36 MLD UASB TREATMENT PLANT IN KANPUR, INDIA

EVALUATION REPORT ON PROCESS PERFORMANCE

MARCH 1996

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CONTENTS

1. INTRODUCTION

This report is concerned with the performance of the 36 MLD anaerobic wastewater treatment plant at Kanpur, India. This plant has been designed to treat the wastewater of approximately 180 tanneries, for which purpose the wastewater has to be diluted with domestic wastewater.

The plant has been put into operation in April 1994. Start-up procedures were followed, and after some five months of operation, during which the UASB reactors had to be re-started several times, the start-up could be considered to be completed.

In this report data on the full operation of the plant during nearly 18 months are summarized. For a good insight in the data, it has been decided to show all the individual data points (leaving not a single one out), instead of showing averaged values or trends. In this way some scattering of data may be evident, but this is inherent to the fact that the actual wastewater flow varies from day to day and from hour to hour. Due to the large amount of data points, still the general picture will be quite clear.

2. FULL PERFORMANCE

2.1 Introduction

Full performance of the UASB plant was obtained after 1 October 1994. From that time, start-up procedures could be considered as completed. Plant operation was reasonably stable. In this chapter, the operational technological results will be presented and discussed, and conclusions regarding future UASB plants and further treatment options will be drawn.

2.2 Flow, reactor loading

The flow to both reactors has been registered as the number of operating hours of the pumps at the pumping station, since automatic flow registration demonstrated to yield erroneous results. Regularly, flow as a function of pumping hours was calibrated against the flow measured at the outlet of the grit chamber. The flow to both reactors is shown in Figure 1.

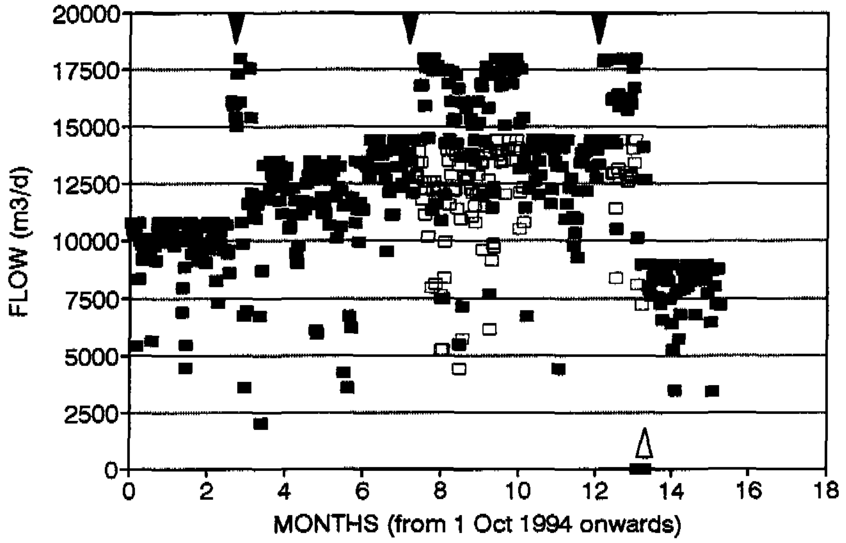

Figure 1. Flow to the two reactors. (■): reactor 1; (□): reactor 2. In most cases, flow was nearly similar, so that only the ■ symbols are visible.

At some stages it was noted that choking of the feed inlet pipes occurred, by the decrease in pumping efficiency. Three times the feeding system had to be cleaned, after which feeding could be resumed at the original flow rate. Cleaning is indicated in Figure 1 with downward arrows.

After 13 months of operation, the flow to the reactors had to be reduced because of pump failure. Reduction was dome by reducing the amount of domestic wastewater to the pant, thereby reducing the intended 1:3 ratio between tannery ad domestic wastewater to 1:1. This is indicated in Figure 1 with an upward arrow.

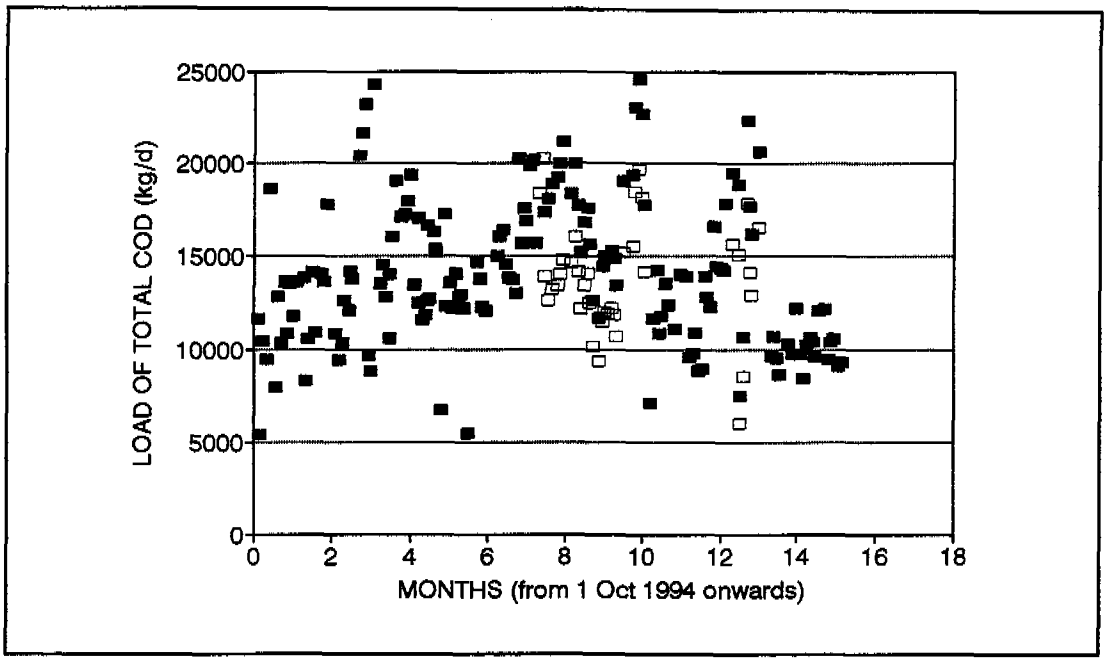

Figure 2. Reactor loading of the two reactors. (■): reactor 1; (☐): reactor 2. In most cases, flow was nearly similar, so that only the ■ symbols are visible.

Reactor loading (the product of flow x total COD concentration) is presented in Figure 2.

2.3 Temperature and pH

Reactor temperature varied from 18°C in winter to 32°C in summer. The course of the temperature over time is presented in Figure 3.

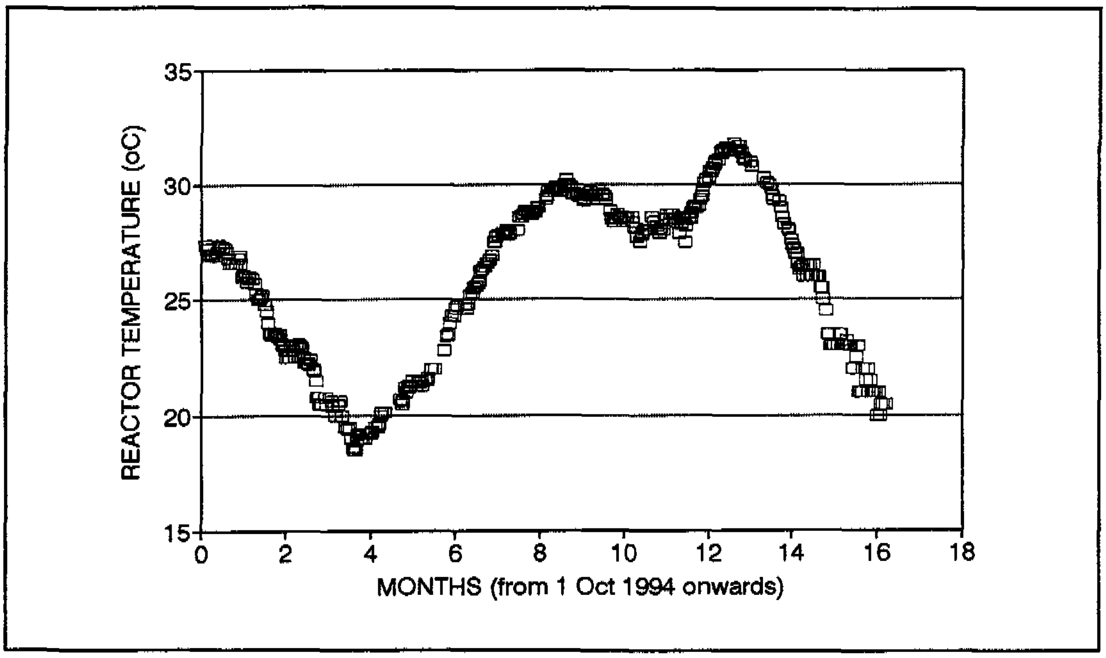

Figure 3. Temperature of reactor 1 as a function of time. Reactor 2 demonstrated temperatures identical to those recorded in reactor 1.

Temperature has a strong influence on the time needed for stabilization of solids, as it exerts influence of both growth rates of bacteria and activity of enzymes. This will be discussed later.

The pH of influent and the effluent of reactor 1 (reactor 2 had similar effluent pH) is shown in Figure 4. The effluent pH is consistently lower than the influent pH by approximately 1.0 pH unit. Variations in influent and effluent pH reflect the variability in the outcome of the measurement, rather than the variability of the pH itself.

The high effluent pH is itself sort of lucky, as the sensitivity of the anaerobic process towards sulphide is assumed to be much higher at a lower pH. This is because at lower pH a higher fraction of the H_2S will be in the undissociated (gaseous) form.

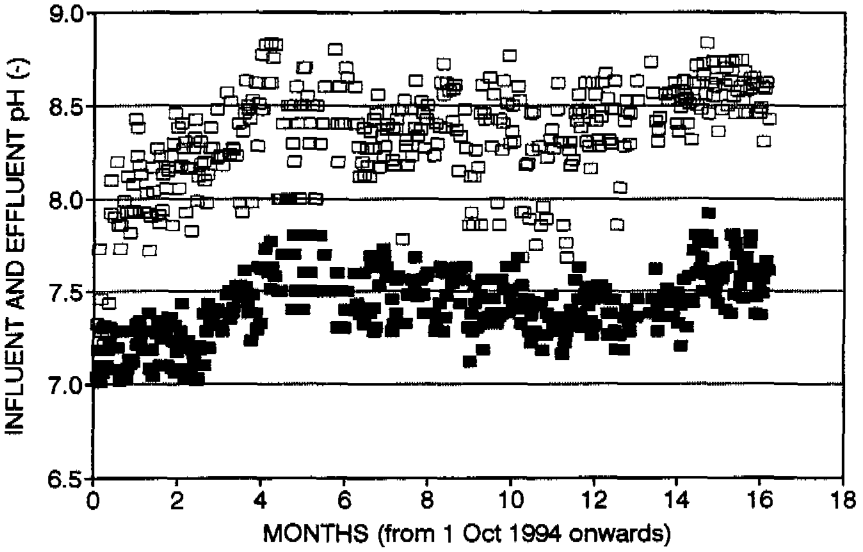

Figure 4. pH of influent (☐) and effluent (■) as a function of time.

2.4 COD, VFA, BOD

The total COD of the effluent is presented in Figure 5. The influent COD_T becomes higher after 13 months because of adopting of a lower dilution ratio (tannery : domestic). Effluent COD_T hardly is affected by this decrease, but it should be realized that the total COD load to the reactors was decreased simultaneously with the decreasing of the dilution ratio. In general, the effluent total COD fluctuates parallel to the influent, but at a much lower degree.

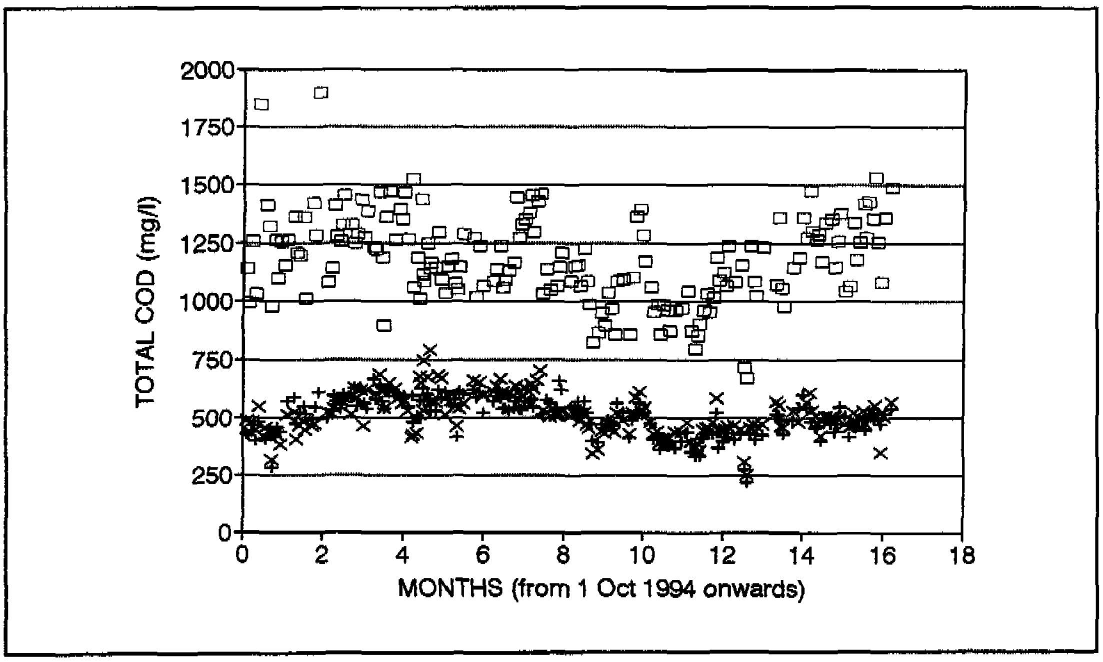

Figure 5. Total COD of influent (□), and effluent of reactor 1 (+) and reactor 2 (x).

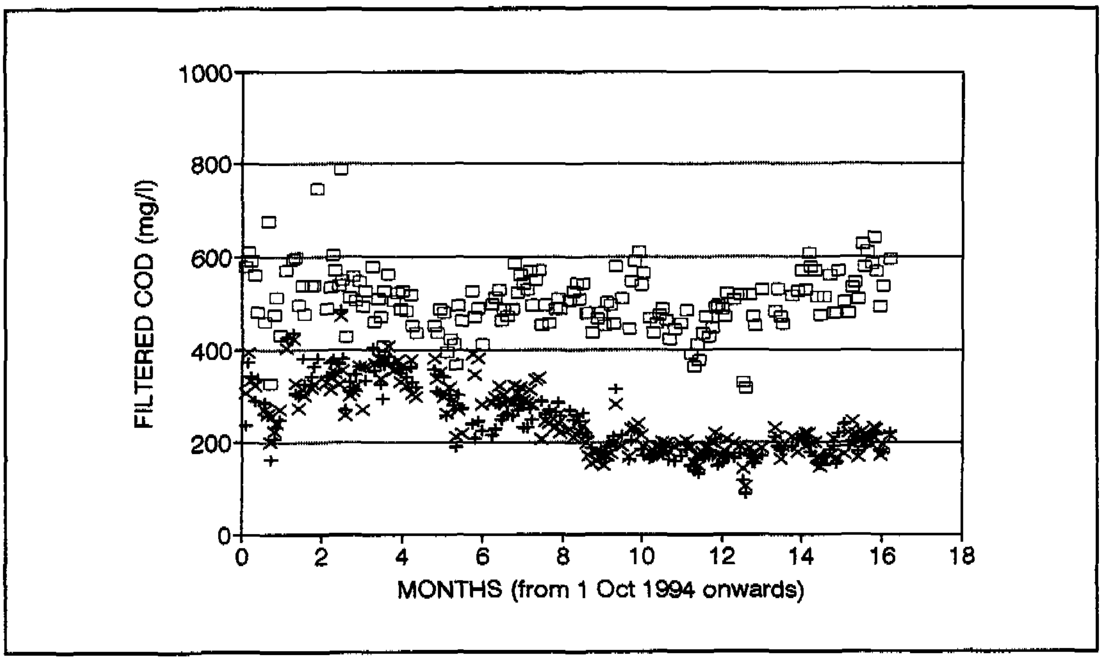

Figure 6. Filtered COD of influent (□), and effluent of reactor 1 (+) and reactor 2 (x), as a function of time.

The filtered COD seems to stabilize after 5 month of operation at a level of 180 to 220 mg/l (see Figure 6). Effluent filtered COD is consisting for a significant part of the COD of the volatile fatty acids in the effluent, which is shown in Figure 7.

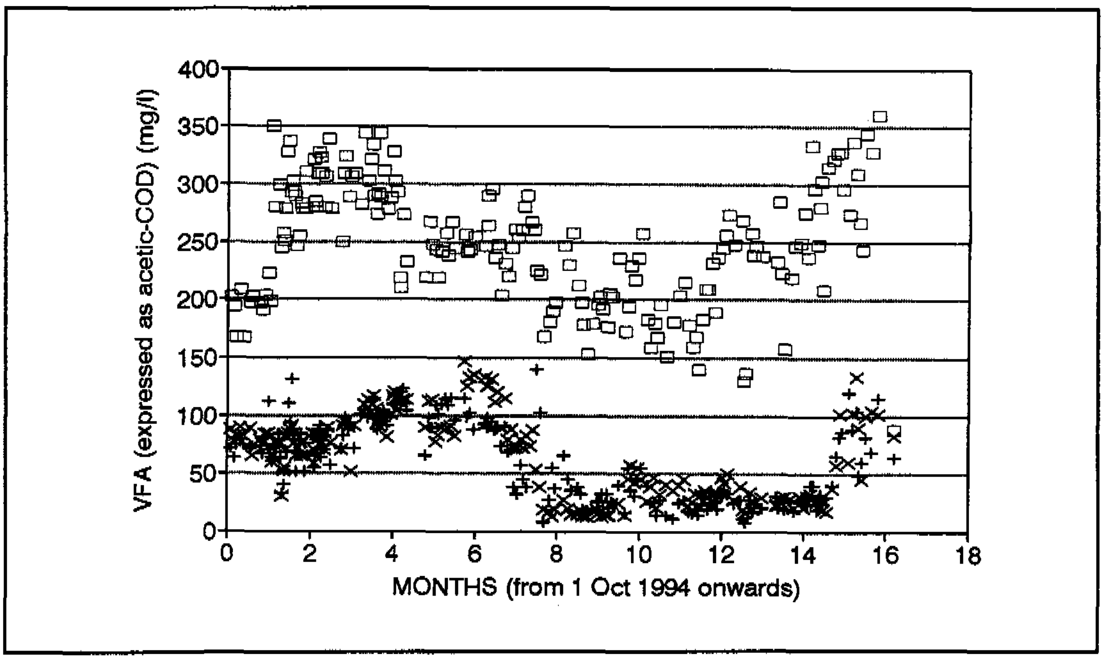

Figure 7. Volatile fatty acids (VFA) of influent (☐), and effluent of reactor 1 (+) and reactor 2 (x), as a function of time.

Influent and effluent BOD are shown in Figure 8. They show basically the same pattern as the influent and effluent COD.

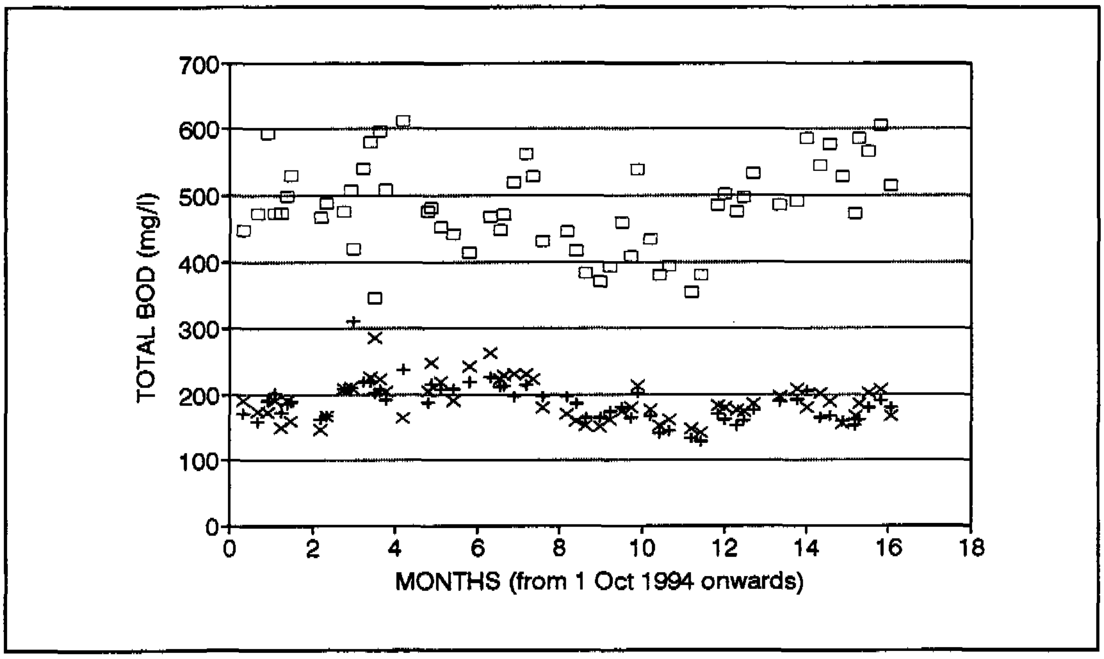

Figure 8. BOD of non-filtered samples of influent (☐), and effluent of reactor 1 (+) and reactor 2 (x), as a function of time.

The BOD of filtered samples showed distinct similarity to that of the VFA, indicating that dissolved BOD for a large part is consisting of volatile fatty acids (not shown).

2.5 TSS and VSS

After start-up the effluent TSS stabilized at fairly stable level of 455 ± 77 mg/l, showing some response to the level of the influent solids. TSS values for influent and effluent are shown in Figure 9. VSS (not shown) demonstrates a great degree of similarity with TSS, the ash content of both influent and effluent being fairly constant at 48.2 ± 6.1 and 43.9 ± 8.6 %, respectively.

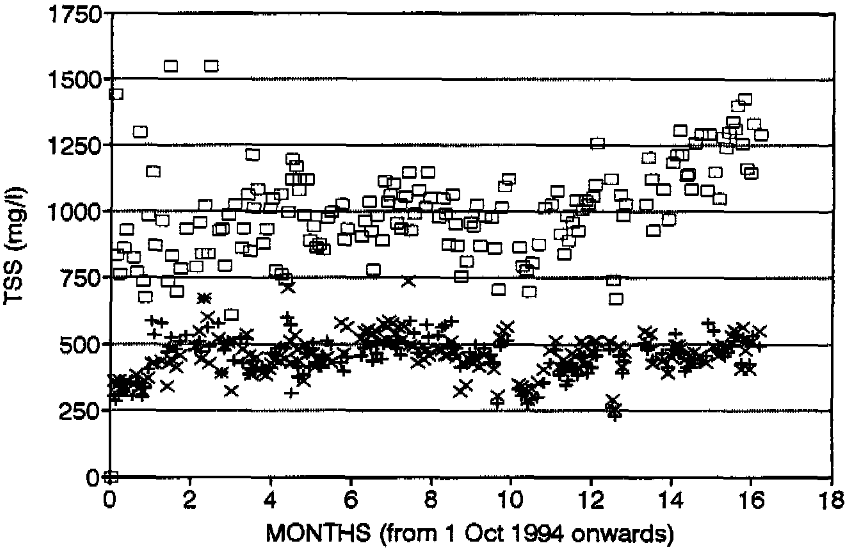

Figure 8. TSS of influent (☐), and effluent of reactor 1 (+) and reactor 2 (x), as a function of time.

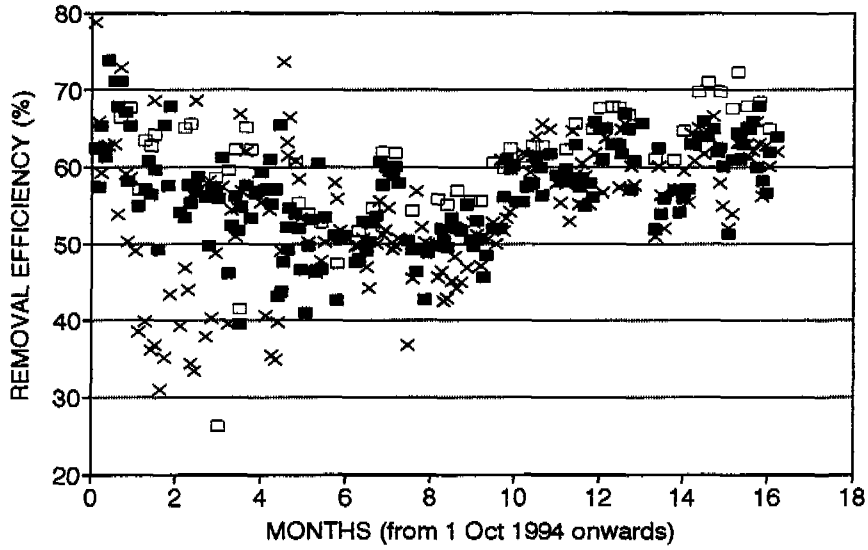

Figure 9. Daily efficiencies for COD_T (☐), BOD (■) and TSS (x) for reactor 1. 2 (x), as a function of time.

2.6 Efficiencies

The efficiency of removal of total COD, BOD and TSS seems to converge into a narrow range, as is depicted in Figure 9 for reactor 1. The efficiencies, averaged per month for both reactors, is shown in Figure 10.

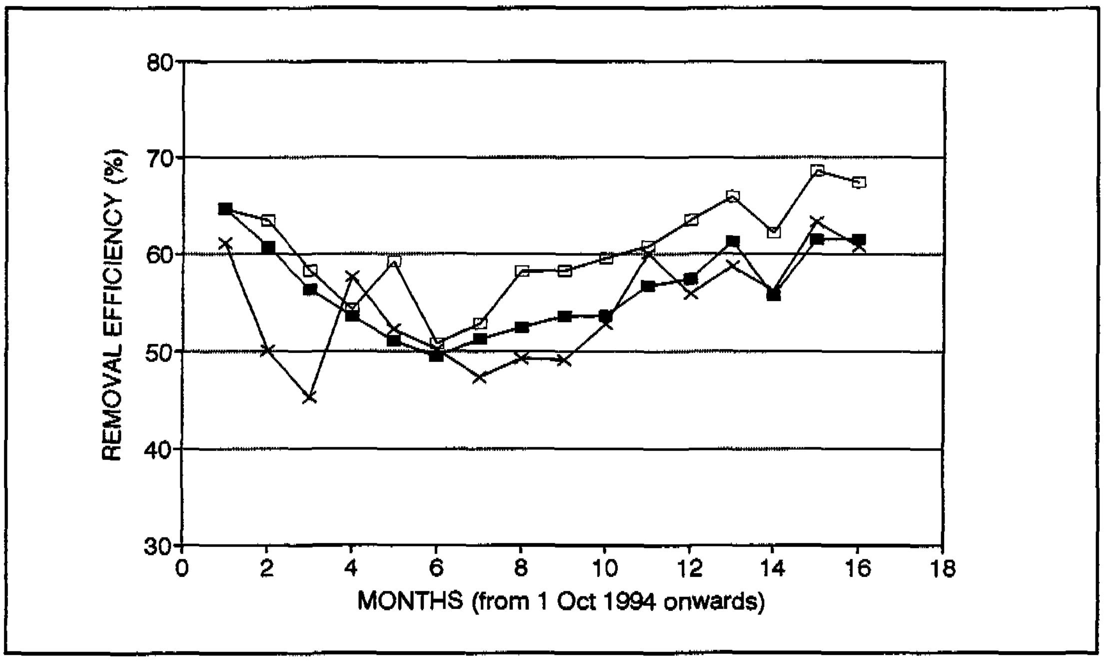

Figure 10. Efficiencies for COD_T (□), BOD (■) and TSS (x) for reactor 1. 2 (x), as a function of time, averaged per month, for both reactors simultaneously.

2.7 Sulphate and sulphide

The influent and effluent values, averaged of both reactors, of sulphate are shown in Figure 11. Contrary to popular belief, there is still a significant amount of sulphate in the effluent. Theoretically it would seem highly probable that sulphate would be nearly completely converted to sulphide, leaving low concentrations in the effluent. Apparently this does not happen, and complete sulphate reduction does not take place.

Sulphide concentrations are already quite high in the influent, but increase quite substantially during the stay of the wastewater in the reactor. This is shown in Figure 12.

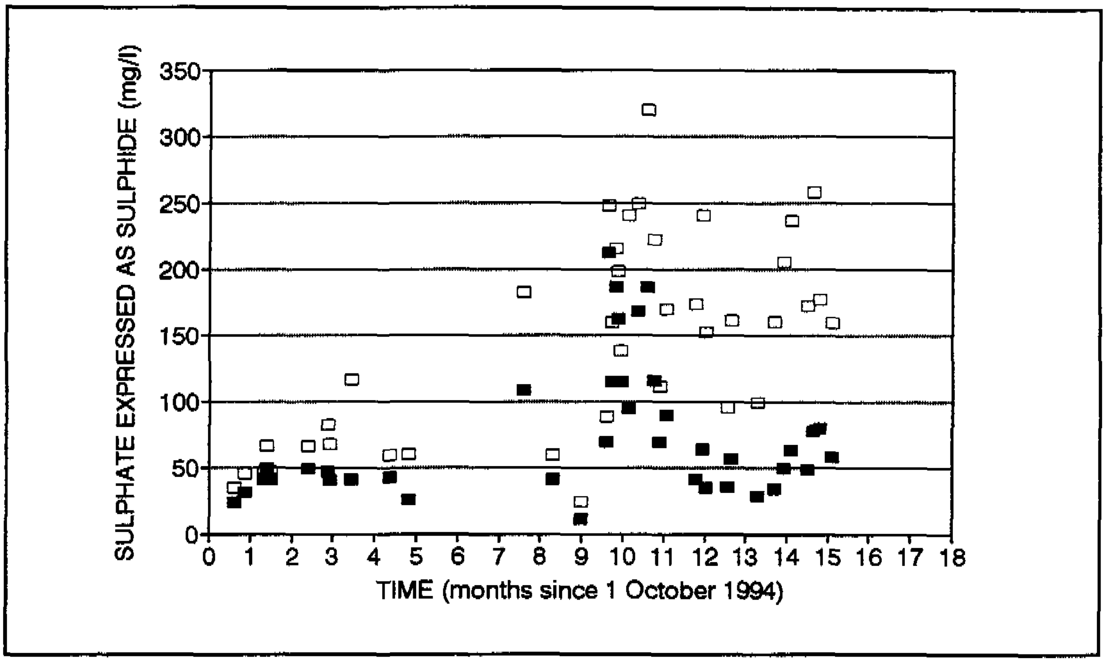

Figure 11. Sulphate in influent (☐), and averaged effluent for both reactors (■), as a function of time. Sulphate has been expressed as sulphide, for comparison with Figure 12.

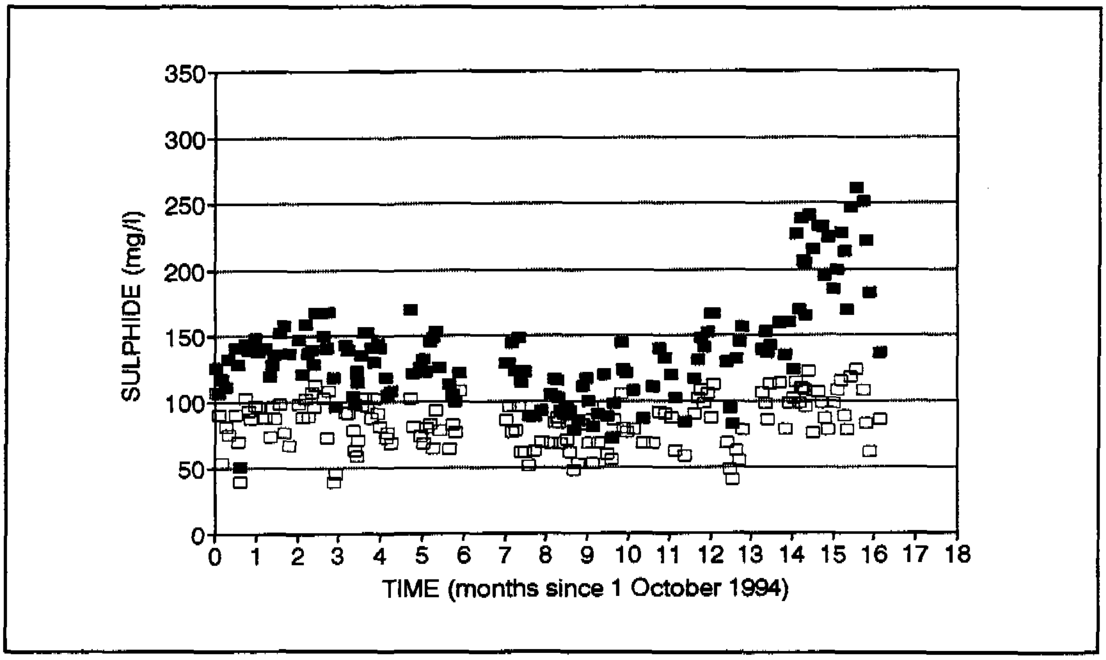

Figure 12. Sulphide in influent (☐), and averaged effluent for both reactors (■), as a function of time.

From Figure 12 it is clear that upon a low dilution ratio of 1:1 tannery : domestic, the sulphide concentration becomes very high. If the pH were somewhat lower than the values actually encountered (see Figure 3), methanogenic conversions would most probably suffer from sulphide intoxication.

The production of sulphide would be the difference between incoming and outgoing sulphide. Sulphide production may be taken as an indication of the actual dilution of tannery wastewater with domestic wastewater, as tannery wastewater will contain much higher sulphate concentrations than does domestic wastewater. In Figure 13 the production of sulphide is shown for reactor 1.

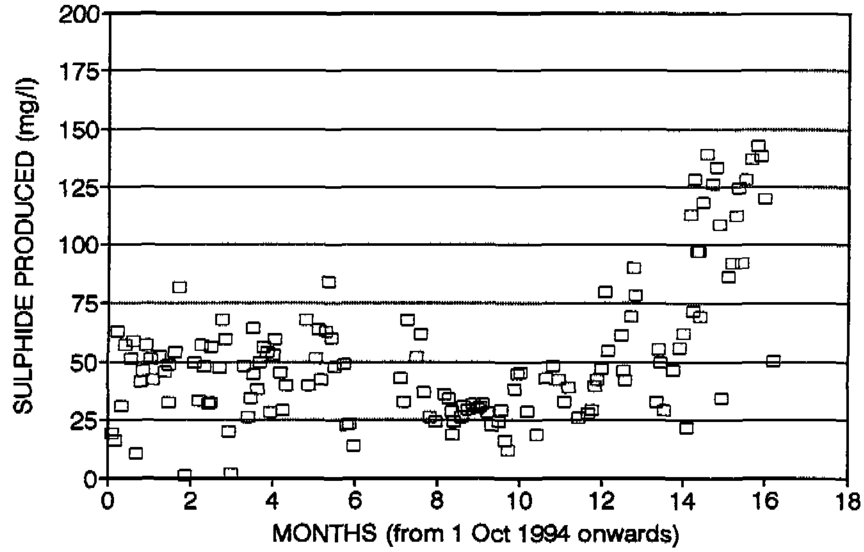

Figure 12. Sulphide production in reactor 1 as a function of time.

It is quite clear that at the end of the period, when the dilution ratio becomes very low, the sulphide production increases to high levels, as did the effluent sulphide concentrations shown in Figure 11.

2.8 Summary of results

The average values and standard deviations of the measured parameters over the complete period are shown in Table 1. Efficiencies after 1 May 1995 have also been included, as the reactors seemed to be steadily improving their performance.

Table 1. Summary of performance results.

		influent		Reactor 1		Reactor 2	
		avg	std	avg	std	avg	std
total flow	MLD			11248	4442	10520	3820
Temperature	C	26	4	26	4	26	4
pH	-	8.3	0.3	7.4	0.2	7.5	0.2
total COD	mg/l	1183	188	504	82	517	89
filtered COD	mg/l	506	67	246	77	252	74
total BOD	mg/l	484	66	187	29	190	31
filtered BOD	mg/l	211	34	97	39	95	27
VFA (meq/L)	meq/l	3.9	0.8	1.0	0.5	1.0	0.5
Alkalinity	meq/l	18.4	2.5	22.1	2.3	22.0	2.1
TSS	mg/l	1000	191	452	77	459	77
VSS	mg/l	480	79	198	49	202	53
Sulphate	mg/l	396	221	193	137	209	139
Sulphide	mg/l	84	19	139	42	137	41
TS	mg/l	4632	870	2456	348	2569	322
VS (MG/L)	mg/l	852	137	329	64	344	66
EFFICIENCY							
COD	%			56.9	6.4	55.7	6.8
BOD	%			60.8	7.5	60.1	8.4
TSS	%			54.4	8.9	54.5	10.1
EFFICIENCIES after 1 May 1995							
COD	%			57.9	5.6	56.9	4.0
BOD	%			63.5	5.0	62.2	3.7
TSS	%			56.4	6.6	56.2	7.1

2.9 Sludge profiles, solids and SRT

A summary of all the sludge profiles taken for reactor 1 is shown in Figure 13. Basically only the higher sampling points (lowest in the Figure) are of principal interest, as they may be reflecting a too high sludge blanket level.

From a sludge profile, by integration over height of the reactor the total amount of sludge in the reactors can be calculated. As sampling for sludge profiles is very difficult and the height intervals are rather high, the amount calculated should be taken as indicative.

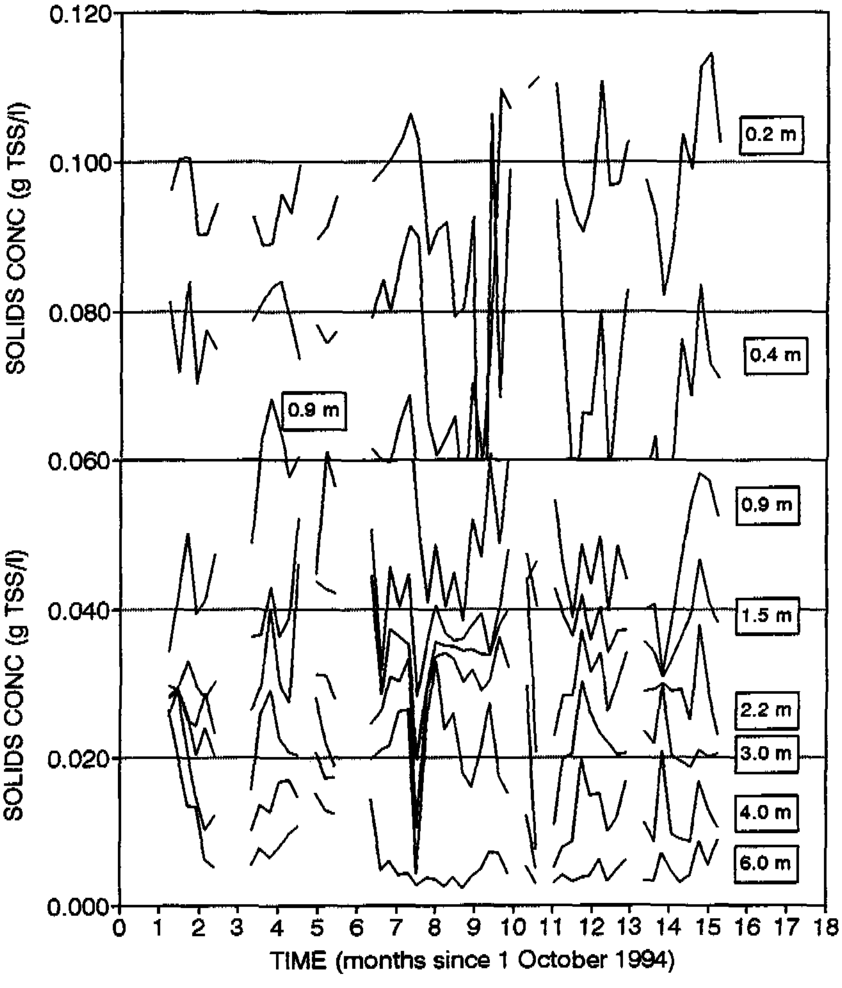

Figure 13. Sludge profiles over reactor 1 as a function of time. The various lines indicate the sludge concentrations measured at various heights, which are indicated in the Figure.

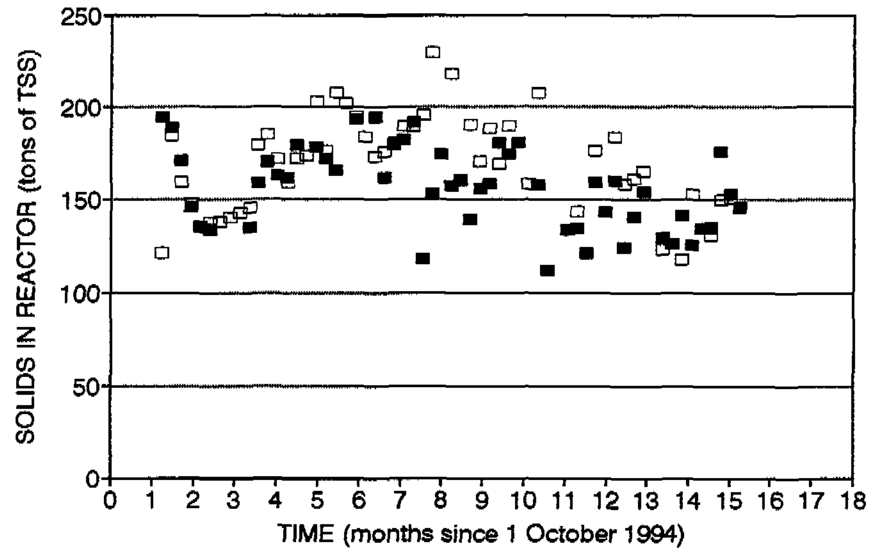

Figure 14. Amount of sludge present in reactor 1 (□) and reactor 2 (■) as a function of time.

A very important operational parameter is the average time the solids spend in the reactor, called solids retention time SRT. This SRT can be calculated from the amount of solids present in the reactor, the effluent solids and the amount of solids discharged. The calculated solid retention times for both reactors are presented in Figure 15.

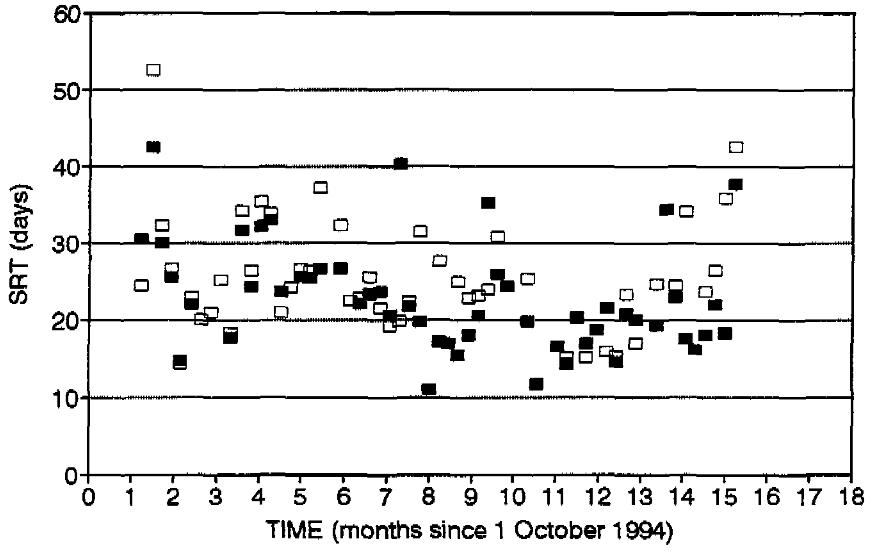

Figure 15. Calculated solids retention times in reactor 1 (□) and reactor 2 (■) as a function of time.

2.10 Discussion

The operation of the Kanpur plant has had some drawbacks, originating in technical problems. It seems that the performance of the plant has not been seriously affected. After start-up the plant has performed remarkably constant, even in winter.

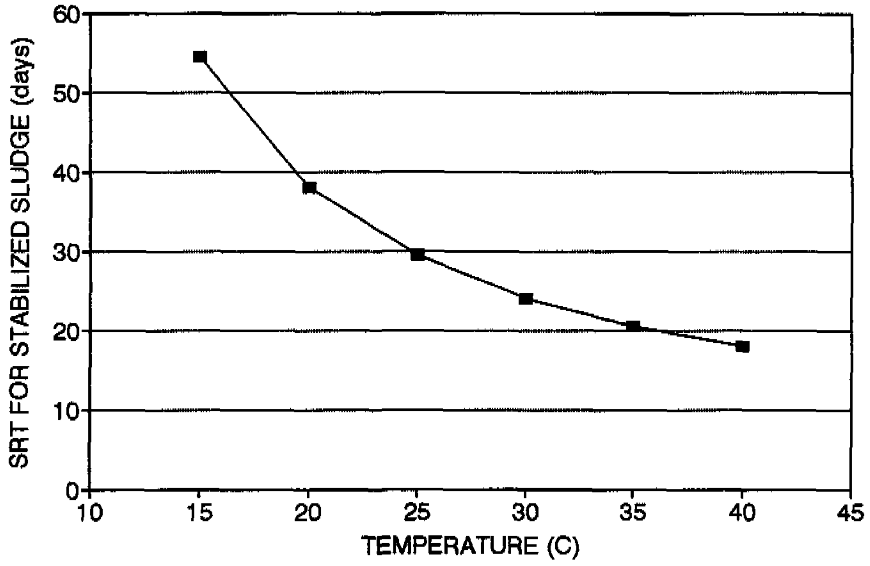

Figure 16. *SRT* considered necessary for good sludge stabilization as a function of temperature.

In Figure 16 the solids retention time *SRT* that is assumed to be necessary for good stabilization of the sludge is shown as a function of temperature. In winter time, the *SRT* of the sludge in the reactors becomes rather low. The dimensionless ratio SRT/SRT_{min} can be taken as an indication of how well the solids are stabilized. It will also provide information on how well peak loadings will be handled. The higher the ratio SRT/SRT_{min} is, the better peak loadings will be handled.

In Figure 17 the ratio $\mathrm{SRT/SRT_{min}}$ is presented for the Kanpur reactors. It can be seen that in winter the ratio is approximately 1, indicating a *SRT* just enough for sludge stabilization, whereas in summertime the ration is much higher, so that a good stabilization can be expected. Apparently the Kanpur plant has no great difficulties in enduring the relatively short period in which the temperature, and hence the ratio SRT/SRT_{min} is low.

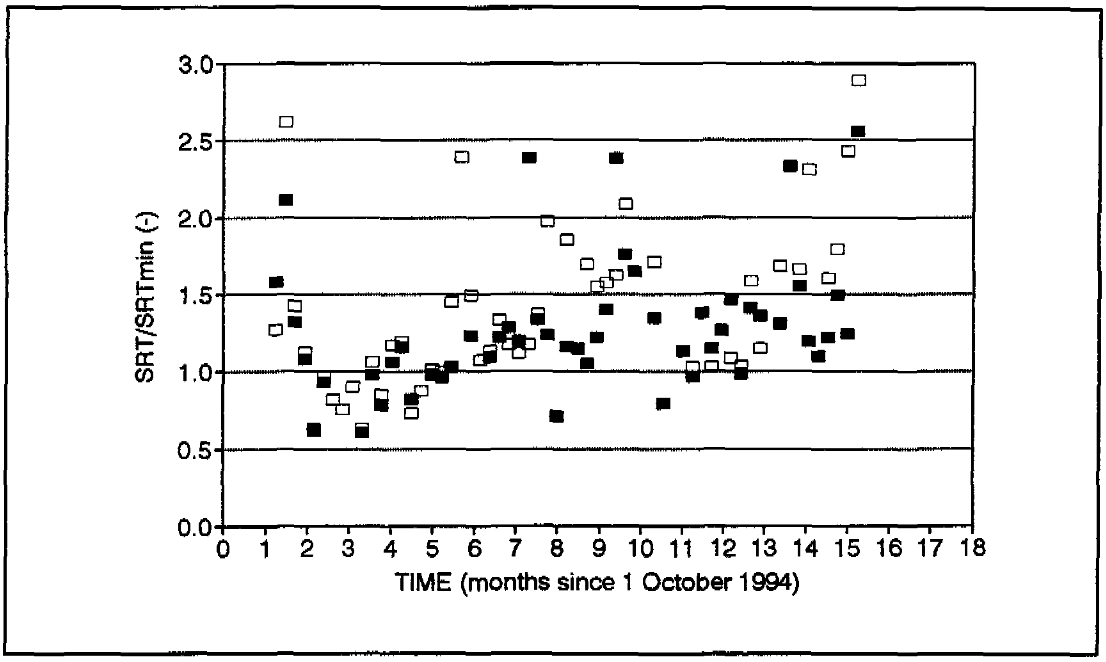

Figure 17. *SRT/SRT*$_{min}$ as a function of time. The ration *SRT/SRT*$_{min}$ is the ratio between solids retention time and solids retention time necessary for good sludge stabilization as depicted in Figure 16.

From the perspective of performance optimization an analysis of the components of the effluent may be interesting. Several measurements can be expressed in terms of COD:

- the total COD of the effluent;
- the VSS of the effluent, by assuming 1 g/l VSS ≈ 1.4 g/l of COD
- the VFA of the effluent, by assuming the VFA consist of acetate, which then will have a COD of 64 mg/l per meq of VFA.

In this way it can be shown what the respective contribution of suspended solids (VSS) and biologically degradable soluble components (VFA) to the effluent total COD is. A high contribution of VFA in the effluent will indicate that the biological performance of the reactor should be optimized. It may be taken as an indication of the *SRT* being too low, or toxic effects of some of the wastewater components, such as sulphide. On the other hand, a high contribution of VSS-COD in the total COD of the effluent will indicate that optimization of process performance should aim at removal of solids from the effluent.

The total-COD, VSS-COD and VFA-COD in the effluent from reactor 1 are shown in Figure 18. From Figure 18 it becomes clear that the effluent solids contribute for a large part to the total COD of the effluent. The contribution of VFA to the effluent COD is quite low, indicating that biologically the reactor performs well.

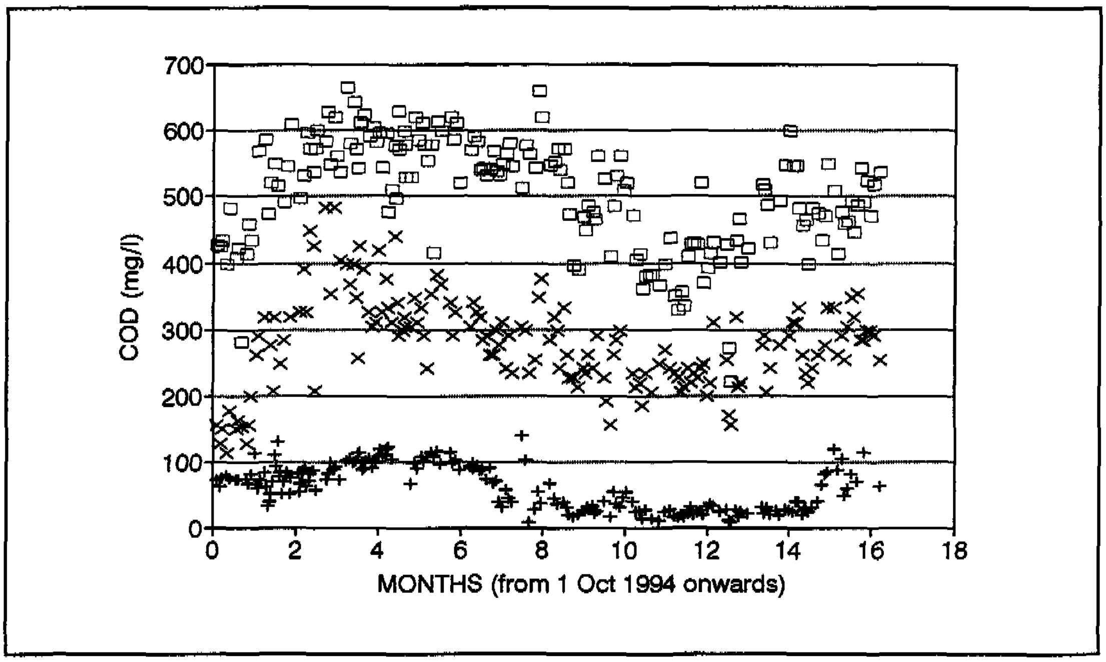

Figure 18. Effluent total COD (☐), COD of VSS (x) and COD of VFA (+) for reactor 1, as a function of time.

The fact that suspended solids contribute for a large part in the effluent COD implies that efforts towards optimization of the performance of the plant should aim at removing solids from the effluent.

3. CONCLUSIONS

1. The Kanpur UASB reactors perform reasonably well, with average removal efficiencies for COD, BOD and TSS of 57 ± 6 %, 61 ± 8 % and 55 ± 9 %, repectively, over the period November 1994 to December 1995. For the period May 1995 - December 1995 the figures are 58 ± 6 %, 64 ± 5 %, and 56 ± 7 %, respectively. The average loading rate during the period was 2.48 ± 0.67 kg $COD.m^{-3}.d^{-1}$.

2. VFA concentrations in the effluent are quite low, indicating that performance of the methanogenic bacteria is good.

3. Upon a low dilution ratio of 1:1 tannery : domestic wastewater, the sulphide concentration becomes very high. Luckily the reactor pH is quite high, because otherwise methanogenic conversions would most probably suffer from sulphide intoxication.

4. Solids retention time in winter time is just sufficient to guarantee efficient solids stabilization.

5. A very significant part of the effluent COD is consisting of the suspended solids in the effluent. This implies that efforts towards optimization of the performance of the plant should aim at removing solids from the effluent.