EXPANSION OF NOODSBERG EFFLUENT PLANT - UTILISING A TRICKLING FILTER

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Abstract

The effluent treatment plant at Noodsberg (NB) was expanded in 1990 by installing a biological trickling filter between the existing anaerobic dam and Pasveer ditch (extended aeration plant). This trickle filter, besides contributing directly to the Chemical Oxygen Demand (COD) removal also enabled improved performance of the anaerobic dam and the Pasveer ditch thereby ensuring that the effluent quality is now consistently better than the General Water Standards. The effect and contribution of the trickling filter towards solving Noodsberg's effluent problem is discussed.

Introduction

From the time of the installation of the Pasveer ditch, in 1977, the NB effluent plant consisted of a three-stage treatment. Firstly, anaerobic treatment in an open pond, secondly extended aeration by way of a Pasveer ditch and thirdly final stabilisation in an open aerobic holding dam. A schematic representation of the layout is shown in Figure 1. The plant was designed to treat a loading of approximately 1 200 kg of COD per day with a target final concentration of 120 mg/lCOD at a flow rate of 27 m^3 per hour.

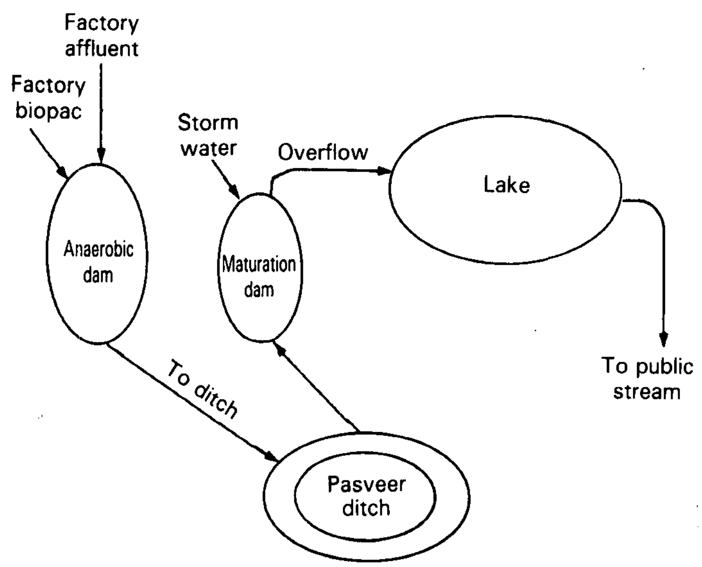

FIGURE 1 Effluent treatment plant — Noodsberg (before expansion).

Between 1983 and 1987 NB's crushing rate was gradually expanded from 260 to 300 tons cane per hour (TCH). In 1982 a 40 ton per hour back-end refinery was commissioned which was expanded to 50 tons per hour in 1986. All these expansions and additions caused the effluent load to increase to such an extent that the existing treatment facilities became inadequate. Furthermore, the COD standard for final effluent was reduced from 120 mg/l to 75 mg/l in 1984.

A study of the analytical results (Table 1) from the plant revealed that because of the overloading very little COD was removed by the anaerobic dam, and that the Pasveer ditch received a COD load of up to 1 330 kg per day, which was well above its design capacity of 990 kg COD per day. It was therefore obvious that the plant capacity needed to be expanded and the Sugar Milling Research Institute (SMRI) was requested to assist with this task.

SMRI recommendations

The recommendation of the SMRI was that the effluent treatment plant be expanded by the installation of a trickling filter between the anaerobic dam and the Pasveer ditch, with part of the outflow from the filter being recirculated back to the anaerobic dam (Purchase, 1989).

Reasons for the recommendation are set out below.

(a) A major problem with Pasveer ditches is the periodic loss of the activated sludge that occurs which leads to a drop in performance because of inadequate biological activity. This loss takes place because of a deterioration in the settling properties of the sludge (sludge bulking) which leads to a carry-over of sludge in the treated effluent leaving the ditch. From past experience serious sludge bulking problems have been found to occur at NB at least once a year. In a trickle filter the sludge is fixed to the rocks (filter media) and cannot be washed away.

(b) Although the capital cost of a trickling filter is slightly more than that for a Pasveer ditch (Bruijn, 1975), it has the distinct advantages of being much more stable, less susceptible to load fluctuations and much easier to operate. Practical experience of the minimal attention and ease with which plants of this nature can be operated had already been gained at NB, which operates two biofilters treating domestic effluent.

(c) The possibility of increasing the capacity of the Pasveer ditch by increasing the aeration was considered as an option but not recommended. This was because in general it was the low sludge concentration rather than the degree of aeration that limited the performance of the ditch.

(d) With a trickle filter the overloaded anaerobic dam would benefit from the recirculation. The reason for this is that inhibitory organic acids which accumulate in an overloaded anaerobic system are readily oxidised in the aerobic conditions of the trickle filter. By combining the two systems the overall load in the anaerobic dam is reduced which together with the detoxification gives increased biological activity.

(e) The trickle filter would also assist in curtailing the sludge bulking problem of the Pasveer ditch. This action is achieved when pieces of sludge or humus (which form when excessive growth of the biological film takes place in the interstices of the filter media) are washed downwards and pass out of the trickle filter with the effluent and assist in forming a better settling sludge in the Pasveer ditch.

Table 1

Summary of COD analyses at Noodsberg in 1988 and 1989

Month		Effluent - chemical oxygen demand results (mg/l)				Percent removal of COD from the Pasveer ditch
		Into the anaerobic dam	Into the Pasveer ditch	Out of the Pasveer ditch	Out of lake	
July	'88	839	763	478	202	37,4%
August	'88	1 110	1 320	473	250	64,2%
September	'88	446	1 007	194	125	80,7%
October	'88	498	990	113	115	88,6%
November	'88	956	1 103	145	110	86,9%
December	'88	1 392	1 140	144	95	87,4%
Mean	'88	874 *	1 054 *	258	150	75,5%
April	'89	1 165	986	366	120	62,9%
May	'89	1 467	1 245	127	99	89,8%
June	'89	1 200	1 308	132	105	89,9%
July	'89	1 150	1 082	95	99	91,2%
August	'89	840	940	39	65	95,9%
September	'89	1 200	977	32	45	96,7%
October	'89	840	981	58	50	94,1%
November	'89	1 250	1 200	139	59	88,4%
Mean	'89	1 139 *	1 090 *	124	80	88,6%

Average volume of effluent in 1988 was 42 m^3 per hour.
Average volume of effluent in 1989 was 36 m^3 per hour.
* When sampling is not continuous it is common to find higher concentrations at the outlet than at the inlet to the anaerobic dam because slugs of high COD escape sampling at the inlet.

Overview of the recommended system

A schematic representation of the recommended system's layout is given in Figure 2. The expanded treatment system was designed for the anticipated conditions and performances as set out below.

(a) **Effluent from the factory:** 50 m^3/hour at 1 400 mg/l COD, giving a loading of 1 680 kg COD/day.

(b) **Anaerobic dam:** With the detoxification provided by the recirculation a removal of between 300 and 600 kg COD per day (20-35%) was predicted.

(c) **Trickle filter supply pump:** 180 m^3/hour.

(d) **Recirculation pump:** 120 m^3/hour.

(e) **Trickle filter:** Removal of between 320 and 640 kg COD per day (20–40%).

(f) **Pasveer ditch:** Removal of between 440 and 760 kg COD per day. Practical experience had shown that it was difficult to achieve acceptable performance from the ditch at the originally designed loading of 990 kg COD per day.

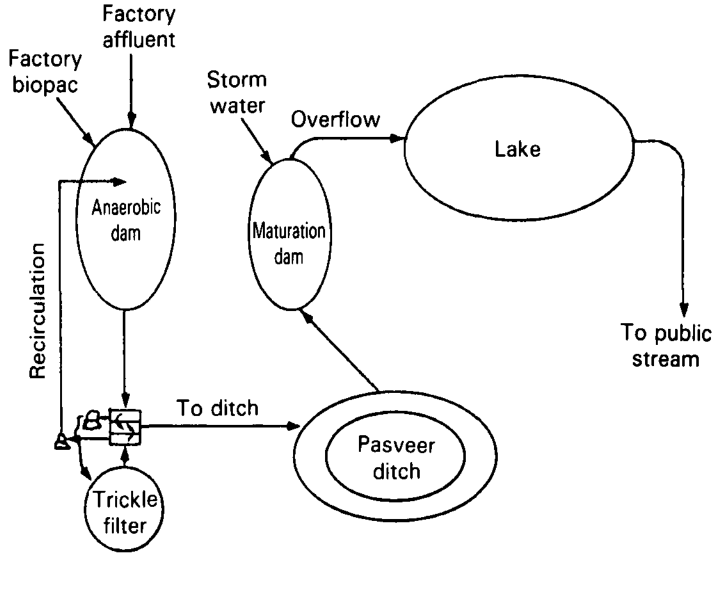

FIGURE 2 Effluent treatment plant — Noodsberg (after expansion)

Descriptions of the new trickling filter

The filter consists of a reinforced circular concrete tank which has an internal diameter of 16,5 m and is 2,5 m deep. The underdrain system and filter media support flooring is provided by means of half-round interlocking calcamite plastic aeration tiles laid radially. A central column supports the distributor centre mast with the distributor rotary arm propelled by hydraulic jet action. The filter medium consists of two layers of rock piles. The bottom layer consists of 150 mm diameter handstones to a height of 650 mm giving a volume of 152 m^3. The top layer consists of stones 38 mm in diameter with a depth of 1,5 m and therefore containing 360 m^3 of stones. The total capital cost of this installation together with the anaerobic dam outlet modifications was R620 000,00.

Plant performance

Plant operation during the 1990 season

A summary of the COD results obtained during the 1990 season is given in Table 2. The trickle filter was completed and commissioned in mid August 1990. By the end of August a COD removal of 15% was being achieved. The filter performance continued to improve right through to the end of the season with the recirculation lowering the COD level in the anaerobic dam. The COD in December was high due to returns from end of season factory wash down.

Table 2

Summary of COD analyses at Noodsberg in 1990

	Factory effluent - COD results (mg/l)					Percent removal of COD from	
	Trickle filter		Pasveer ditch		Out of lake	Trickle filter	Pasveer ditch
Month	In	Out	Into	Out of			
June			1 029	136	43		86,8
July			1 001	70	37		93,0
August	1 093	934	934	102	36	15	89,0
September	1 102	832	832	78	50	25	90,6
October	991	771	771	58	65	22	92,5
November	866	583	583	57	57	33	90,2
December	1 397	1 061	1 061	56	56	24	94,7
Mean	1 090	866	887	80	49	24	90,9

Average volume of effluent into the trickle filter was less than 80 m^3 per hour.
Average volume of effluent into the Pasveer ditch was 36 m^3 per hour.

As with any new plant there were a few initial problems.

(a) **Outlet line from trickle filter.** On start up it was found that the outlet from the trickle filter was undersized and could handle less than 100 m^3 an hour. This, of course, meant the feed to the filter had to be throttled back accordingly. This reduced flow resulted in partial ponding of the filter bed. The ponding was caused by blockages resulting from excessive biological growth on the rocks. With trickle filter COD loadings above 0,4 kg/m^3/day the biological growth on the rocks tends to be so fast that blockage of the filter takes place unless the hydraulic load is above 10 m^3/m^2/day (Purchase, 1989), in which case excess growth is flushed out of the system. The original 180 mm diameter outlet pipe was replaced by a 315 mm diameter pipe during the 1991 off-season. This enabled the flow to the trickle filter to be operated thereafter at a higher rate and resulted in the elimination of the ponding problem.

(b) **Instrumentation and control.** The new installation provided for the effluent flowing out of the anaerobic dam to be collected in a suction pit, which could overflow directly into the Pasveer ditch. The line feeding this pit was provided with a valve which would be automatically shut off in the event of a power failure. This shut off facility proved unreliable and resulted in massive overloading of the Pasveer ditch on a number of occasions. The problem was corrected by replacing the suction pit of the filter supply pump with a straight through pipe thereby eliminating the need for a flow level control.

Plant operation during the 1991 season

A summary of the COD results obtained during the 1991 season is given in Table 3. This was the first full season of operation for the trickle filter. A gradual increase in COD removal across the trickle filter was obtained over the season, reaching up to 40% in the latter part. This COD reduction together with the detoxifying effect of the recirculation resulted in a drop of more than 28% in the COD level of the effluent leaving the anaerobic dam from May to November. For the first time in years, the treated effluent leaving the Pasveer ditch was within the General Water Standards.

The contribution of the trickle filter to containing sludge bulking is hard to assess, as some sludge bulking did occur but the problem was not as severe as previously experienced.

The only other problem encountered during the 1991 season was with dead leaves, twigs and other matter from the anaerobic dam frequently blocking the distributor outlet of the trickle filter and the supply pump impellor thereby decreasing throughput to the filter. This problem was eliminated by inserting an additional, finer screen at the anaerobic dam discharge point.

Table 3

Summary of COD analyses at Noodsberg in 1991

	Factory effluent - COD results (mg/l)					Percent removal of COD from	
	Trickle filter		Pasveer ditch		Out of lake	Trickle filter	Pasveer ditch
Month	In	Out	Into	Out of			
May	939	689	689	54	42	27	92
June	969	679	679	36	38	30	95
July	1 050	698	698	66	59	34	91
August	934	661	661	66	77	29	90
September	634	414	414	46	51	35	89
October	742	442	442	58	64	40	87
November	671	402	402	45	49	40	89
December	5 000 *	3 600	3 600	70	49	28	98
Mean	1 367	948	948	55	54	33	91

Average volume of effluent into the trickle filter was about 85 m^3 per hour.
Average volume of effluent into the Pasveer ditch was 36 m^3 per hour.
* December loading very high because molasses storage tank foamed over.

Discussion

Anaerobic dam pH control

Previously the effluent entering the anaerobic dam required liming to maintain a pH of around 6,5 to prevent 'souring' of the dam. With the trickle filter being fed directly from the anaerobic dam, it is important not to over lime the dam because soluble calcium acetate can be formed and carried over to the filter, where it is converted into insoluble calcium carbonate and thus chokes up the filter. The ability of a trickle filter to operate successfully on unlimed (pH 4,5) effluent from an anaerobic dam has been demonstrated at Felixton (Ravnö and Lewis, 1976). During the 1991 season, no lime was added to the anaerobic dam with the filter being relied on to neutralise any excess acid formation in the dam. This was successfully accomplished with the biological activity in the filter raising the effluent pH from 5,8 to 7,4. It is conservatively estimated that this has resulted in a nett saving of 50 tons of lime at a cost of R14 100.

Nutrient dosing

For successful operation of both trickle filters and Pasveer ditches the addition of nitrate and phosphate nutrients is essential (Bruijn, 1976). Previously, batch dosing of nutrients to the Pasveer ditch was acceptable because of the two to three day residence time in the ditch. However, due to the short residence time, a constant supply of nutrients is necessary for a trickle filter. For this purpose a pair of dosing pumps was provided in order to give the required constant supply of nutrients to the filter. In trying to optimise the dosage, difficulty was experienced with sticking to the ratios recommended in the literature. Thereafter, starting from a low base, the nutrient dosage rates were gradually increased over a period of time. The increased dosages gave no significant improvement in COD removal across the trickle filter. It has, in fact, been found in practice that both plants (trickle filter and Pasveer ditch) can operate efficiently with low levels of nutrients and that as long as a trace of nutrients is present the plants will perform well, even up to maximum levels of COD loading. This has led to a drop of about 25% in chemical consumption. Table 4 gives details of the optimum nutrient levels in the effluent feed to the trickle filter and Pasveer ditch determined in practice.

Table 4

Optimal nutrient levels for trickle filter and Pasveer ditch

Nutrient	Into trickle filter	Out of trickle filter*
Phosphorus (ppm in effluent stream)	12	5
Nitrogen (ppm in effluent stream)	15	8

* Out of the trickle filter is the same as into the Pasveer ditch

Psychoda flies

Vast numbers of the psychoda larvae occur in the filter bed and play a very important part as scavengers in devouring deposited material, thus helping to keep the spaces between the media free. The adult flies do not themselves feed, and once they have laid their eggs, play no further part in the process. The swarming flies were, however, becoming a nuisance around the effluent plant, causing discomfort to operating personnel, until they attracted the migratory European swallows. Large numbers of these birds feed on the flies, helping, not only to get rid of the flies, but also to increase the bird population in the area.

Other factors contributing to solving NB's effluent problem

Although the trickle filter contributed directly to Noodsberg's treated effluent meeting general water standards, there were other contributory factors which need mentioning. A few seasons ago a programme of effluent monitoring was introduced. The sources of all the effluent entering the anaerobic dam were traced, analysed and appropriate action was taken if the loading was found to be high. Some of the major problem areas are discussed.

(a) Molasses storage area. Spillages, washings, pump gland leaks etc. from the molasses storage area contributed to an effluent in excess of 4 000 ppm COD. With an improved molasses loading procedure and pump maintenance, spillages are now kept to a minimum. Furthermore, the storage area sump pump now returns back to the storage tanks.

(b) Cooling tower overflows. Overflows from the cooling tower constituted a large loading of COD to the anaerobic dam. It was decided to control the level of the tower's sump to below the overflow level by dumping excess condensate to effluent. The condensate dump facility was so designed that excess condensate could be dumped to either the anaerobic dam or storm water, i.e. bypassing the treatment plant. This has not only helped to maintain a constant loading to the effluent plant, but it has also diluted the COD in the anaerobic dam.

(c) Stop-day evaporator and pan drainings. Previously water that had been used for cooling down and flushing evaporators and pans was dumped to effluent, thus further loading the effluent plant. Minor modifications carried out to the dump system enabled this water to be diverted to the factory cooling tower where it could be contained.

Conclusions

The trickle filter installation at Noodsberg has been in operation for nearly one and a half seasons with the effluent plant producing results consistently better than General Water Standards for the first time in many years. The trickle filter has not only contributed directly to the effluent plant COD removal; but it has also enabled improved performance of both the anaerobic dam and the Pasveer ditch. The previously overloaded anaerobic dam has benefited largely from the recirculation of water treated by the trickle filter, the overall effect being to decrease the COD level of water leaving the dam by more than 28%. With the lower COD loading resulting from improved performance of the anaerobic dam and the extra removal from the trickle filter, the Pasveer ditch performance has improved substantially. The new installation has also eliminated the need for lime dosage to the anaerobic dam and reduced the requirements for nutrient dosage, thereby effecting large savings in chemical costs. Although the trickle filter installation has played the greatest role in improving effluent plant performance, better management of high COD factory effluent streams has also had a contributory effect.

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