

# ARTIFICIAL WETLANDS FOR THE TREATMENT OF MILL EFFLUENT

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## Abstract

Experimental artificial wetlands for treating sugar mill effluent have been in operation at Felixton and Mount Edgecombe for almost two years. The roots of reeds and bulrushes growing in the wetlands supply oxygen for the oxidation of sugars. Chemical oxygen demand (COD) removal was the main yardstick by which the performance of the units was measured, and removals of 80% and more were achieved under varying conditions. At Felixton problems were experienced with surface slime formation limiting throughput and at Mt Edgecombe, where two flow rates were used, the higher flow rate caused surface clogging and reduced throughput.

## Introduction

The main water borne pollutant from a sugar mill is sugar (or its breakdown products). Sugar requires about an equal part of O<sub>2</sub> to oxidise it to CO<sub>2</sub> and water. The amount of oxygen required for this oxidation can be measured and is referred to as the chemical oxygen demand (COD) of the water. In a natural stream this oxidation is performed by biological processes using oxygen entering the water by surface absorption, particularly when turbulent, and from oxygen respired by green plants. This however is a slow process. The general standard for discharge into a stream set by the Water Act is 75 ppm COD. Tongaat-Hulett mills generally discharge raw effluent to treatment plants at concentrations varying from 1 000–4 000 ppm COD (average 2 000 ppm), and at flows of 1 000–2 000 m<sup>3</sup>/day. If all the COD were provided by sugar, the average daily sugar loss would be between one and eight tons.

## Outline of present treatment processes

Treatment at Tongaat-Hulett mills other than FX is firstly by anaerobic digestion in open ponds and secondly by irrigation onto cane fields. The open pond anaerobic process is not very effective, removing at best about 50% of the COD. Irrigation on cane at about 1 mm/d is effective and removes most of the remaining COD. However reasonably large areas of land need to be locally available. For example, 1 000 m<sup>3</sup>/d of effluent requires at least 100 ha of cane. The COD of run-off through the soil is generally below 50 ppm but, when the soil is saturated, water runs off the surface and the COD rises considerably. Smell can be a nuisance when effluent is irrigated close to residential areas as the volatile fatty acids produced during anaerobic digestion are obnoxious.

At FX there have been no facilities for irrigation and, since the construction of the new Felixton mill, a full treatment plant consisting of anaerobic digestion followed by an activated sludge aeration process has been in operation. For various reasons this plant is not normally able to achieve general standards. It was for this reason, and the opportunity of studying an alternative method of effluent treatment, that the Sugar Technology Department (STD) of Tongaat-Hulett Sugar decided to research the use of artificial wetlands.

## Description of artificial wetlands

Artificial wetlands (AWs) have been investigated in many countries in Europe (Brix, 1987), the USA (Gersberg *et al.*, 1986) and Japan (Wathugala *et al.*, 1987) for more than 10 years, and offer a promising low cost and low technology option to the problem of effluent treatment. In South Africa the Council for Scientific and Industrial Research (CSIR) initially took the lead in promoting their use, especially for rural sewage treatment. Twinch and Ashton (1983) describe nutrient cycling in wetlands, and Alexander and Toerien (1985), Alexander and Wood (1987) and Wood and Rowley (1988) described the use of AWs for the treatment of sewage and industrial waste water. Rogers *et al.* (1985) have published a booklet on wetlands for waste water treatment. A national co-ordinating committee on artificial wetlands was set up in 1988 by the CSIR (Anon, 1988) and trial units were established mainly for the polish treatment from small scale sewage works. In all these trials the artificial wetlands are used to remove COD, nitrogen, phosphorus, and suspended matter. SASOL has also constructed an artificial wetland for effluent treatment at Secunda (Pienaar, 1988).

It is the policy of the Department of Water Affairs (Conley *et al.*, 1987) that natural wetlands should not be used as treatment systems for point sources of effluent. If artificial wetlands are constructed they should be part of the treatment works and not be in a river bed. Buzzard and Govender (1988) report the disastrous effect on wildlife in the Sezela lagoon after uncontrolled run-off from the factory and an accidental discharge of smuts. The lifeless lagoon was subsequently rehabilitated. Gambrell *et al.* (1987) however report the monitored use of natural swamps near the Mississippi river for the treatment of sugar refinery cooling water.

STD has been evaluating artificial wetlands for the past two seasons, mainly for the removal of COD from mill effluent. Experimental units have been set up at Felixton (FX) and Mt Edgecombe (ME), where two different strength effluents were studied. Although nitrogen and phosphorus are measured routinely, their final levels are usually low and within the general standards and therefore do not normally cause a problem. This paper therefore deals only with COD removal.

The artificial wetlands (Figure 1) consist of reeds or bulrushes planted in a prepared bed of sand. The reed *Phragmites australis* and the bulrush *Typha latifolius* can tolerate waterlogged conditions and can transport oxygen to their roots where it is necessary for growth. A detailed description of *Phragmites* is given by Gordon-Gray and Ward (1970). The vertical downward flow method with flooded surface was chosen for simplicity. At FX the inlet to the AW is metered through a V-notch. At ME a steady flow is achieved by having fixed lengths of hose pipe fed from a constant header tank. A drainage pipe surrounded by coarse sand is provided underneath the sand, which collects the effluent after it has passed through the root zone of the plants. The root zone acts as a fixed medium with aerated patches where aerobic bacteria in the sand obtain oxygen from the roots,

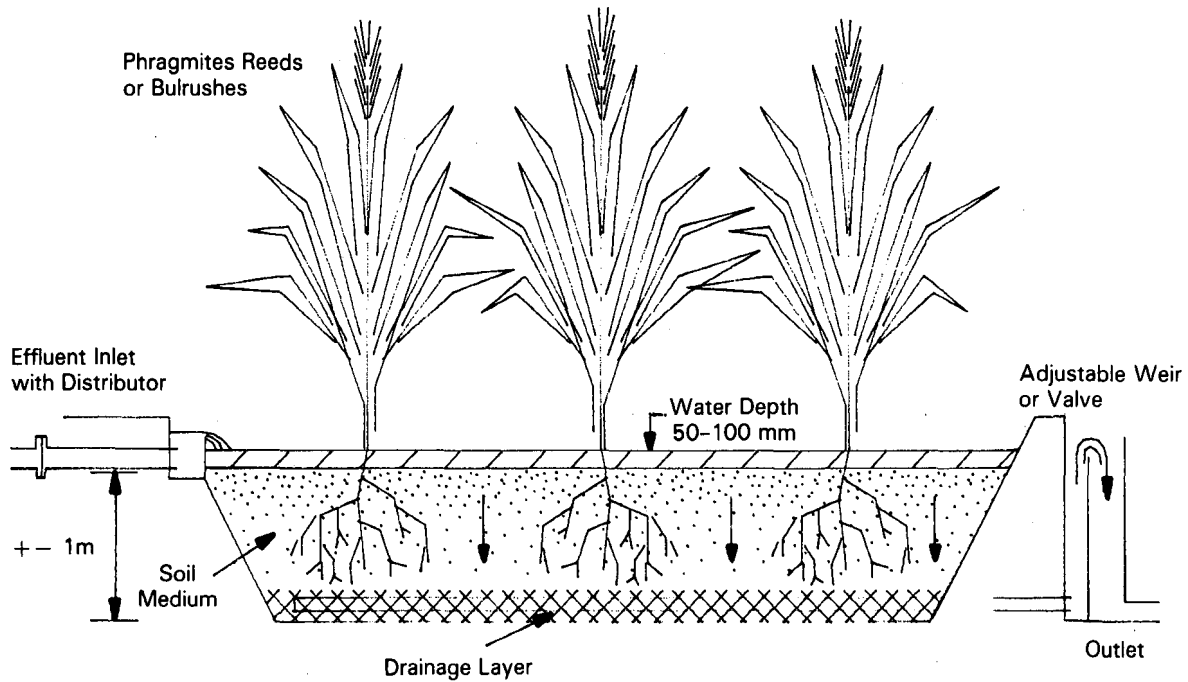


FIGURE 1 Artificial wetland.

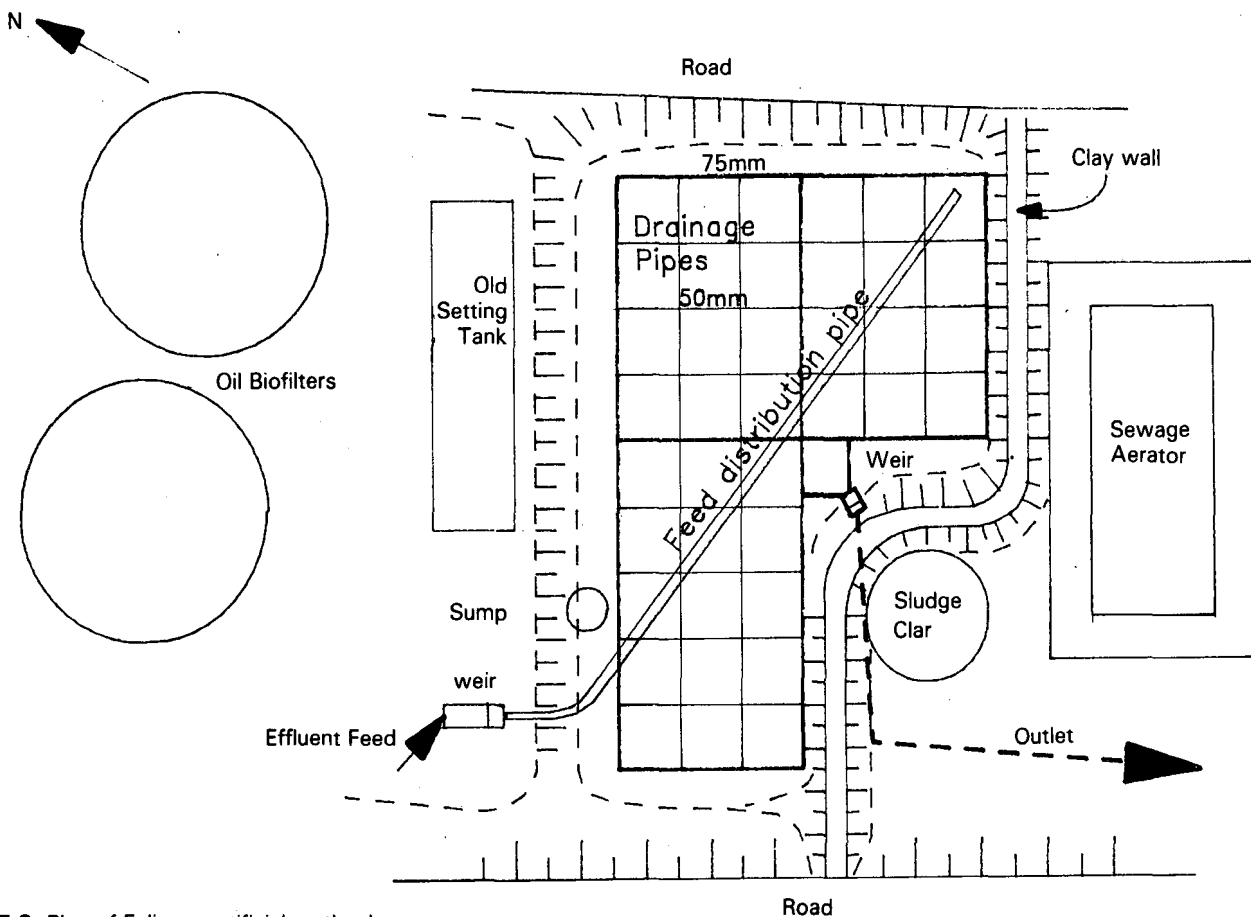


FIGURE 2 Plan of Felixton artificial wetland.

together with anaerobic bacteria in adjacent anoxic zones they break down the organics in the water (Brix, 1987). An adjustable weir in the outlet establishes the depth of water at the surface. The AW is said to be clogged when this weir is fully down and water starts overflowing the wall.

Wood and Hensman (1988) reported that a wetland could treat oxidation pond sewage effluent at flow rates of

0,2 m/d to general standards. The original intention at FX was to run the AW on effluent of 400 ppm COD as a polishing process, and at ME on anaerobic effluent of 1 000 ppm COD to see how it would cope at the higher loading.

At FX a 1,5 m deep 2 000 m<sup>2</sup> dam was made (see Figure 2). A grid of slotted drainage pipes was laid in a 300 × 300 mm trench. The trench was then filled with small stone chips

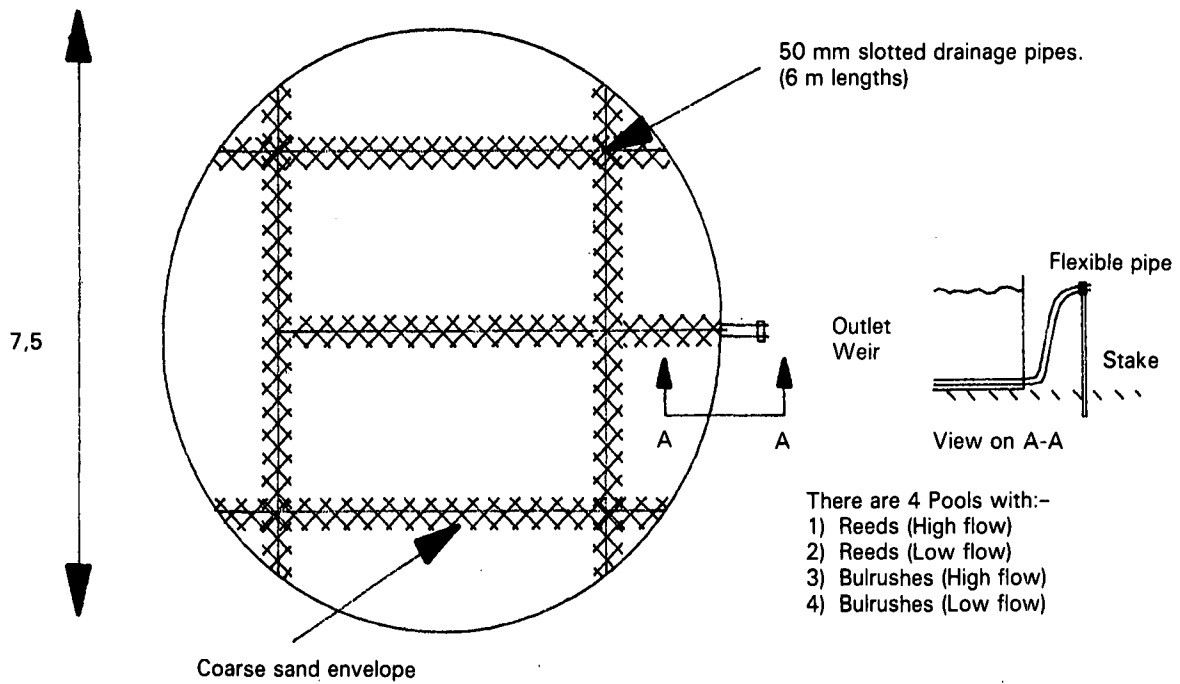


FIGURE 3 Plan of Mount Edgecombe.

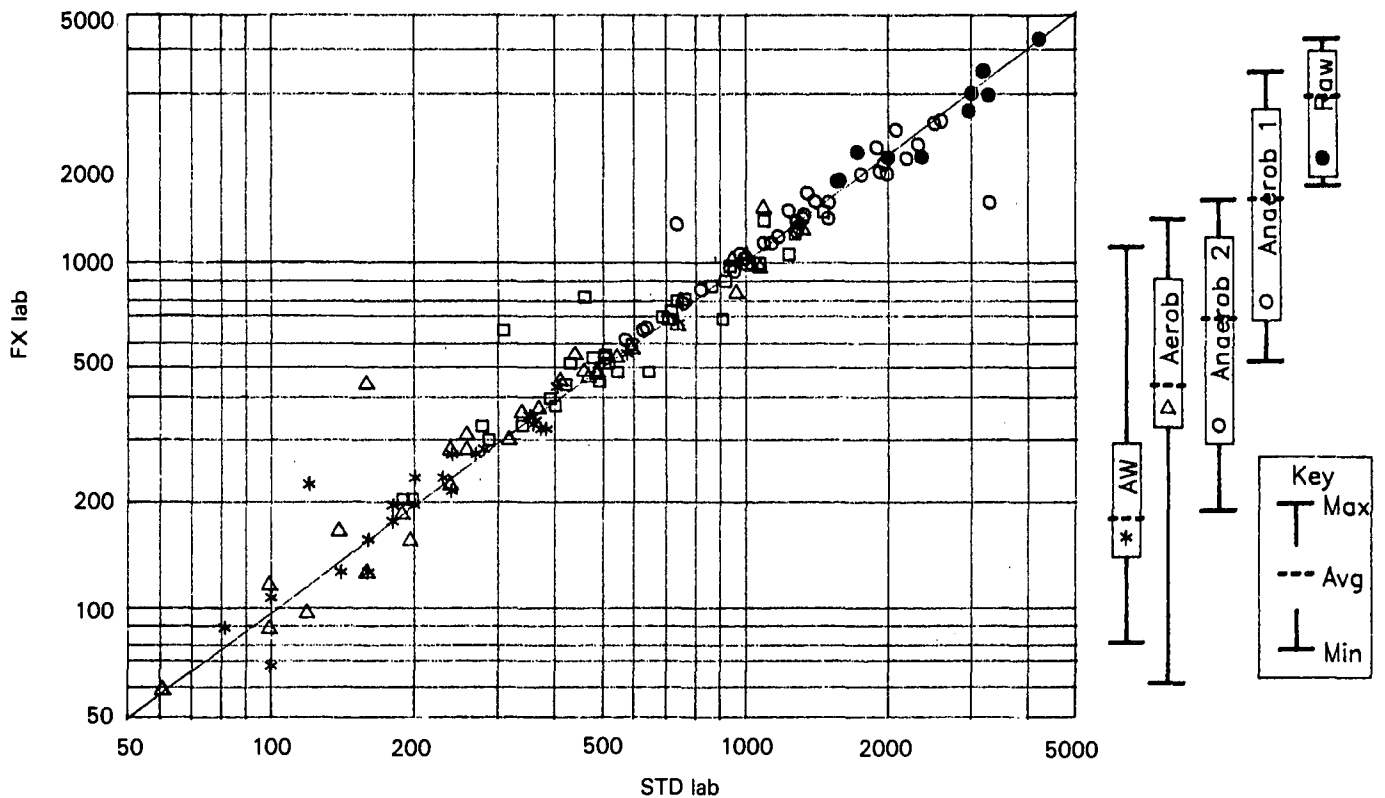


FIGURE 4 COD analyses of Felixton effluent plant – inter-laboratory comparison.

and the rest of the dam filled with fine river sand. The flow rate initially chosen was 0,2 m/day (or 0,2 m<sup>3</sup>/m<sup>2</sup>/day), but was later reduced to 0,05 m/day after the flow was restricted by surface clogging. A permeability test done by SASA Experiment Station showed that the original clean sand had a percolation rate of 12 m/day.

At ME (Figure 3) four portable swimming pools were used as containers for the experimental wetlands. Two were planted

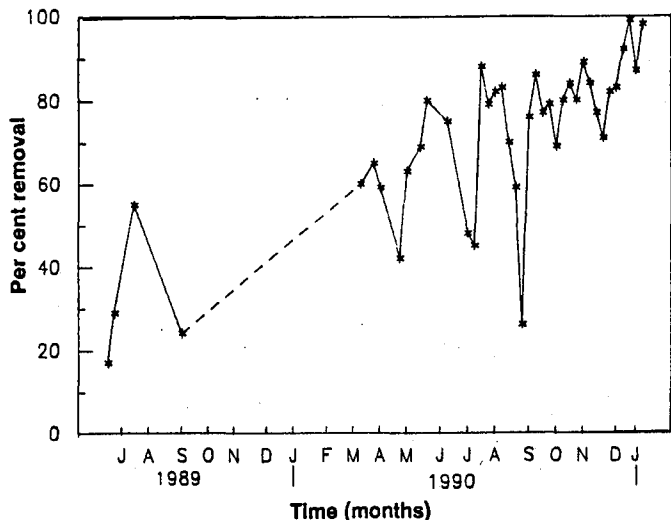
with reeds and two with bulrushes, and fed at two different flow rates, viz 0,2 m/d and 0,6 m/d in a 2 × 2 factorial experiment. During the second year of operation the flow through the pools with the higher flow rate could not be maintained because of surface clogging. The 50 mm slotted drainage pipes were covered with an envelope of coarse river sand. Fine river sand was used for the rest of the fill to a depth of 1 m in the 1,2 m deep pool.

**Results**

*Felixton treatment plant*

Figure 4 shows the ranges of COD values for the various parts of the effluent treatment plant and indicates the generally good comparison between the STD and FX laboratories in the analysis of COD. The symbols represent the five outlet CODs of the raw, anaerobic 1 & 2 (in parallel), aerobic and wetland samples. The bars show the ranges and averages of these five samples. The two anaerobic dams are in parallel, with No. 2 always giving better results.

*COD removals by AW at FX*



**FIGURE 5** Felixton artificial wetland COD % removal.

Figure 5 shows the COD removals of the FX AW since it was first put on stream. There were numerous interruptions in the first season of operation, mainly due to surface clogging and subsequent cleaning, even though the feed to the AW was aerobic effluent after the activated sludge clarifier. (This effluent often had a milky appearance.) A sample of this slimy surface layer examined under the microscope showed a mixture of algae, bacteria and yeast. The surface clogging was at first thought to be due to aerobic effluent and algal growth from sunlight due to an absence of a leafy canopy. It also contained 5,6% Ca<sup>++</sup>, 1,6% CO<sub>3</sub><sup>-</sup> and 1,3% SO<sub>4</sub><sup>-</sup> indicating that it was derived from carry-over from the sludge clarifier. The results obtained during the off-crop are not included in the graph as the incoming water had a low and erratic COD. This period is shown as a dotted line.

Feed to the AW at FX was changed to anaerobic effluent at the beginning of 1990 as this method appeared to be working well at ME at the time. The AW nevertheless continued to clog up and the feed was reduced from 0,2 to 0,05 m/day in July 1990. At this rate the average COD removal was 81%, i.e. reducing the COD from 1 435 to 270. The full data for this period of steady running are shown in Table 1.

*ME results*

Results of the four ME trials are so similar that they have all been included in the same figure (see Figure 6). Again there were numerous interruptions in 1989 and the first part of 1990. The mill off-crop is again shown as a dotted line. From July 1990 however, a steady feed to the AWs was achieved,

**Table 1**  
Summary of steady AW operations at FX at 0,5 m/day

Month 1990/91	Inlet COD	Outlet COD	% COD Removal
July	1 250	650	48
	990	550	45
	970	120	88
	1 600	330	79
August	1 240	220	82
	1 930	330	83
	2 250	680	70
	1 070	440	59
September	810	360	56
	1 000	240	76
	1 590	230	86
October	1 230	290	77
	950	200	79
	1 110	340	69
	810	160	80
November	1 700	280	84
	1 010	200	80
	1 620	180	89
	670	110	84
	560	130	77
December	450	130	71
	500	90	82
	570	70	83
	1 950	150	92
January	6 550	380	94
	3 500	460	87
	890	20	98
Average	1 435	270	81

and average removals were around 85%. As steady conditions were established the outlet weirs from the two high flow AWs were progressively lowered in an attempt to maintain the flow rate and prevent overflowing. It became apparent that lowering the weirs did not increase the head through the bed as the clogging occurred at the surface and, as the water drained away from the fill, the outlet did not maintain a full liquid head.

There were also a series of interruptions at ME which can be seen from gaps in the weekly analyses in the graphs. In particular there was an unreliable supply of effluent to the experiment. This was finally overcome by installing a separate supply pump. Another problem was caused by root punctures, particularly from the reeds, resulting in leaks. It is clear that results have improved during the last three months of the season.

Table 2 shows CODs and % removal of the four ME AWs during the last three months of the 1990 crop when samples were taken bi-weekly. There are a few spurious results which affect the averages. During this period the two high flow AWs were overflowing because of surface clogging and the rate through the AW was therefore lower than the stated value. It was estimated to be about the same as the low flow AW.

At both FX and ME there was no noticeable influence of throughput rate on COD removal. It was apparent therefore that the surface clogging on the beds significantly reduced the ability of the AWs to handle reasonable throughput rates. Results indicated that wetlands themselves could have shown very much higher volume efficiencies if the surface clogging could have been eliminated.

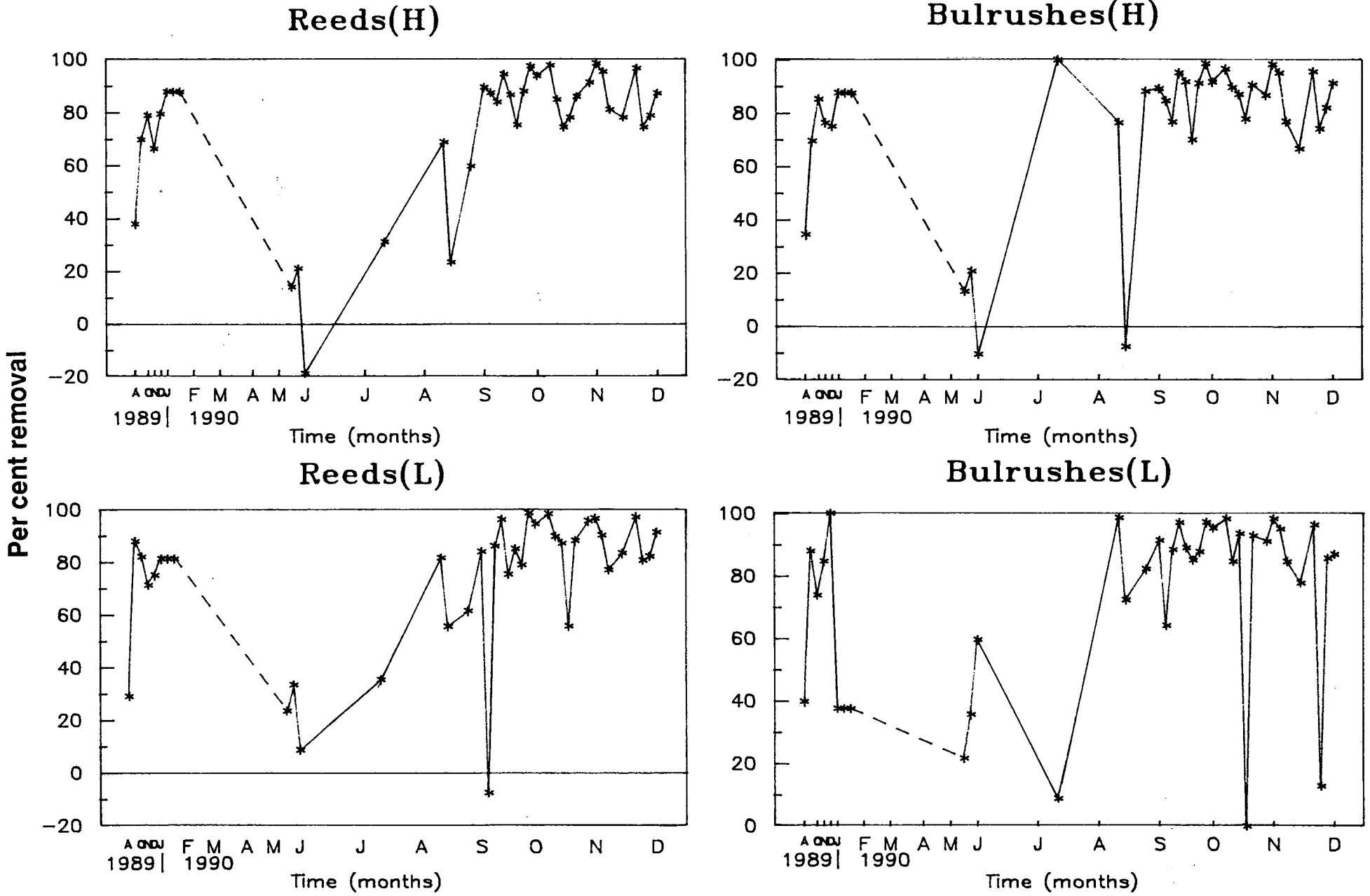


FIGURE 6 Mount Edgecombe artificial wetland COD removal.

**Table 2**  
**Comparison of High (H) and Low (L) flow bi-weekly COD results at ME for the period Sep to Dec 1990**

Month	Feed	Reeds (h)		Reeds (L)		Bulrushes (H)		Bulrushes (L)											
		COD	Rem %	COD	Rem %	COD	Rem %	COD	Rem %										
1990	COD	COD	Rem %	COD	Rem %	COD	Rem %	COD	Rem %										
										Sep	1 010	410	59,4	390	61,4	120	88,1	180	82,2
											930	100	89,2	150	83,9	100	89,2	80	91,4
											780	100	87,2	840	7,7	120	84,6	280	64,1
											860	140	83,7	120	86,0	200	76,6	100	88,4
											2 060	120	94,2	80	96,1	100	95,1	60	97,1
											730	100	86,3	180	75,3	60	91,8	80	89,0
											400	100	75,0	60	85,0	120	70,0	60	85,0
											1 140	140	87,7	240	78,9	100	91,2	140	87,7
											1 426	40	97,2	20	98,6	20	98,6	40	97,2
Oct		2 140	140	93,5	120	94,4	180	91,6	100	95,3									
		2 370	60	97,5	40	98,3	80	96,6	40	98,3									
		390	60	84,6	40	89,7	40	89,7	60	84,6									
		310	80	74,2	40	87,1	40	87,1	20	93,5									
		360	80	77,8	160	55,6	80	77,8	360	0,0									
		840	120	85,7	100	88,1	80	90,5	60	92,9									
		450	40	91,1	20	95,6	60	86,7	40	91,1									
		1 170	20	98,3	40	96,6	20	98,3	20	98,3									
		410	20	95,1	40	90,2	20	95,1	20	95,1									
		520	100	80,8	120	76,9	120	76,9	80	84,6									
Nov		360	80	77,8	60	83,3	120	66,7	80	77,8									
		2 750	100	96,4	80	97,1	120	95,6	100	96,4									
		310	80	74,2	60	80,6	80	74,2	270	12,9									
		560	120	78,6	100	82,1	100	82,1	80	85,6									
		460	60	87,0	40	91,3	40	91,3	60	87,0									
	947	103	85,5	133	81,9	89	86,9	103	82,3										

**Conclusions**

- The flow rate through the wetlands at ME was limited to 0,2 m/d by surface clogging, which prevented higher flows. At FX the flow was limited to 0,05 m/d by surface clogging from a combination of carry-over and microbiological growth. These values are significantly lower than others reported and so lead to unrealistically large areas for effluent treatment, i.e. the areas required would be 0,5 and 2 ha respectively for each 1 000 m<sup>3</sup>/day.
- COD removals of over 80% are achieved after about one year of establishment, and performance seems to be largely independent of the original concentration of solubles. Since the AWs have been used as secondary treatment steps, treating incoming water of generally 500 – 1 500 ppm COD, they cannot be compared directly with anaerobic dams treating raw effluent of 1 000-4 000 ppm COD.
- Artificial wetlands offer a simple low cost and low maintenance alternative for effluent treatment where suitable land is available and where the incoming water is free from suspended matter, only if surface clogging of the wetland can be eliminated.

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