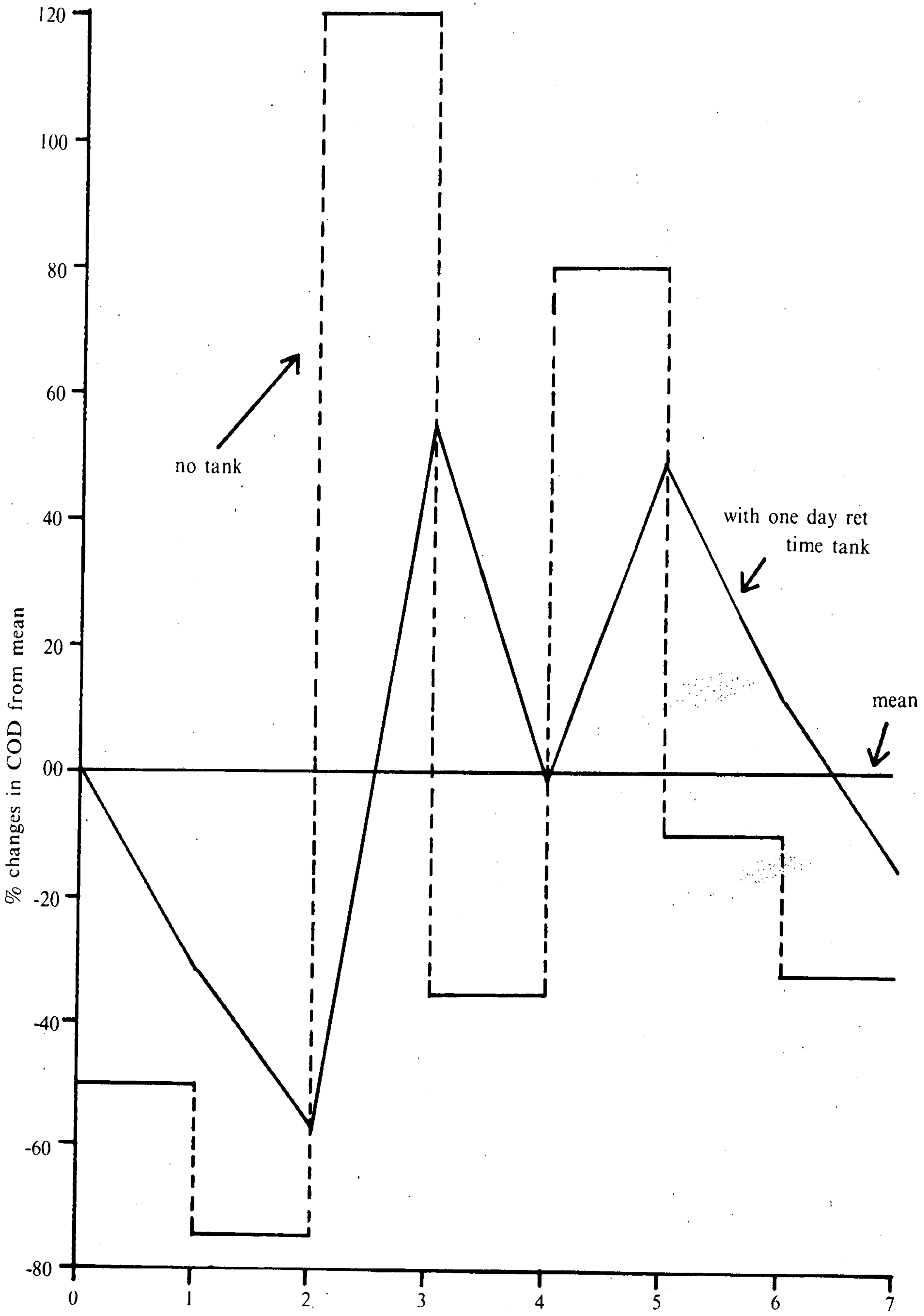


Figure 8 Variation of strength of dunder water during typical week with and without a holding tank

in mind the increased solubility of oxygen in water at 10^{0}C and the increase in transfer rate with decreasing saturation there appears to be reasonable agreement between the manufacturers estimate and the observed transfer rates.

Disposal of Excess Sludge

There are various methods of conditioning excess sludge for disposal that usually have the object of producing an odour free sludge that is sufficiently solid for transportation.

It appears, however, that this may not be necessary with the excess sludge produced from dunder water treatment since 60 gallons of thickened sludge applied to a 1 m^2 drying bed containing 7,5 cm of crushed stone overlain by 10 cm of builder's sand standing in the open dried to a solid easy to handle, in less than 12 days. Daily analysis showed an approximately linear decrease in water content from an initial 98,5% to 33,0% on the 12th day by which time the sludge had dried to a hard cake containing 3,7% nitrogen and 0,8% phosphorus. No objectionable odours were detected during the drying period. In practice the liquid draining from the sludge would be recycled through the plant and would probably contribute a part of the required nutrient supplement.

Conclusions:

1. The activated sludge treatment of dunder water is feasible.
2. Dunder water is lacking in nitrogen and phosphorus and their addition can lead to an increase in the overall reaction rate and is necessary to produce a settleable sludge floc.
3. At a temperature of 25^{0}C the optimum load factor is in the region of 0,6 g COD/g MLSS/d.
4. A good quality effluent is produced with an average settled COD and BOD of 97 and 13 mg/l respectively.
5. The excess sludge produced may be successfully dewatered on drying beds in a period of 12 days.

Acknowledgement

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Appendix

Tentative design criteria for treatment of total dunder water flow from the Darnall Sugar Mill

Basic Data - Dunder Water
flow = 160 000 gal/d (727 m^3/d)
average COD = 3 700 mg/l
total load = 5 920 lb/d (2685 kg/d)

Power Requirement for Oxygen Transfer

The optimum load factor was found to be 0,6 g COD/g MLSS/d and at this loading the oxygen requirement would be approximately 0,55 lb O_2/lb COD removed (from Vosloo[6]). Assuming an oxygen transfer rate of 70 lb O_2/hp/d (42,6 kg O_2/kw/d), as was found in practice, it follows that an aerator of the type used should be capable of removing:

$\frac{70}{0,55}$ = 127 lb COD/hp/d (77 kg COD/kw/d)

and to treat the total dunder water flow the average power required would be $\frac{5\,920}{127}$ = 47hp
or 35 kw

It should be borne in mind that the above power requirement is based on an average value for dunder water but, as has already been mentioned, the COD fluctuates widely and may easily be more than double that of the average value for a day, in which case extra power in the form of a standby aerator would need to be brought into operation in order to prevent development of anaerobic conditions. Clearly, if a holding tank for the incoming dunder water was provided and the contents properly mixed, then, depending upon the size of tank, a degree of smoothing of the COD fluctuations would be obtained. In order to give some idea of the potential value of a holding tank, the following hypothetical case is given.

Assume that an aeration basin is operating at its design loading, i.e. fully utilising 47 hp (35 kw), and then the strength of the dunder water flowing into the holding tank suddenly doubles for one day. Since the contents are mixed the feed strength will slowly rise and therefore extra aeration will be required; how much extra, in terms of horsepower, will be needed by the end of the day?

Retention Time in Holding Tank	Extra Power Required
Nil	100% immediately
1 day	up to 60%
2 days	up to 40%
3 days	up to 28%

While a holding tank is considered necessary it would be unwise to install a tank with too long a retention time as it has been noted that upon storage dunder water begins to ferment, particularly if sewage bacteria are present.

The smoothing effect of a one day retention holding tank on a typical set of dunder water COD values for 1 week is illustrated in Figure 8 where the percent change from the mean value is given. It is evident that when the COD values rapidly changed between day Nos. 1 and 2 from -76% to + 120% of the mean, the change in COD contents of the holding tank would have been gradual, rising from - 58% to + 52%, i.e. the change in strength of the dunder water entering the aeration basin would be much reduced.

Volume of Aeration Basin

The volume of the aeration basin required is dependent upon the operational MLSS concentration in the basin. Also, the maximum concentration that may be maintained in the basin, without loss of sludge in the effluent from the settling tank, is dependent upon the expected SVI of the sludge and the sludge return ratio to be practiced.

From the fact that in a dynamic system the weight of suspended solids leaving the basin (overflow to the settling tank) must equal that being returned (settled sludge), the following relationship may be derived, assuming that the sludge will settle at least as well as in the SVI test.MLSS (maximum in basin) $= \frac{p \times 10^6}{(p+1) \times SVI}$

where p = sludge return ration i.e. volume of $\frac{\text{returned sludge}}{\text{volume of feed}}$

Clearly the lower the SVI the more sludge the aeration basin can hold and as p is increased so the MLSS will increase but the increase will be partially counteracted by a lesser degree of compaction of the sludge in the sludge settling tank due to the decrease in retention time.

As already mentioned, the SVI of the sludge in the laboratory tests at the optimum load did not exceed a value of 100 but with varying loadings, as would happen in practice, high SVI values may be expected. An SVI of 120 is considered the limiting value for a sludge with satisfactory settling characteristics and if this value is substituted in the formula and a sludge return ratio of 1 assumed, it can be calculated that a maximum concentration of approxiamtely 4 200 mg/l MLSS can be maintained in the aeration basin.

If a working level of 4 000 mg/l MLSS is adopted, as was found to be satisfactory in the laboratory, the following values may be calculated:
Operated at a load factor of 0,6

$\frac{5\ 920}{0,6}$ = 9 867 lb (4 475 kg) MLSS would be requried in the system and the volume of the aeration basin would be

$\frac{9\ 867 \times 10^6}{4\,000 \times 10}$ = 246 675 gal (1 121 m³)

$\frac{246\ 675}{160\ 000} \times 24$ = 37 hours in the basin.

Dimensions of the Settling Tank

The upward velocity in the settling tank should not exceed 3 ft/hour; if designed for a velocity of 2 ft/hr the area of the tank can be calculated

$\frac{160\ 000}{6,24 \times 24 \times 2}$ = 534 ft² (49,6 m²)

With a depth of 9 ft (2,74 m), excluding the cone, the volume would be approximately
30 000 gal (136 m³)

With a sludge return ratio of 1 the retention time in the tank would be of the order of 2,5 hours which would be expected to be adequate.

Sludge Growth and Excess Disposal

At a load factor of 0,6 and with a MLSS of 4 000 mg/l the growth was found to be approximately 15% per day (Figure 5). In order to estimate the volume of settled sludge to be discarded from the base of the settling tank, it must be assumed that the MLSS will settle at least as well in the settler as in the SVI test. For an SVI of 60, the sludge layer represents 24% of the total volume after 1 hour. It follows that the volume to be wasted daily would be:

$\frac{15 \times 246\ 675 \times 24}{100 \times 100}$

= 8 860 gal/d (40,2 m³)
with a dry weight of 1 480 lb (671 Kg).

It appears from the foregoing that the sludge may be successfully dewatered to a form easy to handle in a period of 12 days.

Supplementary Nutrients

At the optimum load factor the addition of nitrogen and phosphorus to the feed such that
COD:N:P = 100:2:0,4
was found to be adequate; while more than 90% of the nitrogen was removed only 66% of the phophorus was utilised (Table 2) and it is therefore assumed that the latter addition may be reduced to give a ratio of
COD:N:P = 100;2:0,24 in the feed.
For a daily load of 5 920 lbs COD this would mean the addition of

$\frac{5\ 920 \times 2}{100}$ = 118,4 lb N(d (53,5 kg N/d

$\frac{5\ 920 \times 0,24}{100}$ = 14,2 lb P/d (6,4 kg P/d)

and the N/P ratio would be 8,4

Urea as a nitrogen source and potassium dihydrogen phosphate as a phosphorus source were found to be satisfactory, but other materials may prove to be equally suitable.

Some idea of the size of plant needed to treat the total flow of dunder water has been given but it should be realised that the oxygenation capacity of the Simplex aerator under operating conditions is still somewhat uncertain and further data on this aspect would be desirable.