EFFICIENT AND LOW COST EFFLUENT TREATMENT USING AN ASH DISPOSAL DAM

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Abstract

The treatment of sugar factory effluent by using an artificially established sand bed wetland was investigated. The process was found to be suitable under all load conditions. Operational data on the running of the plant between May 1988 and December 1988 have been evaluated. Good COD reductions of the effluent have been achieved, suggesting that the wastes treated are amenable to this method of treatment. The data are lacking in certain aspects as this method of treatment is still in its infancy.

Introduction

Effluent treatment as well as fly ash control is not a very popular budget item as it represents extra cost without direct return. However, strict laws controlling the quality of water and flue discharges have been enforced during the past twenty years, resulting in large amounts of capital being spent on effluent treatment and flue gas scrubbing. Umzimkulu mill has an effluent treatment plant which consists of an anaerobic dam of 9 000 m^3, and an aeration pond (pasveer ditch) of 2 500 m^3, which performed within the standards of the Water Act prior to the floods of September 1987. Waterborne ash from boiler grates and scrubbers is pumped to a land fill system where the solids are allowed to settle out, and clean water is obtained by percolation through the ash bed.

After the floods of September 1987, which destroyed most of the aeration control equipment, it was a matter of urgency to find a solution to prevent serious pollution of the Umzimkulu River. The ash disposal dam, with a surface area of 19 000 m^2 and a volume of approximately 70 000 m^3 of sand carbon, was thought to be an ideal filter medium. From May 1988 all factory effluent at an average rate of 35 m^3/h was pumped with the 330 m^3/h waterborne ash to the settling dam. Over a period of eight months, COD removal of up to 95% has been recorded without any signs of clogging of the dam, which could have been disastrous to the ash disposal system (Table 1). As it stands, a saving of R80 000 is achieved annually. This includes chemical, maintenance and labour costs, but does not include depreciation costs.

Description of the System

The system being used is an ash disposal system. It resembles an artificial wetland, but differs in several respects, namely:

- Artificial wetlands are lined with a geomembrane to prevent seepage. Umzimkulu ash dam is not lined
- Artificial wetlands maintain a substantial water table. The Umzimkulu ash dam maintains a variable water table depending on hydraulic loading
- Artificial wetlands are normally covered with vegetation.

The function of the ash disposal system is to separate the ash from the water, the latter being returned for re-use. The ash originates from the wet flue gas scrubbers and furnace grates.

The hydraulic loading based on the total surface area is 0,32 $l/min/m^2$. However, only a third of the surface is used for deposition at any one time, and the hydraulic loading on this surface is close to 1 $l/min/m^2$. Tracer tests to establish the retention time of the dam were inconclusive. However, from the behaviour of the dam when subject to an isolated shock load, it is estimated that the residence time lies between 2 and 20 hours. Solids loading into the dam varied between 0,22% and 0,28%, which means that about a ton of solids is deposited per hour. The cross section of the dam is shown below to illustrate the dam contents. The wall height has been raised annually and has risen by approximately 11 m from 1983 to 1988.

Treatment mechanisms

Treatment is accomplished through a combination of physical, biological and chemical interactions between the bed, the microbial community and the plant life.

(i) **Physical Method**

Filtration through granular media. The media consist of a bed of sand and carbon. The removal of particulate matter as the water percolates through the bed is the major contributor to the purification process. Laboratory filtration, although it cannot be reproduced at the ash dam, consistently produced COD removal of 80 to 90%.

(ii) **Microbial Process**

The ash bed is moist in most parts and when fed with a warm, nutrient-rich liquid, microbiological activity is expected. The black surface maintains its temperature above 35°C due to absorption of solar energy. On the surface, about half the ash dam is covered with vegetation, namely buffalo grass (*Stenotaphrum*), bulrush (*Typha*), *Scirpus* and duckweed in the pool areas. Besides its effect on nutrient uptake during growth, the long term effect of buffalo grass is not known. Samp reed (*Phragmites*) on the other hand has been well researched and it may be worth while to cultivate it. The finely branched aquatic roots of swamp reed absorb a significant portion of nutrients, and the immersed stem and leaves do likewise (Wrigley and Toerien[3]).

Oxygen diffuses from the roots and creates aerobic zones within the rhizosphere (root zone). This stimulates the development of diverse microflora and microfauna which assist in the breakdown of organic matter. Aerobic zones facilitate the nitrification process and the effluent passes intermittently through aerobic and anaerobic zones where nutrification and denitrification lead to good nitrogen removal properties (Wrigley and Toerien[3]). The aerobic condition also contributes to phosphate absorption and precipitation. Swamp reed (*Phragmites*) also has an elaborate root system, which will prevent clogging of the bed.

(iii) **Chemical Process**

A large proportion of the ash deposited on the bed consists of charred cellulose, which is carbon. With the high temperature of the flue gases the carbon is expected to be activated. Activated carbon has the ability to absorb residual organic matter dissolved in the effluent. The organic matter best absorbed onto the carbon surface comprises those substances which are non-biodegradable, while highly biodegradable substances are poorly absorbed.

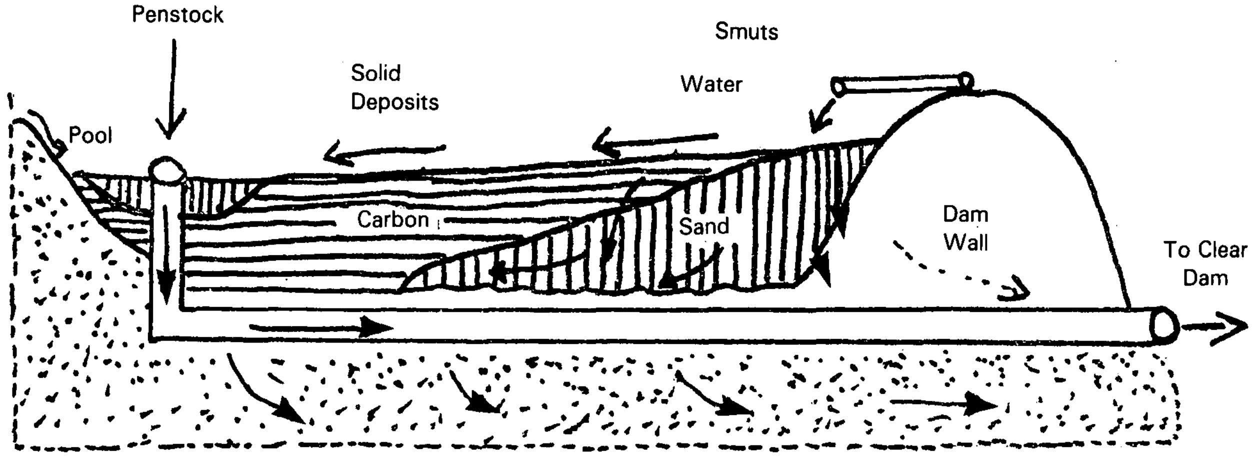

FIGURE 1 Side view of Ash Disposal Dam

Dam Characteristics

Media filtration takes place closest to the dam wall, where 90% of the sand is deposited at an average temperature of about 60°C. Very little microbial activity can be expected. Blanket drains constructed to drain the wall remove about 45 m^3/hr and constitute 15% of the volumetric loading at a retention time of 2 hours. Most of the plant life starts about 60 metres from the dam wall where, due to the prolific vegetation, a wetland system has been established. Vegetation has increased dramatically since the mill effluent has been included in this system. The effluent contains sugar, organic matter and overflow from septic tanks. Although the septic tank overflow is relatively small in quantity, it supplies nutrients which are normally deficient in sugar mill wastes.

Ash water is discharged at the wall of the dam. The settling out process starts here, with the heavier sand particles settling out first. Thereafter the lighter fraction, consisting of charred bagasse, settles out, while the water runs in channels on the surface. The path of the channels changes continuously, providing a natural mechanism for even deposition of ash (Schlaudraff[2]).

Towards the penstock, where a pool has formed, finer particles settle out, while floaters are trapped in the vegetation. To check the effect of channelling, COD's, pH and temperatures were measured at 18 different points in July and November 1988. Both sets of results show the same trend, with higher COD values at the centre of the dam in direct line with the penstock. The central area, being closest to the subterranean pipe and in the region of highest flow, has a higher sand content. On the sides and around the penstock crystal clear water pools exist, supporting bird and aquatic life. The water reaching these pools passes through a mainly carbon bed.

Table 1
Summary of Monthly Analyses

	Influent		Effluent		% Removal
	pH	COD	pH	COD	
May	8,3	597	7,6	82	
June	8,1	713	7,4	141	80
July	8,6	865	7,8	140	84
August	8,4	519	7,9	112	78
September	8,8	710	7,9	94	87
October	8,2	392	7,7	36	91
November	8,6	724	7,8	40	95
December	8,5	1154 *	8,0	71 *	94
Average	8,4	709	7,8	93	87

* Liquidation losses during factory boil-off and washing down.

Summary of Analysis for December 1988 (mg/1)

	Influent to ash dam	Effluent from ash dam
pH	8,5	8,0
COD	1154	71
Dissolved solids	76	76
Suspended solids	2760	155
Phosphates (PO_4)	12	10

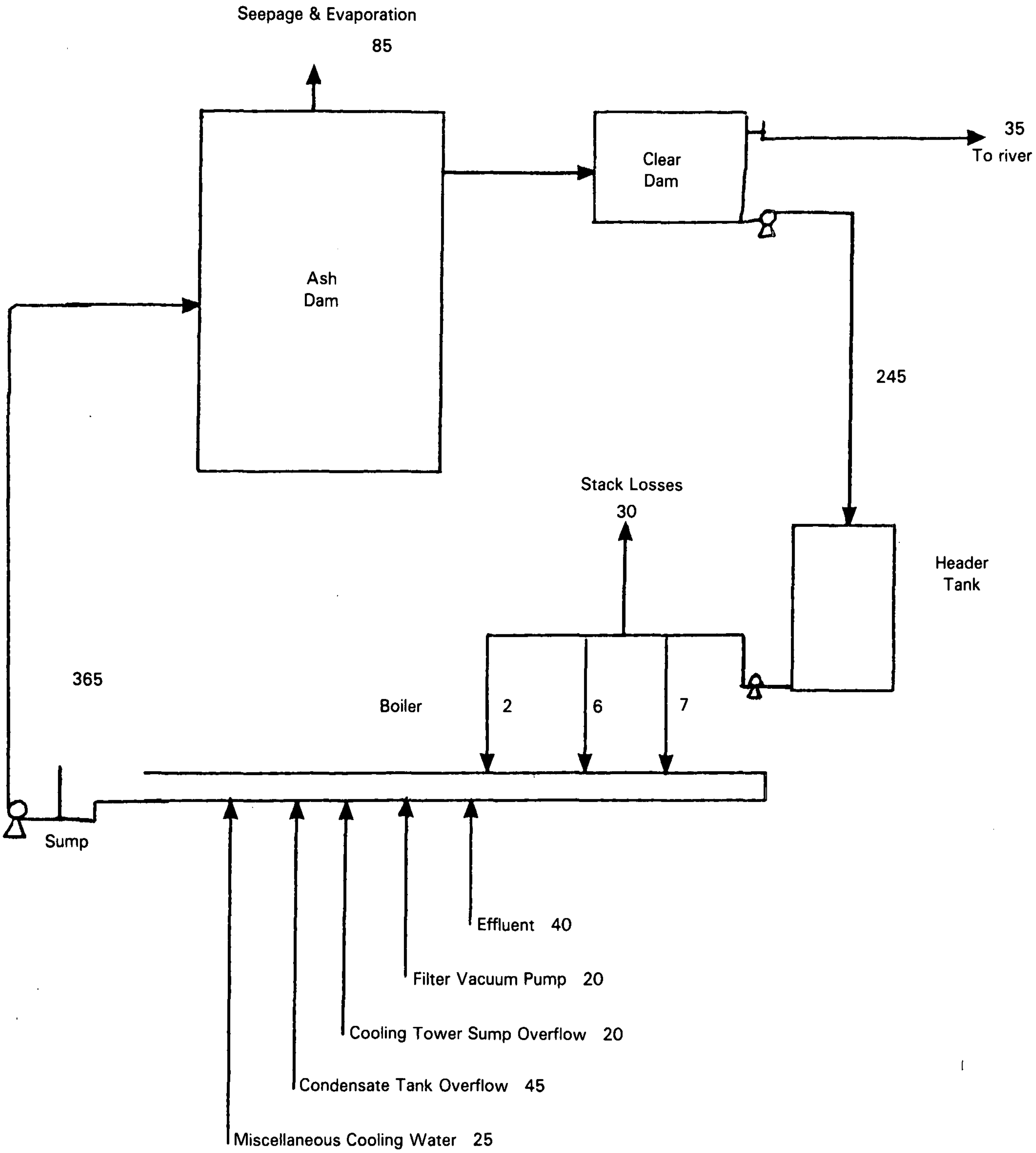

FIGURE 2 Water balance of Ash Disposal and Effluent Treatment ($m^3 h^{-1}$)

Table 2
Percentage reduction in COD within various samples when incubated at 30° for 24 hours after feeding with synthetic effluent.

Date	Initial COD (mg/l)	Samples *				
		1	2	3	4	5
14.12.88	1300	87	1	74	12	51
15.12.88	1300	92	27	85	41	84
20.12.88	700	78	39	69	55	68
21.12.88	700	82	51	73	56	82
22.12.88	570	83	65	75	51	68

* 1. Large percentage carbon.
2. Large percentage sand.
3. Large percentage carbon with dead grass.
4. Mud with high bagasse content.
5. Mud with high carbon content.

Laboratory Tests

Core samples were taken from the dam at 5 specific points and sent to SMRI where they were incubated with periodic additions of synthetic effluent of known COD value, so that the COD consumption rates could be assessed. The results (Table 2) showed that the COD's decreased by more than 80% within 24 hours in many cases. The core samples with high contents of carbonised bagasse were particularly active. Sample Number 2 was almost pure sand and showed negligible activity at first, but during the incubation period the activity increased steadily. On a volumetric basis the COD reduction in the cores was generally in excess of 0,7 $kg/m^3/d$, which compares favourably with conventional aerobic biological filters. Activities as high as 1,8 $kg/m^3/d$ were measured when the initial COD was 1300 mg/l.

The laboratory tests confirmed that there was sufficient microbial activity in the settled smuts to explain the observed reduction in COD when effluent was passed through the smuts dam. Based on the estimated volume of smuts and the COD loading, an activity of 0,8 $kg/m^3/d$ would be necessary to account for the observed COD abatement.

During incubation the samples were not aerated nor agitated, so most of the activity must have been anaerobic.

Discussion

The ash dam may be defined as an artificial wetland cum trickling biofilter. It is able to purify effluent through the mechanisms of filtration, biological action and chemical adsorption. This method of effluent treatment is still in its infancy and data obtained to date are sparse. Many questions remain unanswered and much work remains to be done in the coming season.

Several years ago an Australian mill tried to dispose of its effluent by pumping it into the conventional ash settling system. This brought about a drop in pH and severe corrosion. Attempts to control pH by adding lime resulted in scaling problems and the practise of adding raw effluent to ash water was discontinued (Henderson and Peatey[1]).

In the eight months that this system has been operating at Umzimkulu, there has been no sign of sliming or appreciable corrosion. The fact that the pH stays above 7,4 without chemical control is very promising. It indicates that the dam is not being overloaded and that the biological population is thriving.

The probable difference between the Australian and Umzimkulu experiences is that the latter system was not overloaded because a substantial ash deposit had been developed over a number of years before effluent was applied to it.

The absence of odour indicated that the upper strata are aerobic and together with the deeper anaerobic strata, are performing satisfactorily. About 30% of the water is lost by seepage and evaporation. The implication of this and the dilution factor still have to be evaluated.

Unfortunately, the laboratory is not equipped with nitrogen analysing equipment, so the extent of nitrogen removal is unknown. There appears to be a negligible drop in phosphates, but this phenomenon will have to be confirmed by measuring total phosphorous next season.

Umzimkulu ash dam is capable of achieving secondary treatment quality specification with respect to COD. The performance of a wetlands system exclusively treating sugar mill effluents cannot be predicted. It may be attractive to polish effluent from secondary treatment plants which fail to deliver within legal specifications.

Conclusions

The use of the ash disposal dam at Umzimkulu as a means of effluent treatment has proved successful with a COD removal of up to 95%. The initial doubts about corrosion and clogging of the ash bed were dispelled after eight months of operation. During the three month off-crop period the dam will dry out and its first cycle will be completed. Further research together with long term experience from this full scale operation is necessary to establish accurate design criteria.

The benefits demonstrated so far are:

- Ease of operation
- Low installation and building costs
- Low operation costs
- Low energy costs
- Insensitivity to fluctuating loads
- Does not need skilled supervision
- Environmentally acceptable, offering considerable potential for wild life conservation.

Acknowledgements

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