FINAL REPORT

ANAEROBIC DIGESTION OF BLEACH EFFLUENT
A PILOT PLANT- AND BENCH SCALE STUDIES

by

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WRC 276/1/92

Ko 145/276

sappi management services

Research and Development

R&D90/034

TITLE: ANAEROBIC DIGESTION OF BLEACH EFFLUENT - A PILOT PLANT- AND BENCH SCALE STUDIES

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DATE: 17 October 1990

ABSTRACT: Anaerobic digestion was considered for the treatment of bleach effluent as an organic and sulphate removal step. This investigation formed part of an overall project, the bleach chemicals recovery process.

A pilot plant investigation using an ADUF (Anaerobic Digestion Ultra Filtration) pilot plant was performed. The principle of the ADUF process is to combine ultrafiltration with anaerobic digestion to retain the sludge. In order to cover different aspects of anaerobic digestion bench scale studies were also performed by UHDE (Pty) Ltd and the CSIR.

Good sulphate and chlorate removal was possible but COD (Chemical Oxygen Demand) reduction was low. Packed bed digestion performed better than sludge blanket digestion (Bench scale study). Results from the completely mixed digester (pilot plant) were better than those from the other reactor types (bench scale). No significant difference was observed between high temperature digestion (thermophylic) and low temperature digestion (mesophylic) - bench scale study. Significant biogas production was observed with the pilot plant operating in the completely mixed mode. (Very little biogas was produced in the other studies).

KEYWORDS: EFFLUENT TREATMENT, BLEACH PLANT, BIOLOGICAL PROCESSES, ANAEROBIC DIGESTION

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SINOPSIS

ANAEROBIC DIGESTION OF BLEACH EFFLUENT - A PILOT PLANT- AND BENCH SCALE STUDIES

Anaerobiese behandeling van die bleikuitvloeisel met die oog op vermindering van die sulfaat- en organiese inhoud was deel van 'n oorhoofse projek - Die bleikchemikalieë herwinningskonsep.

Bankskaalstudies deur die WNNR en UHDE (Mpy) Bpk asook 'n loodsaanlegstudie deur SAPPI is onderneem. 'n ADUF (Anaerobic digestion ultrafiltration) loodsaanleg wat van ultrafiltrasie gebruik maak om die slyk te behou is vir die loodsaanlegstudie gebruik.

Goeie afname in sulfaat- en chloraatkonsentrasies kan bereik work maar CSB (Chemiese suurstofbehoefte) reduksie was minder suksesvol. Die gepakte bed verteerder is met die slykkombers verteerder vergelyk en eersgenoemde het beter presteer (bankskaalstudie). Die resultate van die volledig gemengde verteerder (loodsaanleg) was beter as die van die ander tipes verteerders (bankskaal). Geen noemenswaardige verskil tussen hoë temperatuur vertering (termofilies) en lae temperatuur vertering (mesofilies) is waargeneem nie (bankskaalstudie). Beduidende biogas produksie is waargeneem met die loodsaanleg in die volledig gemengde modus - maar baie min in die ander studies.

1. INTRODUCTION

Aerobic digestion was considered as an organic and sulphate removal step, as part of an overall process - bleach chemicals recovery process. Due to the following advantages over other biological processes:

(a) Energy recovery via biogas production
(b) Sulphur recovery via hydrogen sulphide production
(c) Low energy requirements
(d) Low nutrient requirements
(e) Low sludge production

it was considered as an economical favourable process.

A pilot plant study was undertaken at the Ngodwana mill. The pilot plant was operating on a side stream of the bleach effluent (Initially a mixture of 4:1 D/C (bleaching stage): E (extraction stage) effluent and later straight D/C effluent). Subsequently it was also decided to contract the CSIR to compare the mesophylic (low temperature) with the thermophylic (high temperature), and the sludge blanket with the packed bed digestion processes. Lastly a company UHDE (Pty) Ltd was also contracted to evaluate the packed bed anaerobic reactor, and especially the applicability of the French patented, S.G.N. plastic packing material.

2. CONCLUSIONS

1. It is possible to achieve the following reduction in concentration, of components in the D/C effluent, with the anaerobic digestion process.

   1.1 Chlorate - 100% reduction
   1.2 Sulphate - 50-80% reduction
   1.3 Chemical oxygen demand (COD) - 30-35% reduction

2. The bench scale studies indicated that the packed bed digestion process performs better than the sludge blanket process.

3. Very good performance was achieved with the pilot plant in the completely mixed mode. The results were better than any of the other studies.

4. No significant difference was observed in the results from the mesophylic (low temperature) and the thermophylic (high temperature) digestion processes.

5. Very low methane production was observed in all the studies except for the completely mixed digester (pilot plant) and it was concluded that the activity of the methane producing bacteria was inhibited by compounds in the effluent, or by competition with sulphate reducing bacteria for energy sources.

6. The low COD reduction can be attributed to the low anaerobic biodegradability of the toxic fraction, which was found to be more aerobically biodegradable (3).

3. RECOMMENDATIONS

3.1 Based on the results obtained anaerobic digestion can be recommended for chlorate and sulphate removal. Further work must however still be done to maximize COD removal.

3.2 The ADUF process - completely mixed digester combined with ultrafiltration - is recommended for another study. The opinion is held that knowledge gained on anaerobic digestion and ultrafiltration can make another anaerobic digestion study on bleach effluent very valuable.

3.3 It is recommended that the following be considered for future pilot plant work:

1. The need for the addition of nutrients
2. The possible advantage of treating a mixture of D/C and E effluent
3. Dilution of the raw feed with a recycle stream to reduce shocks at the point of contact between sludge and feed.

4. LITERATURE REVIEW

4.1 Definitions

Bacteria can be classified as aerobic - those that can live only when oxygen is present, anaerobic - which require that oxygen not be present, and facultative - which can live either in the presence or absence of oxygen.

Aerobic digestion (9) can be defined as a bacterial fermentation, by which organic matter is broken down in the absence of dissolved oxygen, to produce a mixture of carbon dioxide and methane gases.

Bacteria can also be classified in 3 groups according to the temperature range in which they can exist. The psychrophiles exist in the psychropilic (10) temperature range - 5 $\longrightarrow$ 20^{o}C. The mesophiles exist in the mesophilic range - 25 $\longrightarrow$ 40^{o}C - with optimum system performance (7) at 35 $\pm$ 3^{o}C. The thermophiles exist in the thermophilic range - 40 $\longrightarrow$ 60^{o}C - with the optimum temperature = 55 $\pm$ 2^{o}C. System performance can falter near 42^{o}C as this represents the transition from mesophilic to thermophilic organisms.

The normal bacterial population in waste water treatment can survive in a range of pH from about 5 - 9, but optimum operation will occur if the pH is around neutral (about 6,5 $\longrightarrow$ 7,5).

4.2 Advantages and Disadvantages of anaerobic digestion

Advantages

1. Energy recovery via production of biogas
2. Sulphur recovery via production of hydrogen sulphide (if sulfates are present)
3. Lower energy requirements
4. Lower nutrient requirements
5. Lower sludge production
6. Sludge can be stored during relatively long shut-down periods and re activated in a short period of time

Disadvantages

1. Difficulty in treating diluted or cold effluents
2. The methane producing step is relative sensitive to pH changes, shock loadings and sulphur concentrations
3. Relatively long start-up periods during which the process is relative sensitive
4. Post treatment is necessary due to odorous compounds

4.3 Reactor types

Different anaerobic reactor types (5) were developed for full scale treatment of effluents. The anaerobic lagoon is a low rate reactor and mixing is only by the evolution of the biogas. The contact reactor - a high rate reactor - is a closed tank with an agitator followed by a settling tank. In the UASB (Upflow anaerobic sludge blanket) system - a high rate reactor - the feed is introduced through a distribution system at the bottom. It flows upward through a layer of micro organisms (sludge blanket). A separation system is installed at the top of the digester to separate sludge particles, gas and treated effluent. In the fluidized bed reactor - a high rate process - the effluent flows through a fluidized bed of micro organisms attached to a carrier material. A certain minimum flowrate is needed to keep the bed fluidized. In a fixed bed digester - a high rate process - the organisms grow either on the surface or in the void space of a packing material (usually a plastic material with a large specific area). The effluent may be passed downward or upward through the bed.

4.4 Pelletization

Little is still known about all the factors contributing to the formation of a pelletized sludge with sufficient strength to resist shear, and at a sufficient rate to compensate for washout.

The following can however be presented as criteria for pelletization (11) or better said as ecological conditions under which pelletization is likely to occur.

1. An environment with a high partial pressure of hydrogen
2. A nitrogen source
3. A limited source of cysteine
4. A neutral pH

Two important conditions under which pelletization is not likely to occur seem to be:

1. A system where the influent substrate does not yield hydrogen in the fermentation processes
2. In a completely mixed reactor

4.5 Fermentation steps

The fermentation of a carbohydrate, lipid or protein substrate to methane gas seems to take place in four stages (11) involving three groups or organisms - solubilization and acidogenesis by acidogenic organisms, acetogenesis of short chain fatty acids by acetogenic organisms and methanogenesis by methanogenic organisms.

Stage 1 - Solubilization/hydrolysis: Non soluble organic compounds are hydrolysed by enzymes excreted from acidifying bacteria (extracellular process (11)). The rate of this process is relatively slow and this is often regarded as the rate controlling step (6).

Stage 2 - Acid formation: The hydrolyzed compounds are converted into organic acids such as lactic acid, butyric acid, propionic acid and acetic acid.

Stage 3 - Acetogenesis: Organics of stage 2 are converted to acetic acid, hydrogen and carbon dioxide.

Stage 4 - Methanogenesis: Methane forming bacteria convert the products from stage 3 into methane.

Sulphate is utilized by sulphate reducing bacteria. Hydrogen sulphide is the major end product, although elemental sulphur or organic sulphurous compounds may also be formed (4). Sulphate reducing bacteria use the same energy sources and thus compete with the methane producing bacteria. The sulphate reducing bacteria are also more effective and less sensitive to pH and temperature variations which cause a lowered methane production.

4.6 Treatability of bleach effluent

The practical COD limit for high rate anaerobic processes is in the range 1000 - 30 000 g.m^3 (5,8).

A screening study was done (5) on effluent streams from different paper mills. The samples which showed the greatest inhibition were predominantly bleach plant waste waters from Kraft mills. Chlorinated organic compounds were the most likely source of inhibition. The COD reduction in the samples of bleach effluent was an average 35% with the value for some samples below 20%. Only about 35% of the COD reduction could be correlated with the methane production.

5. EXPERIMENTAL WORK

5.1 Experimental work - Pilot Plant

The pilot plant investigation was divided into two stages for convenience of discussion. Stage one was the period during which completely mixed conditions were maintained in the digester. For stage two changes were made to have conditions in the digester approaching that of a sludge blanket.

5.1.1 Stage 1 - Completely mixed digester

During this period the pilot plant was operated in the ADUF (Anaerobic Digestion Ultrafiltration) mode with completely mixed conditions prevailing in the digester. ADUF mode implies incorporating ultrafiltration as a method of retaining the anaerobic sludge. The sludge is then recycled to the digester.

The pilot plant consisted of a $5m^3$ dome shaped insulated digester. Gas removal was via a water trap and gasmeter. The digester was designed to overflow (at the $3m^3$ level) into a 6001 overflow tank. The feed was introduced via a sparge ring and flow inlets - two were bent to give a circular motion and two were straight to enhance proper mixing.

As mentioned a bank of tubular ultrafiltration membranes was used to separate the sludge from the product. The concentrate from UF unit contained the sludge and was thus recycled. The permeate was the product stream (it was put to drain during the pilot plant study). The membranes were fed from the overflow tank.

The concentrate was combined with the raw feed, heated in a tubular heat exchanger and fed to the digester. The pH was read in the line feeding the membrane unit. Adjustments were made by dosing a saturated MgO solution in the overflow tank. Ammoniumcarbonate additions for alkalinity adjustment as well as diammoniumdiphosphate additions for nutrient requirements were done in the overflow tank.

Three methods were evaluated for membrane cleaning namely:

1. Sodiumhypochlorite solution
2. Sodiumhydroxide solution
3. Enzymatic detergent (Biotex)

The enzymatic detergent (Biotex) was found to be most effective.

5.1.2 Stage 2 - Sludge blanket

The pilot plant configuration during stage one, made it very difficult to adjust the effective residence of the feed in the digester. The digester was operated in the completely mixed mode and it was dependant on the concentrate recycle stream to maintain these conditions. Secondly the feedrate which could be handled in the plant depended on the rate of permeate produced by the UF unit. Based on this, it was decided to change the pilot plant configuration to make the operation of the digester independent from the UF unit. At the same time it was hoped that pelletization of the sludge would be enhanced by maintaining operating conditions in the digester favourable for a sludge blanket.

The aim was thus to keep the option open to operate the plant in the ADUF mode but only to incorporate the UF membranes after the process has stabilized. This configuration would of course also make it possible to evaluate the process without the UF unit.

A new distribution system was installed at the bottom of the digester. This was fed from a secondary sparge ring. A piston type reciprocating pump (dosing type) was installed as feedpump. The overflow tank was incorporated as an external settling tank - although it was used as is, with no additional settling aids. Provision was make to feed the membranes from this tank on a level control basis. When using the membranes the concentrate would be returned to this tank (and not directly to the digester as before). The underflow from this tank was returned to the digester via the original sparge ring with the four inlets. When the membranes were not used the overflow from this tank was the final product for the process.

The level in the digester was changed from $3m^3$ to the $5m^3$ level. A stainless steel coil was also installed in the digester for temperature adjustment of the digester contents. Provision was make for hot/cold water circulation.

5.1.3 Trials

The reader is referred to Table 1 & 2 as well as Figures 1 to 5 presented in the appendix for a summary of the trials and the results obtained.

5.1.3.1 Stage 1

During stage one various operational problems were encountered. Temperature control was very difficult, pumps gave problems and due to a free chlorine shock (7 ppm) activity of the bacteria was lost -

additional sludge was loaded. Nevertheless, when analysing the data it is clear that the pilot plant performance during stage 1 was better than during stage 2. In fact the results even seem to be better than those obtained during the CSIR and UHDE studies (see discussions under 5,2 and 5,3).

As can be seen from Table 1 and Figures 2 and 3 the sulphate - and COD reductions were the highest of the whole period - over 50%. It was also during this period that most gas formation was observed. (Accurate gas readings were not possible due to level changes in the digester).

It is difficult to provide reasons for the good results obtained during this period. The following can be presented as possible contributing factors to the performance. Firstly the feed to the pilot plant was made up by mixing D/C (bleaching stage) and E (extraction stage) effluents in the ratio of 4:1 (D/C:E). It is possible that the E stream was contributing to the better performance by diluting the toxic compounds in the D/C stream to a less inhibiting level for the bacteria. Secondly and probably more important is the fact that the digester was operated in the completely mixed mode. This factor differentiates the pilot plant study from both the CSIR and UHDE studies.

It is however important to see these results against the background of the very low space loading rate 0,2 - 0,48 kg COD/m^3 day. (Space loading rate is calculated from the sludge volume in the digester, the volumetric feedrate, and the COD content of the feed e.g. 213 $l/h/3m^3$ x 1596 mg COD/l = 0,113 kg COD/m^3 day).

5.1.3.2 Stage 2

Operational problems during stage two were less prominent. Temperature control with the coil was improved however due to the urgency of the bleach chemicals recovery project there was a great need for results. Therefore it was decided to increase the feed to the anaerobic plant dramatically. It was thought worth while to take the risk although the plant was not performing well. The feedrate was increased in the period 32-36 weeks, to a peak space loading rate of 1,4 kg COD/m^3 day in week 35. For the rest of the period the space loading rate was very low - 0,3 kg COD/m^3 day.

During the last few weeks of the trial period the anaerobic plant was operated on a very low priority basis. Due to more positive results produced in other pilot plants of the same overall project, it was decided to preferably keep them running during periods of low effluent availability.

The data representing stage 2 - week 26 and onwards reflects the poor performance of the pilot plant during this period. Even during periods of very low space loading rates COD and sulphate reductions of less than 40% was experienced. It can be seen from Table 1 that very low reductions were sometimes experienced. No conclusions could be made from the performance when higher space loading rates were used. The performance of the plant was bad before the increase in space loading rates and it continued to perform badly.

5.1.4 **Analytical Results**

A summary of the analytical results is presented in Table 2. By viewing the results for the different components it is clear that for chlorides, silicates, sodium, calcium, magnesium and iron very little change took place over the anaerobic digester. Chlorate reductions were good and it can be assumed to be 100%.

The phosphate analysis indicates an increase on various occasions. This was due to the addition of diammoniumphosphate for nutrient requirements. The nutrient dosage was never optimized. The rule of thumb: COD:N:P in the ratio of 500:15:3 was used during the pilot plant study for calculation of quantities for nutrient dosage.

5.2 **Bench Scale Studies - CSIR**

The CSIR was contracted to perform a bench scale study to evaluate the following: Firstly mesophylic versus thermophylic digestion, and secondly the fixed film reactor was to be compared with the sludge blanket reactor/digester. In addition a comparative study was also done on the effect of sugar and hydrogen respectively as additional energy source.

No significant difference was observed in the results from the thermophylic and mesophylic digestion processes. When evaluating the two different reactor types - sludge blanket and fixed film - it was found that the fixed film reactor could tolerate external changes better and gave better performance on the whole. Start up performance of the sludge blanket reactors were however better.

The results obtained indicated that a COD reduction of 35%, a sulphate reduction of >80% and a chlorate reduction of 70% could be achieved by a retention time of 4 days.

Hydrogen gas was found to be a viable energy source for anaerobic digestion of the bleach effluent. The retention time was shortened to 20 hours with COD reduction the only parameter not positively enhanced by addition of the hydrogen gas.

It was concluded that anaerobic digestion is not the ideal process for COD removal from the D/C stage bleach effluent. The combination processes were suggested as alternative to only anaerobic treatment namely: a combined anaerobic - aerobic process or a combined anaerobic - activated carbon process.

5.3 Bench Scale Study - UHDE (Pty) Ltd

A three month bench scale study was undertaken to investigate the suitability of the S.G.N. (Societe Generale) fixed film anaerobic digestion process, to treat the D/C bleach effluent. The aim with the study was to evaluate the fixed film process and especially by using the S.G.N. plastic packing material.

It was however found that the biodegradability of the effluent was very low - an average COD reduction of 35% was achieved. Methane bacteria was shown to be sensitive to the toxic compounds in the effluent. Sulphate reduction was very high - 100% - at low feedrates but lower - 50 to 60% - at higher feedrates. Chlorate reduction was complete. Degradation of AOX concentration was 60-85% at lower feedrates but went down to 50% at higher feedrates. Unfortunately insufficient time was available to monitor sulphate and AOX reduction over a longer period at the higher feedrates. As part of the testwork boiling and air stripping of the effluent was also done but no improvement in the biodegradability was observed.

It was concluded that anaerobic digestion is not suited for biodegradation of the COD fraction of the D/C effluent because of the presence of toxic compounds. Good results in reducing sulphate and chlorate levels were however achieved.

6. ACKNOWLEDGE

The work of the following technikon students on this project is hereby acknowledged:

W. MAKHUBEDU, R. MATHABA, B. MKIZE, A.A. MNQUNDAMISO, M. MOALUSI, E. MSIBI, V. SIBIYA, J. THULO.

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8. APPENDIX

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FIG.: 1 FEEDRATE OVER TRIAL PERIOD

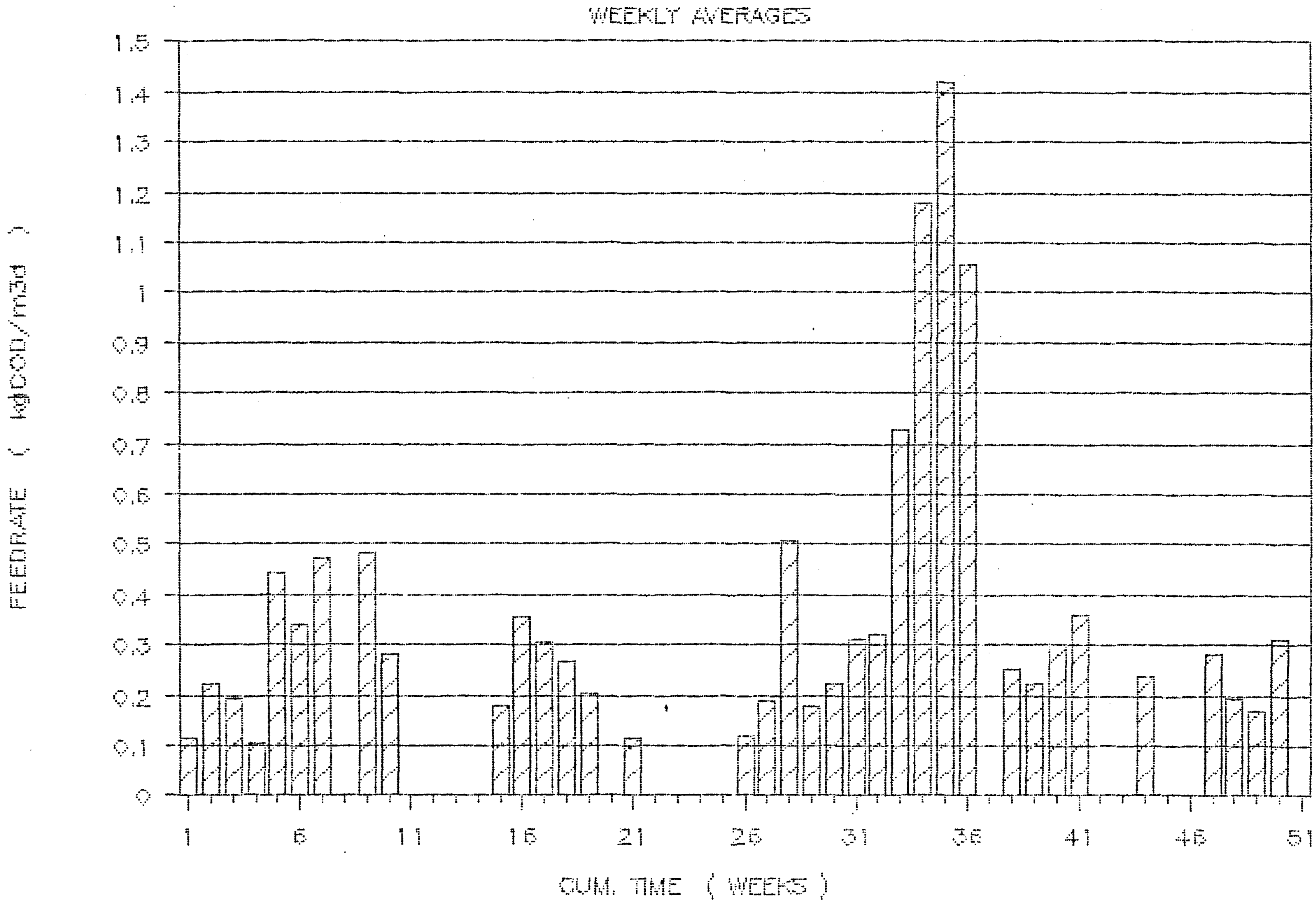

FIG.: 2 COD REDUCTION, PRESENTED AS %

WEEKLY AVERAGES OVER TRIAL PERIOD

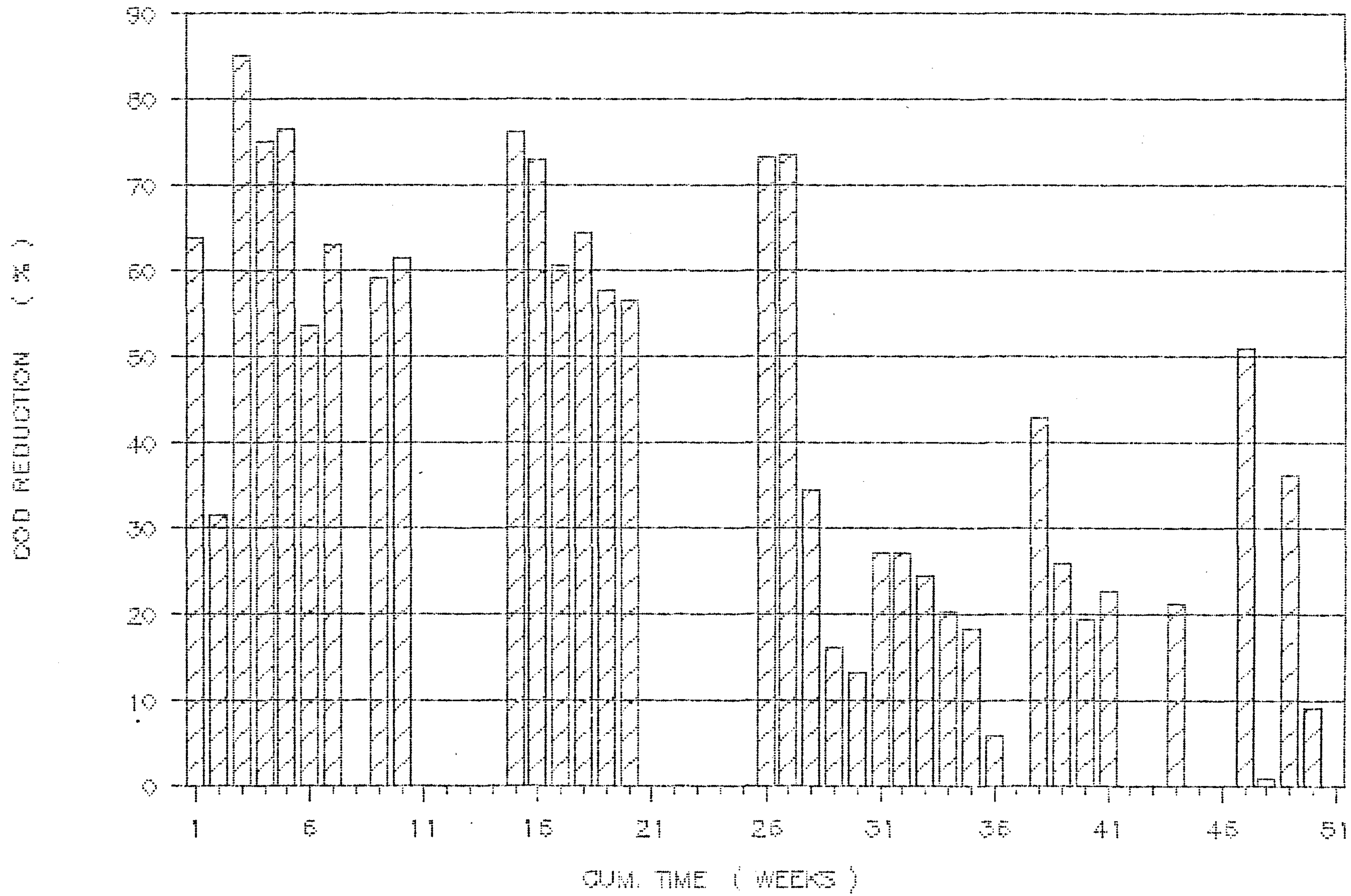

FIG.: 3 SULPHATE REDUCTION

WEEKLY AVERAGES OVER TRIAL PERIOD – %

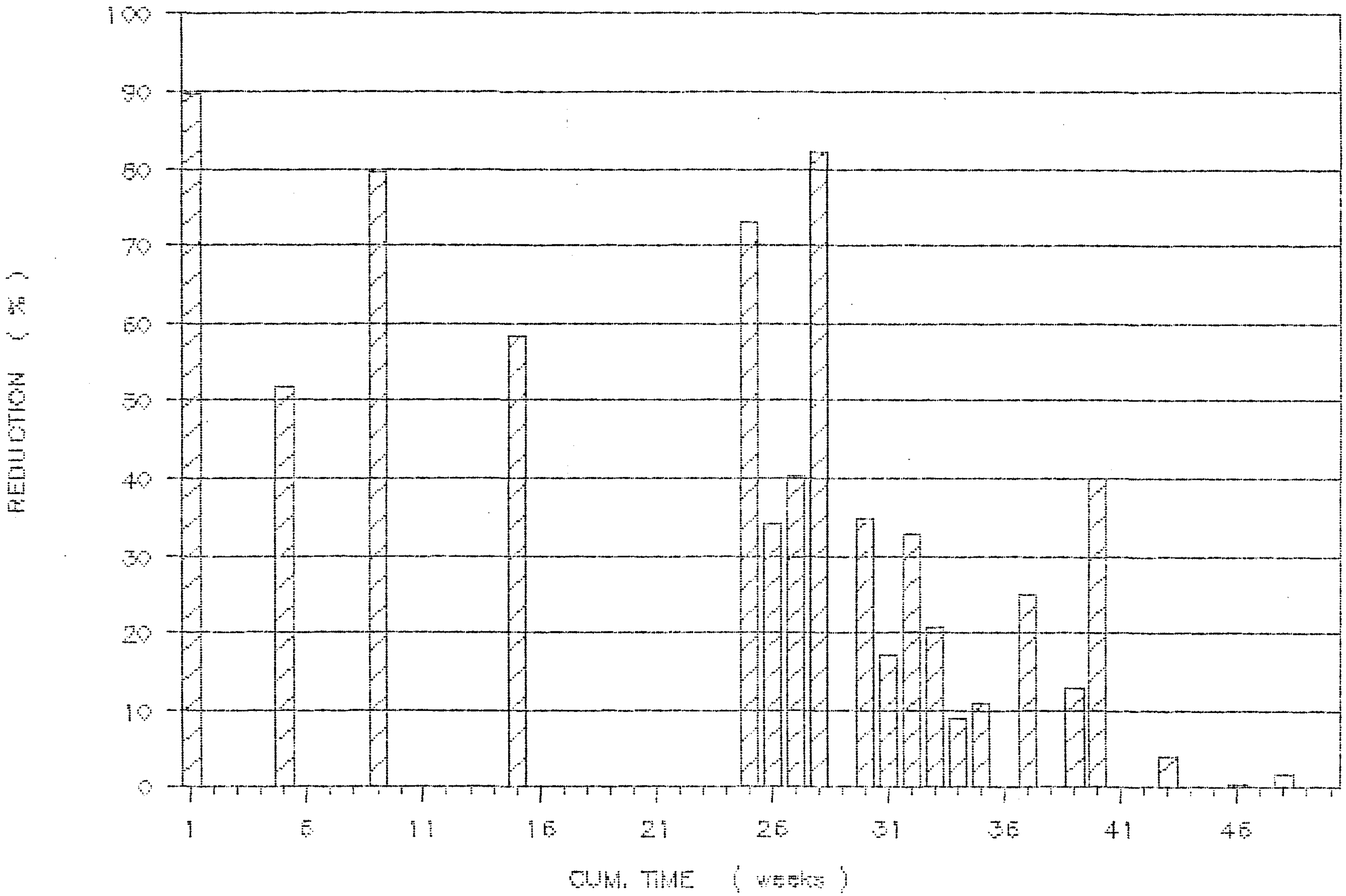

FIG. : 4 COD — IN & OUT

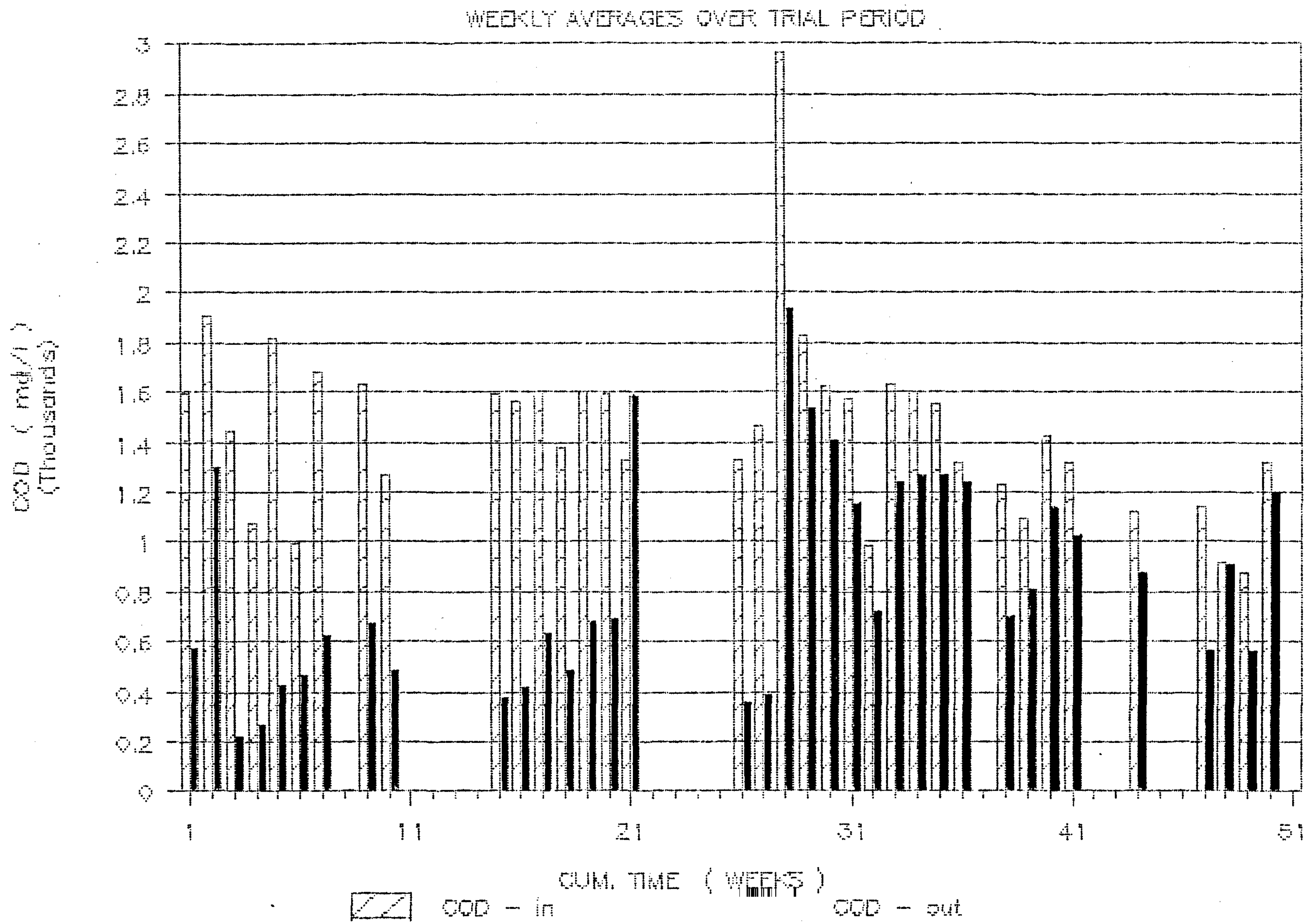

FIG.: 5 SULPHATES — IN & OUT

WEEKLY AVERAGES OVER TRIAL PERIOD

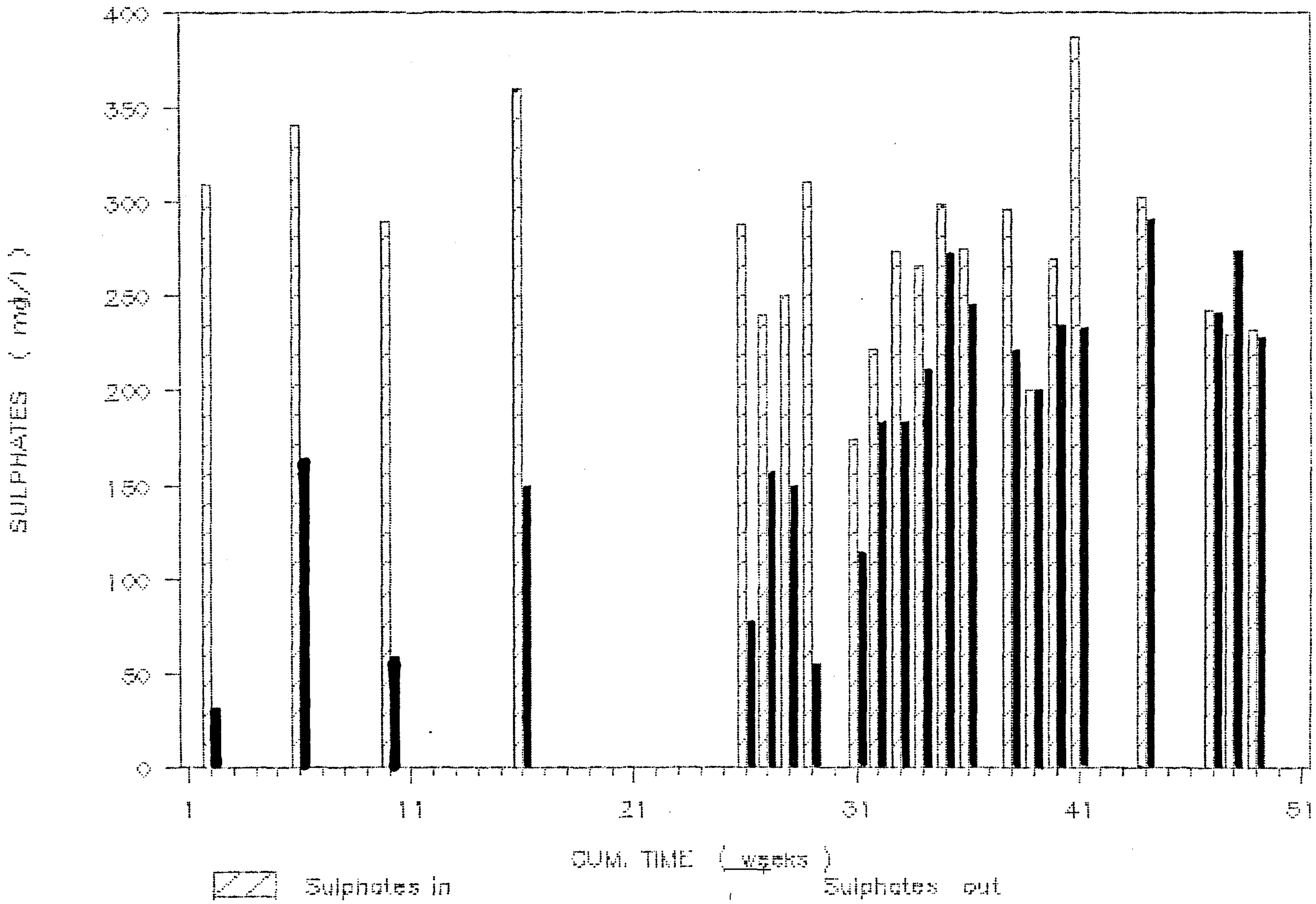

TABLE : 1 PLANT DATA (WEEKLY AVERAGES)

WEEK	FEEDRATE WEEKLY AV l/d	FEEDRATE WEEKLY AV kgCOD/m3/d	COD (mg/l) WEEKLY AVERAGE in	COD out	COD % red	SULPHATE (mg/l) WEEKLY AVERAGE in	SULPHATE out	SULPHATE % red	VFA (mg/l) WEEKLY AVERAGE in	VFA out	VFA dif	ALKALINITY (mg/l) WEEKLY AVERAGE in	ALKALINITY out	ALKALINITY dif	pH	TEMP C
1	213	0.113	1596	576	64				189	75	114	384	955	571	7.6	33
2	348	0.221	1908	1303	32	309	32	90	235	29	206	511	943	432	7.6	35
3	399	0.192	1447	215	85				330	108	222	331	539	208	7.7	33
4	290	0.104	1072	266	75				339	191	148	482	657	175	7.4	34
5	732	0.443	1816	426	77				292	165	127	30	868	838	7.4	35
6	1030	0.342	997	461	54	340	164	52	280	225	55	10	777	767	7.2	33
7	842	0.472	1682	621	63				291	320	-29	62	860	799	7.1	32
8	770								266	275	-9	21	771	750	7.2	32
9	881	0.481	1637	669	59				308	227	81	9	827	818	7.3	33
10	670	0.283	1268	488	62	290	59	80	289	297	-8	19	881	862	7.3	32
AVERAGE	618	0.295	1491	558	63	313	85	74	282	191		186	808	622	7.4	33
15	336	0.178	1592	375	76				227	104	123	155	864	709	7.9	
16	684	0.356	1562	420	73	360	150	58	322	81	241	80	891	812	7.5	35
17	576	0.308	1603	628	61				280	102	179	78	918	840	7.5	36
18	576	0.264	1376	489	64				182	112	70	192	940	748	7.7	37
19	377	0.202	1605	680	58				343	180	163	107	932	825	7.5	32
20			1589	690	57				281	172	109		770		7.8	34
21	258	0.114	1328	1584	-19				291	318	-27	122	858	736	7.9	34
AVERAGE	468	0.237	1522	695	65	360	150	58	275	153		122	882	778	7.7	35
26	446	0.119	1332	356	73	288	78	73	278	93	185	180	936	756	7.4	35
27	652	0.191	1461	384	74	240	158	34	334	154	180	175	982	807	7.3	35
28	855	0.507	2962	1940	35	250	149	40	260	190	70	285	1064	779	7.3	36
29	483	0.177	1830	1530	16	311	56	82	202	443	-241	364	1778	1414	7.6	35
30	695	0.225	1620	1403	13				202	364	-162	292	1111	819	7.3	35
31	989	0.312	1576	1148	27	175	114	35	232	256	-24	296	1071	775	7.3	35
32	1627	0.322	990	720	27	222	184	17	254	226	28	224	745	521	7.2	34
33	2226	0.728	1636	1236	24	274	184	33	247	232	15	373	702	329	7.1	32
34	3678	1.177	1600	1273	20	266	211	21	187	257	-70	439	805	366	7.1	32
35	4571	1.420	1553	1266	18	299	272	9	201	190	11	432	555	123	6.8	32
36	4000	1.056	1320	1240	6	275	245	11	170	186	-16	587	655	68	6.7	35
37	486															33
AVERAGE	1726	0.567	1625	1136	30	260	165	36	233	236		332	946	614	7.2	34

TABLE 1 CONTINUES : PLANT DATA (WEEKLY AVERAGES)

WEEK	FEEDRATE WEEKLY AV		COD (mg/l) WEEKLY AVERAGE			SULFHATE (mg/l) WEEKLY AVERAGE			VFA (mg/l) WEEKLY AVERAGE			ALKALINITY (mg/l) WEEKLY AVERAGE			pH	TEMP C
	l/d	kgCOD/ m3/d	in	out	% red	in	out	% red	in	out	dif	in	out	dif		
38	1029	0.253	1230	700	43	296	222	25	171	179	-8	285	625	340	7.3	33
39	1029	0.224	1090	808	26	200	200	0	161	186	-25	570	984	414	7.0	
40	1060	0.302	1424	1144	20	270	235	13	191	177	14					32
41	1371	0.362	1320	1020	23	388	233	40								33
42	1769										0			0		
43	1603										0			0		
44	1057	0.237	1120	880	21	303	291	4	213	157	56	365	1005	640		32
45	1015										0			0		
46	1194										0			0		
47	1224	0.280	1144	560	51	242	241	0	142	190	-48	307	810	503	7.2	34
48	1043	0.192	920	910	1	230	274	-19	157	206	-49			0	7.0	34
49	959	0.169	880	560	36	232	228	2	231	705	-474	885	685	-200	7.2	33
50	1170	0.309	1320	1200	9				115	152	-37	506	926	420		32
51	1104										0			0		
AVARAGE	1188	0.259	1161	865	26	270	241		173	244		486	839		7.1	33

TABLE : 2 ANALYTICAL DATA

WEEK	CHLORIDES mg/l		CHLORATES mg/l		SILICATES mg/l		PHOSPHATES mg/l		SODIUM mg/l		CALCIUM mg/l		MAGNESIUM mg/l		IRON mg/l	
	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out
1																
2	1735	1633	417	180			21	49	112	751	70	32	237	44	2.9	1.3
3																
4																
5																
6																
7																
8																
9																
10	2056	2018	444	191	124	13			1485	1270	90	70	320	.390	1.1	0.2
11																
12																
13																
14																
15																
16																
17	2333	2292	425	0			0	9	1689	1547	90	70	259	320	1.7	0.7
18			488	0			0	69								
19																
20																
21							15	47								
22																
23																
24																
25																
26																
27																
28																
29																
30																
31	1810	1810	236	0												
32	1764	1609	236	0	54	50	18	28	600	700	45	44	125	133	1.1	0.8
33	2347	1847	162	24	88	92	10	22	950	865	133	125	514	419	2.4	2.3
34	2418	2411			54	62	55	76	802	857	119	124	400	485		
35	2146	2352	317	125	60	61	20	16	837	898	102	109	385	379	1.2	1.6
36	2679	2666	297	112	24	18	15	19	900	913	75	81	325	315	1.3	2.0
37																

TABLE 2 CONTINUES : ANALYTICAL DATA

WEEK	CHLORIDES mg/l		CHLORATES mg/l		SILICATES mg/l		PHOSPHATES mg/l		SODIUM mg/l		CALCIUM mg/l		MAGNESIUM mg/l		IRON mg/l	
	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out
38	2150	2045	267	269	34	39	9	19	1096	1113	87	84	343	319	1.5	1.2
39	2148	2021	213	28	42	45	6	27	883	977	98	92	510	427	0.7	0.9
40	2347	2340			37	39	5	14	920	968	89	88	344	376		
41	2428	2443							1500	1200	98	87	481	384		
42																
43																
44	2252	2254			50	52	8	10	1138	1138						
45																
46																
47	2148	2280	272	0	57	64	8	10	905	1107	68	69	613	571	1.4	1.1
48	2185	2145	562	0	75	82	8	13	817	1000						
49					138	188	20	40								

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