KINGDOM OF THE NETHERLANDS
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REPUBLICA DE COLOMBIA
DEPARTEMENTO NACIONAL
DE PLANEACION
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ANAEROBIC TREATMENT AND RE-USE OF DOMESTIC WASTEWATER

PILOT PLANT STUDY CALI-COLOMBIA

PROGRESS REPORT Nº. 3

september 1984

-HASKONING-ROYAL DUTCH CONSULTING ENGINEERS & ARCHITECTS B.V.
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ANNEXES

1. INTRODUCTION AND PRELIMINARY CONCLUSIONS

1.1 Introduction

The year 1984 started well: the pilot plant was running with a loading rate that was higher than was expected one year before. In the period March to June 1984 however, many problems occurred again with the influent pump and much time was needed for reconstruction of the pilot plant in order to permit higher flow rates and for designing and supervising the construction of the post-treatment systems. This resulted in much delay in the performance of the research programme, so it is inevitable now to reduce the programme.

The new Dutch assistant engineers, who arrived in Cali mid 1984, proved to be well introduced in the matter of anaerobic treatment).

The UASB-programme met much enthousiasm in Colombia on the part of official bodies like waterboards and of consultant engineers and industries having wastewater problems. Making a start with meeting the need for information about the UASB-system, a one-day course was given to personnel of the University del Valle, the regional water authority (AQUAVALLE) and the municipal wastewater service (EMCALI). In spite of this and in spite of a more active participation of Colombian students in the research, insufficient qualified personnel is available to meet the growing need of performing treatability studies and, in the near future, constructing and starting-up anaerobic (pilot) plants. Until now, some requests from the waterboards or individual engineers for information about the

UASB-system could be handled by the Dutch team and by the Colombian counterpart, however their first interest is the implementation the research programme.

The pilot plant showed very good results so far, in spite of the many problems with the influent pump. This makes the UASB-design economically very competitive to the traditional wastewater treatment systems such as stabilisation lagoons, oxidation ditches, and other aerobic and anaerobic systems.

In July 1984 the post-treatment systems were put into operation, some of them promising good results.
The UASB pilot plant probably can be operated at even higher loading rates than applied so far. The need for information can be satisfied for a great deal in the October seminar. Within the project, both on Colombian and Dutch side, a still growing enthousiasm exists, which ensures a fruitful cooperation and which enables solving the many unexpected problems that occur.

1.2 Preliminary conclusions

With respect to the technical research programme and the socio-economic studies the following preliminary conclusions can be drawn:

- The results obtained over the passed six months clearly proof the feasibility of the UASB-process for treating low strength domestic waste at temperatures in the range 24-30°C. Hydraulic loads of $6 m^3 m^{-2} d^{-1}$ are exceptionally accommodated, viz. at COD-removal efficiencies (based on filtered or settled effluent samples and raw influent samples) ranging from 75-85%. The BOD-treatment efficiency even is in the range 75 - 93%.

- The UASB-reactor performs satisfactorily with only one feed inlet line per $4m^2$. On the other hand it should be pursued to connect each separate feed inlet line with its own feed supply box. For a proper operation of the influent flow distribution over the various boxes it is recommended to apply a finer screen, mesh 1.5 - 2 cm.
- Once the top of the sludge blanket reaches the effluent weirs, sludge should be discharged from the reactor in order to maintain a high SS-removal efficiency.

Large scale introduction of (UASB) wastewater treatment becomes technically and economical feasible in the Valle Department, as is illustrated in the follwoing chapters.
As the Valle Department is playing a "poineering" role in the whole development of Colombia, the obtained experience with pollution control in general (and wastewater treatment more in specific) will be of importance for the future of the rest of the country.

At the national level of government, a principal willingness towards activities in the area of waste-water treatment - as part of an overall anti-pollution policy - is expressed in the formulation of more and better legislation*). Specific willingness is also made clear in the shown interest of the Ministry of Health (INAS), through its executives, for the development of suitable wastewater treatment systems.

*most important: 1974, Codigo Nacional de Recursos Naturales Renovables y de Proteccion al Medio Ambiente (Decreto 2811)
1979, Ley 09, Sanitaria Nacional.

On the regional level i.c. the Valle Department, the organisation responsible for the conservation of replaceable natural resources (CVC), made a step further, already demanding that all disposals (industrial and domestic) should be treated within the coming years.
Thus, it can be said that in Colombia and especially in the Valle Department, a strong institutional willingness exists for treatment of wastewaters.

In general, the financial situation in many organizations responsible for water supply and sewerage, is very bad. In the urban parts, the rapid growth of the cities put a priority on the extension of water supply and sewerage, whereas the quality of the drinking water as well as of the existing distribution systems and sewerage need much attention too.
Therefore at this moment no financial resources are available to invest in new treatment plants.
At this moment actual implementation of wastewater treatment in the Valle Department is possible in so called "urbanicaziones" (urban extensions of about 500 to 5000 people). In these projects (private or institutional), treatment plants have to be included before a

building permission will be provided for the project. This type of "urban extension" is quite typical for (whole) Colombia.

A special extra budget has to be given for wastewater treatment, by the national or regional government.

In rural areas are in general less possibilities for wastewater treatment because many other priorities play a role, like better food, housing, drinking water and excreta disposal. Thereby, great part of the rural population lives in dispersed areas where collective sewerage is impossible.

Thus, in spite of the institutional willingness, the actual possibilities of introduction of wastewater treatment i.c. the capability to pay investments, in the public sector is rather low for existing urban areas.

In the industrial sector however more capability as well as willingness exists to build treatment systems. In this area most activities can be expected in the coming years.

As a last point, the organizational and technical conditions for wastewater treatment should be considered.

Domestic wastewater treatment could be implemented in the existing organisational structure given by the public and private enterprises operating drinking water supply and sewerage.

In principle, these organizations are technically capable of managing new treatment plants. Thereby, the study of sanitary engineering at the Valle University, provides a growing potential of young engineers in this field. Lower personnel is trained within the organizations itself.

Technical constraints like local construction capacity and available materials will not play a role in the implementation of (UASB) wastewater treatment, at least not in most cities of Colombia and in the Valle Department as a whole.

what about the problem with the pump

Though often in a bad condition, most urban parts (70%) have connections to a sewerage system. In most cases use can be made of gravity for transporting sewage.

2. THE PILOT PLANT

2.1 The process research programme

The pilot plant was operated from November 1983 - August 1984 as shown in Annex 1. It is obvious that much delay occurred from the many problems with the influent pump. Because of this, a new Flygt pump was ordered for from Sweden on May 5 1984 and arrived in Cali on August 14 1984.

This means that the new goals, i.e. reaching the maximum possible loading rate already in May 1984, operating the plant under normal conditions and performing tests on hydraulic and eventual organic shockloads, as well as obtaining knowledge about the periodical maintenance of the plant, could not be achieved so far.

Since results obtained at hydraulic retention times of 8 and 6 hours were far above expectations, it was considered to be useful to operate the plant at lower retention times. With the available submersible pump, a retention time of 4 hours could be reached. For operation at lower retention times, a pump of higher capacity is needed. The results obtained with the pilot plant in terms of removal of pollutants (COD, BOD) are described in Chapter 5.

2.2 Influent pump

As described in the Progress Report no. 2 (page 7) two small submersible pumps were bought to deliver water to the pilot plant. Until April 1984 this situation was

~~the total~~ major results / tests of the project, are endangered by this; so the statement is a bit weak

more or less satisfactory. However, in April 1984 both pumps got damaged and repair took much time. In fact the locally fabricated pump forms the most vulnerable part of the pilot plant.
For reasons described in Chapter 2.1, a new and more powerful pump was ordered for.

2.3 Piping systems

Higher flows will result in higher friction losses in the piping system from the submersible pump to the reactor. In the piping system a grit chamber is incorporated, to remove sand from the wastewater. The higher friction losses would result in a higher pressure on the grit chamber, since this is a closed structure. To prevent this higher pressure, that was calculated to be approx. 8 m.w.c., the piping system was replaced by a 4" system. Friction losses will be reduced, the pressure on the grit chamber will be not more than 3 m.w.c. which is still more than the pressure on the old chamber. The new pipes were installed during the recent dispatch term of the HASKONING process engineer.

2.4 Grit chamber

The grit chamber, reinforced in August 1983, did not resist the alternating suction and pressure that occurred when the influent pump was switched off and on. It started leaking, also due to corrosion. When it started leaking, it was welded to close the leaks. This happened twice and it became clear that his was not a proper solution. A new grit chamber was designed.
This one is bigger and stronger than the old one, since it is expected that the new pump not only will deliver

a higher flow, but also more sand. The chamber is made of stronger sheet and reinforced with steel ribs, since a higher pressure is expected resulting from the higher friction losses (see Chapter 2.3).

2.5 Flow control unit

The flow rate control unit was made of galvanised iron sheet. The sheets were corroding severely and one sheet was totally corroded. The adjustable weirs were fixed with iron bolts and nuts. Due to corrosion it was not possible to loosen them anymore, so changing the flow rate was impossible. An other reason for renewing the unit was the necessity for passing a much higher flow than originally intended (Chapter 2.1). The new unit is provided with stainless steel weirs, bolts and nuts. The connections to the pipe from the pump and to the pipe leading to the reactor have been enlarged to 4" diameter. The new unit was installed on April 14, 1984.

2.6 Flow dividing weirbox

The weirbox dividing the flow over the two inletboxes was corroding as well. New connections for the pipes were made, a period of standstill of the pump was taken benefit of to give the unit a new paint.

2.7 Inlet boxes

As described in the 2nd Progress Report (Chapter 2.2.4) clogging of the inlet pipes occurred frequently. A solution for this problem was found in designing an inletsystem, in which each inlet pipe receives influent over its own V-notch. The new inletboxes were installed on June 11 1984 and are working satisfactorily now. At times, however, some of the V-notches get obstructed. Daily inspection is necessary and, if needed, the boxes and their V-notches are cleaned, using a waterjet.

2.8 Effluent gutters

As described in Progress Report no. 2 (paragraph 2.2.5) the effluent gutters did not give satisfaction. Other gutters were made, of stainless steel. A passage through the reactor's wall needed to be enlarged. The new gutters look much better and have, equally divided over the length, 20 V-notches to ensure an equal flow of the effluent. The new effluent system was put into operation since February 18 1984, and functions satisfactorily.

2.9 Gascollectors

Taking advantage of the occasion that the plant was not running for reconstruction works on the effluent system, on February 17 1984, a crane, kindly made available by EMCALI, lifted one of the gascollectors from the reactor. Inspection of the innerside showed that the paint was worne almost totally, but that the partly uncovered metal did not suffer any deterioration. This can be declared from the absence of oxygen, the neutral pH and the fact that only iron was used, no other metals.
On the outside, especially on the welding seam on top, some corrosion takes place.

2.10 Pressure experiments

The pressure experiments that were described in Progress Report No. 2 (page 41) appeared to be quite impossible. A funnel, with a rubber stopper in the outlet, was put on one of the inletpipes.
The funnel was filled, volume approx. 2 gals., and then the stopper was pulled out so that the water could run into the inletpipe. The time needed to empty the funnel was measured. It turned out that no difference in time could be noticed between open pipes and locked ones.

3. LABORATORY AND EQUIPMENT

3.1 Chemical- and physical water analysis

The monitoring scheme, as described in the 2nd Progress Report, has been executed strictly. One alteration was made: since results of ammonium and total Kjeldahl nitrogen were very constant, it was found sufficient to analyse these compounds once per week, instead of three times as was done before.

The analysis of CDO are performed by the Dutch personnel. Usually the HACH method is used, but when new vials are not available, the analyses are executed according to the Standard Methods.

The other analyses were performed by a labtechnician of the Univalle. Results were not always satisfactorily, but in general the situation is acceptable.

The analysis of the samples of the effluent of the various post-treatment systems will be carried out in the same way as the samples of the UASB reactor. This means a higher workload for Dutch as well as for Univalle's personnel.

3.2 Microbiological analysis

The microbiological analysis of samples from the UASB plant have been and will be carried out by a staff member of the laboratory of microbiology of the Sección de Saneamiento. Results are fully reliable and give full satisfaction.

The analysis of NMP (Número Más Probable, Most Probable Number) of Escherichia Coli will be replaced by the analysis of Feacal. Coli, as soon as the growing media for this test will arrive. It is found that the latter test will give more useful information for a waste-water treatment system than a non-specific E. Coli method, since some non-feacal coliforms can originate from other sources than human feaces or can grow outside the human body.

Since June 1984 two Colombian students started to analyse the parasites in the samples. For them this will be part of their graduation thesis.

The analysis of the samples from the post-treatment systems will be analysed on the same way as the samples from the UASB pilot plant.

3.3 Gas analysis

For a description on this subject see paragraph 5.7.

3.4 Equipment

3.4.1 COD-analyses

Since November 1983 a COD testing method is used, consisting of ready-for-use reagent vials, to which 2 ml of sample to be analysed must be added, a compact reactor and a colorimeter (HACH). As reported in Progress Report No. 2 (page 15) the equipment functioned well. A major constraint, however, is that new reagent vials have to be sent regularly from the Netherlands. In February 1984 a load of vials, sent by airfreight, contained many tins with leaking vials. It was not possible to determine with full reliability leaking vials from good ones. Since new vials could not be sent on short term, COD analyses were done for a period of some weeks by the standard method, coincidently sufficient reagents were available to meet the consumption.

An adapter for reading the tubes on a Bausch-Lomb Spectronic was bought. Since the wavelength for reading was not known, some try-outs were performed. Until now results are not perfect, so both the colorimeter and the spectronic are used for reading the vials.

Mr. Heynekamp, the new assistant engineer, performed some tests with COD standard solutions of potassium phtalate, with samples analysed in duplo, as well as blanks in duplo. Results show that differences up to 30 mg/l for the blanks can occur, while differences of 10 mg/l are quite frequent.

Assuming that the same differences occur in the reading of the effluent smaples, (and also on the other samples) differences in reading of 20 mg/l may occur and sometimes even of 60 mg/l. This means that readings in the range of 50 mg/l are very unreliable. The same differences occur with samples with a higher reading, but then differences of 20 mg/l have less impact.

Including the analyses to be performed for the post-treatment systems, now approx. 65 vials per week are required. For reasons of precesion it is desirable to use the method with the vials, but instead of using new vials for every sample, it is proposed to reuse the vials with self prepared reagents.

To be able to perform the analysis in this way, some new equipment as dispensers and Finn pipettes are ordered.

The costs of these are comparable, if not competitive, to the costs of new vials. Morteover, the Colombian party will not depend on importation of vials in the future. Can they handle them? what reliability

3.4.2 Gaschromatograph | what for | so late? |

On February 13 1984 the gaschromatograph was started. Results were very poor, injection of distilled water produced many gost peaks. A column was refilled with the so called stationary phase.
For several reasons, no nitrogen avaialble, a leaking line of nitrogen supply (the leaks are very small but the loss of gas is great in comparison to the consumption of the chromatograph) and insufficient time, the chromatograph was not used until May 7 1984. It then became clear that the results from the newly filled column were quite poor as well.

According to staffmembers of the Section of Chemical Processes, the nitrogen gas contains traces of oxygen. A slow combustion of the stationary phase is the result. A filter removing oxygen from the nitrogen gas would solve the problem. Information about these filters and a quotation have been asked for.

3.4.3 Kjeldahl distilling apparatus

A distilling apparatus, complement to the already present destruction equipment was bought and installed on March 31, 1984. It is functioning quite well.

3.4.4 Incubator

The incubator, now being used for the performance of batch tests at the controlled temperature of 30°C, had a failure in January. It was repaired by the purchaser's technician free of costs, since the term of guarantee had not expired yet.

What agreement on upkeeping / repair of the equipment in future

4. POST TREATMENT

4.1 General

As mentioned in Progress Report No. 2 it was felt desirable to study the possibilities of a post-treatment of the anaerobic effluent. Depending on the ultimate purpose of the wastewater effluent, a post-treatment may be necessary.
When the receiving waterbody is stagnant, e.g. lakes, canals, it is useful to remove plant nutrients such as phosphorus and nitrogen to prevent algae bloom. On the other hand, when the treated effluent is used for irrigating purposes the nutrients should be remained in the water, but the reduction of pathogens and parasites is of great importance in this case.

The following post-treatment systems have been installed at a pilot-plant scale near the UASB-plant in Cali:

a) anaerobic filter
b) trickling filter
c) intermittent sand filter
d) lagoon
e) duck weed lagoon.

Some of the systems need decanted water to avoid clogging. For this purpose a settler has been installed. The settler can be studied as a seperate treatment system.
The other post-treatment systems mentioned in Progress Report No. 2 (micro aerophilic; activated sludge) will be studied at laboratory scale.

In the following paragraphs a short description will be given of each system. Table 4.1 summarizes the systems including the operation programmes.

The post-treatment systems receive effluent of the UASB plant via a piston pump. The piston pump is protected against course materials by a 6 mm mesh filter. A piston pump is chosen because it does not damage the sludge particles. Other pumps may damage the particles, resulting in a loss of their supreme settling characteristics.

A piping system from the piston pump delivers the water to all systems, including the settler. Decanted UASB-effluent can be obtained from a piping system, which is connected to the settler overflow. In this system the water flows by gravity.
Each post-treatment system is provided with a tube pump to ensure a constant flow. Only the settler-flow is controlled by a valve.

The post-treatment systems are operated by Mr. Wildschut and Mr. Heynekamp, Mr. Sanchez a Colombian student cooperates in studying the anaerobic filter.

The effluent of the various systems will be analysed according to the scheme given in Table 4.2. The influent for the systems is either the UASB-plants's effluent or the settler's effluent. Details about the research programme are given in the paragraphs of each individual system.

4.2 Settler

4.2.1 Description

The settler consists of a square (1.10 m x 1.10 m) metal vessel. The bottom part of the settler has inclined walls to collect the solids. The depth, measured from the water surface, is 45 cm. The volume amounts to 780 liters.
The flow rate is controlled by a regulating valve in the influent tube. In the effluent piping system a facility has been made to enable measuring the flow rate.
The settler can be divided in two equal compartments. By leading the flow through one compartment, a high loading rate of the settler can be studied with a relatively low effluent consumption.

The influent enters the settler in a compartment separated from the rest of the tank by a baffle, placed at 7 cm from one wall and reaching to 35 cm below the water surface. In this compartment the velocity of the incoming water is reduced and the dissolved gas (the effluent from the UASB-reactor is oversaturated with methane and carbondioxide) can escape.
The decanted water is discharged by means of an overflow system at the wall opposite to the inlet compartment. The weir of the outlet gutter is provided with 8 V-nothes to ensure a uniform distribution of the flow over the width of the settler. At 5 cm from the effluent weir a baffle has been placed that reaches 10 cm below the water surface in order to avoid scum leaving the settler.

TABLE 4.1 PROGRAMME POSTTREATMENT
TIME SCHEDULE

SYSTEM	STARTING DATE	START-UP PERIOD (weeks)	RESEARCH PERIOD DURATION (weeks)	LOADING RATE	SOURCE[1]	PERSON[2] IN CHARGE
TRICKLING FILTER	19 July	3	5	10 $m^3.m^{-2}.d^{-1}$	s	LRW
			5	20 $m^3.m^{-2}.d^{-1}$		
			5	40 $m^3.m^{-2}.d^{-1}$		
ANAEROBIC FILTER	10 July	2	4	HRT 90 min	e	ASa
			4	HRT 45 min		
			4	HRT 20 min		
INTERMITTENT SAND FILTER 1	16 July	3		0.8 $m^3.m^{-2}.d^{-1}$	s	CEH
2	16 July	3		0.4 $m^3.m^{-2}.d^{-1}$	s	CEH
SETTLER	6 July	2	1	HRT 60 min	e	LRW
			1	HRT 45 min		
			1	HRT 30 min		
			1	HRT 15 min		
LAGOON	12 July	3	6	HRT 10 d	e	LRW
			6	HRT 5 d		
			6	HRT 3 d		
DUCK WEED LAGOON	16 July	3	6	HRT 5 d	e	LRW
			6	HRT 3 d		
			6	HRT 1 d		

1 Sources: e: effluent from UASB-reactor
s: settled effluent UASB-reactor

2 persons in charge: CEH: Mr.Heynekamp
ASa: Mr.Sanchez
LRW: Mr.Wildschut

TABLE 4.2 PROGRAMME POSTTREATMENT SCHEME OF ANALYSIS ON EFFLUENT

SYSTEM	PARAMETER														
	NUMBER OF ANALYSIS PER WEEK														
TRICKLING FILTER	1T	2	2	2	2	7	7	1	1	1	1	1	1	7	
ANAEROBIC FILTER	1T	2*	2	2	2	7	7	-	-	-	-	-	1**	7	7G
ITERM. SAND FILTERS	1T	2	2	2	2	7	7	-	1	-	-	1	1	7	
SETTLER	1T	2	2	2	2	7	7	1	-	-	1	1	1	7	2SS
LAGOON	1S	-	2	2	2	7	7	1	1	1	1	1	1	7	7 0_2
DUCK WEED LAGOON	1S		2	2	2	7	7	1	-	-	1	1	1	7	

* COD: plus one profile per month over the height of the filter

** coliforms and parasites: plus one profile per week over the height of the filter.

G : gasproduction
S : soluble
SS : spill sludge total solids
T : total
0_2 : dissolved oxygen

The effluent from the gutter flows into a tube which leads the settler's effluent via a siphon system to the other post-treatment systems.

4.2.2 Programme

Being a physical system a settler does not need adaption. Yet, a start-up period of one week was introduced for checking the technical performance. After that the setller is operated at four different loading rates, each for a period of one week. The surface loading rates are: 0.65, 0.87, 1.30 and 2.60 m/h (or HRT 60, 45, 30 and 15 minutes).

It has been noticed before that the sludge collected on the bottom of the settler still produces gas. Incidentally the gas production causes floating of the sludge; which deteriorates the performance of the settler. Therefore it is thought to be useful to install a gas separator settler compartment. This will be done after the research-programme has been executed.

The settler's effluent is analysed daily on pH and temperature, weekly on ammonium, Kjeldahl nitrogen, phosphate, parasites and coliforms, and twice a week on COD (total and soluble) BOD, TSS and VSS. The flow rate is checked daily.

The collected sludge is discharged daily. The volume of the discharged sludge is measured and collected to obtain a composed sample. Twice a week the composed samples are analysed on total solids. In this way a mass balance of the settler can be made.

4.3 Trickling filter

4.3.1 Description

The trickling filter is made of a vertically placed, concrete sewer pipe (diameter 50 cm, length 2 m). The pipe is placed on a brick base. Perforated PVC pipes at the bottom of the filter ensure free entry of air. The filling material of the filter consists of river stones with a diameter between 10 and 15 cm. The porosity of this filling material is 44%. At a height of 1 m a sample point has been installed. Just below the sampling port a concrete baffle has been placed to the inner wall of the filter. The baffle is intended to direct the water, which flows along the wall, back into the filter.

At the top of the filter a little splash plate has been made to distribute the water uniformly over the filter surface.
At the bottom of the filter a 5 liter storage tank has been installed. In the event of failure of any of the feedpumps, the contents of this basin will be recirculated automatically over the filter to avoid drying out.

4.3.2 Programme

In temperate climates starting-up a trickling filter takes two to three months. It might be expected that in warmer climates, e.g. with an average water temperature of 24°C, three weeks are sufficient to obtain a fair amount of active bacterial material in the filter. The system has been started at a loading rate of 10 $m^3.m^{-2}.d^{-1}$. After start-up, the filter will be operated at three different loading rates, each for a period of 5 weeks. After three weeks operation at a certain loading rate it is assumed that the filter has reached a steady state. Two more weeks the steady state situation will be studied. The loading rates to be applied are 10, 20 and 40 $m^3.m^{-2}.d^{-1}$.

After this programme the filter will be operated for a period of a nominal loading rate, derived from the results obtained.

The filter is fed with settled effluent from the UASB-reactor.

The analytical programme provides a daily measurement of pH, temperature and flow rate. Twice a week COD (total and soluble), TSS and VSS of the filter effluent will be determined. Weekly analyses include nitrate, nitrite, ammonium, Kjeldahl nitrogen, phosphorus, total BOD as well as the presence of parasites and coliforms. Incidently the oxygen concentration of the filter effluent and halfway the filter will be measured.

4.4 Anaerobic filter

4.4.1 Description

The anaerobic filter consists of a iron tube with a length of 2.10 m and a diameter of 28 cm. The tube is supported in a metal frame. The inlet is situated in the centre of the bottom plate, the outlet is at 2 m height (or 10 cm from the top end). Sampling ports placed at 20 cm height intervals enable collection of the filter's contents. The top end is sealed with a PVC foil to the gas produced. The gas production is measured with a brine displacement system. The filter material consists of river stones with a diameter of 2 to 4 cm. The porosity is approx. 38%.

4.4.2 Programme

After two weeks of adaption the filter will be operated at 4 loading rates, viz. at hydraulic loading rates of 0.25, 0.50, 1.14 and 2.28 $m^3.m^{-2}.d^{-1}$ respectively. Each laoding rate will be studied for a period of 4 weeks. Before altering the loading rate, the liquid phase in the filter will be removed and analysed on total and volatile solids.
The filter is fed with raw effluent from the UASB-reactor.
The effluent of the anaerobic filter is analysed daily on pH, temperature and flow rate, twice a week on COD (total and soluble), TSS and VSS and weekly on parasites and coliforms. The gas production is measured daily.
Furthermore, weekly samples will be taken at different heights of the column for analysing the presence of parasites and coliforms.

4.5 Intermittent sandfilters

4.5.1 Description

The filters consist of a twin tank, made of brick finished with impermeable cement (surface 0.65 x 0.65 m; total depth 1.40 m).
The bottom of the tank is covered with bricks up to 0.3 m height. At 0.30 m a perforated PVC pipe of 3" diameter collects the water from the filter. Up to 5 cm above the collection pipe a layer of river stones with a diameter of 2 to 3 cm is applied, then a 5 cm layer of stones of 10 mm and finally a 5 cm layer of grit of

5 mm diameter. These layers serve as a support for the actual filter material. The filter material is sand with an effective diameter of 0.35 mm and a uniformity coefficient of approx. 2. The height of the sand layer is 0.60 m.
The filters are covered with wooden lids to avoid leaves and bird droppings of a nearby tree from fouling the filter. The filters are operated independently from each other.

4.5.2 Programme

Originally the two sand filters were operated alternatively. Later it was thought to be more useful to operate them independently, i.e. at different loading rates. The filters will be operated at hydraulic loading rate of 0.8, and 0.4 $m^3.m^{-2}.d^{-1}$ respectively. To avoid rapid clogging the filters are fed with decanted effluent of the UASB-reactor.
The filters are operated in four daily cycles. Each cycle includes feeding for one hour on top of the filter and a rest-period of 5 hours. When the water has not been infiltrated completely in the sand bed within 2 hours the filter is assumed to be clogged. In other cases the upper 2 - 3 cm of sand will be removed and replaced by clean sand.
The filters' effluent are analysed daily on pH and temperature, twice a week on COD (total and soluble), TSS and VSS and weekly on nitrate, BOD (total), phosphate, coliforms and parasites. The flow rate is checked daily.

4.6 Lagoon

4.6.1 Description

The lagoon consists of a iron sheet tank of 0.30 m width, 1.20 m long and 1.5 m deep. For insulation purposes the tank is placed 0.50 m into the ground. In addition the upper part of the tank is insulated with 2.5 cm thick polystyrene, to prevent excessive heating of the lagoon contents during day time.
The influent enters the lagoon at the bottom at one third of the length of the lagoon. The effluent leaves the lagoon at the opposite short end. A baffle reaching to 0.50 m below water surface avoids short circuiting when at night relatively warm influent enters the lagoon.

An oxygen electrode has been installed at the centre of the surface at approx. 10 cm depth. The oxygen concentration can be measured and recovered continuously.

4.6.2 Programme

The biological processes in a lagoon occur relatively slowly.
Therefore a start-up period of 3 weeks is considered to be the absolute minimum for reaching a more or less steady state.
After this period the lagoon will be operated at loading rates of 0.1, 0.2 and 0.33 $m^3.m^{-2}.d^{-1}$ (HRT 10, 5 and 3 days respectively). Each loading rate will be continued for a period of 6 weeks. The lagoon is fed

with raw effluent from the UASB-reactor. The lagoon's effluent is analysed weekly on Kjeldahl nitrogen, ammonium, nitrate, nitrite, phosphate, soluble BOD, coliforms and parasites; twice a week on COD (soluble), TSS and VSS and daily on pH and temperature. The oxygen concentration is measured and recorded continuously. Daily the flow rate is checked.
At each loading rate the hydraulic characteristics of the lagoon will determined by a trace-experiment (lithium).

4.7 Duck weed lagoon

4.7.1 Description

A duck weed lagoon had not been included in the original proposal for post-treatment systems. Based on his promising experiences in Israel with this type of waste water treatment systems, Mr. Wildschut proposed to add a duck weed lagoon (Lemnaceae).* This has been done at minimum additional costs.
The difference with traditional lagoon systems is that the growth of biomass does not take place within the water but at the surface. In this way the biomass can be harvested easily. The harvested duck weed can be used as a fodder for cattle and fish, because it is rich in proteins and easy to dry and to process.

The lagoon consists of a iron sheet tank (surface 1.20 m by 0.4 m, depth 0.25 m). The hydraulic retention times to be investigated are 5, 3 and 1 day. The chosen retention time will be maintained for 5 weeks.

5. RESULTS

5.1 Introduction

The way the UASB-plant has been operated over the period November 25 to August 10, 1984 is already discussed in Chapter 2.1, and is further summarized in Annex 1. Due to several - occasionally prolonged - periods of pump breakdowns, it was impossible to keep the plant in continuous operation over the whole 6 month period covered by this report. Despite that it can be stated that the main objectives of the intended research program for this period have been achieved. Moreover feed interruptions - although generally not pursued - provide additional useful information about the process, e.g. the rate of a secondary start-up, the rate in which the gas production drops down, which in return reflects the extent in which the retained sludge is stabilised. In evaluating the results obtained so far, it should be taken in mind that the original goal of the project was to proof the feasibility of the UASB-system at a minimum liquid retention time of 8 hours, because then the UASB-system certainly would become economically competitive as compared to conventional aerobic systems. As already described in Progress Report No. 2, Chapter 5, the results obtained at HRT=8 hours were in fact better than expected. In view of these very satisfactory results, in the previous period considerable emphasis has been put on:

a) establishing the maximum hydraulic loading potentials of the system,

b) assessing the minimum number of feed inlet nozzles (lines).

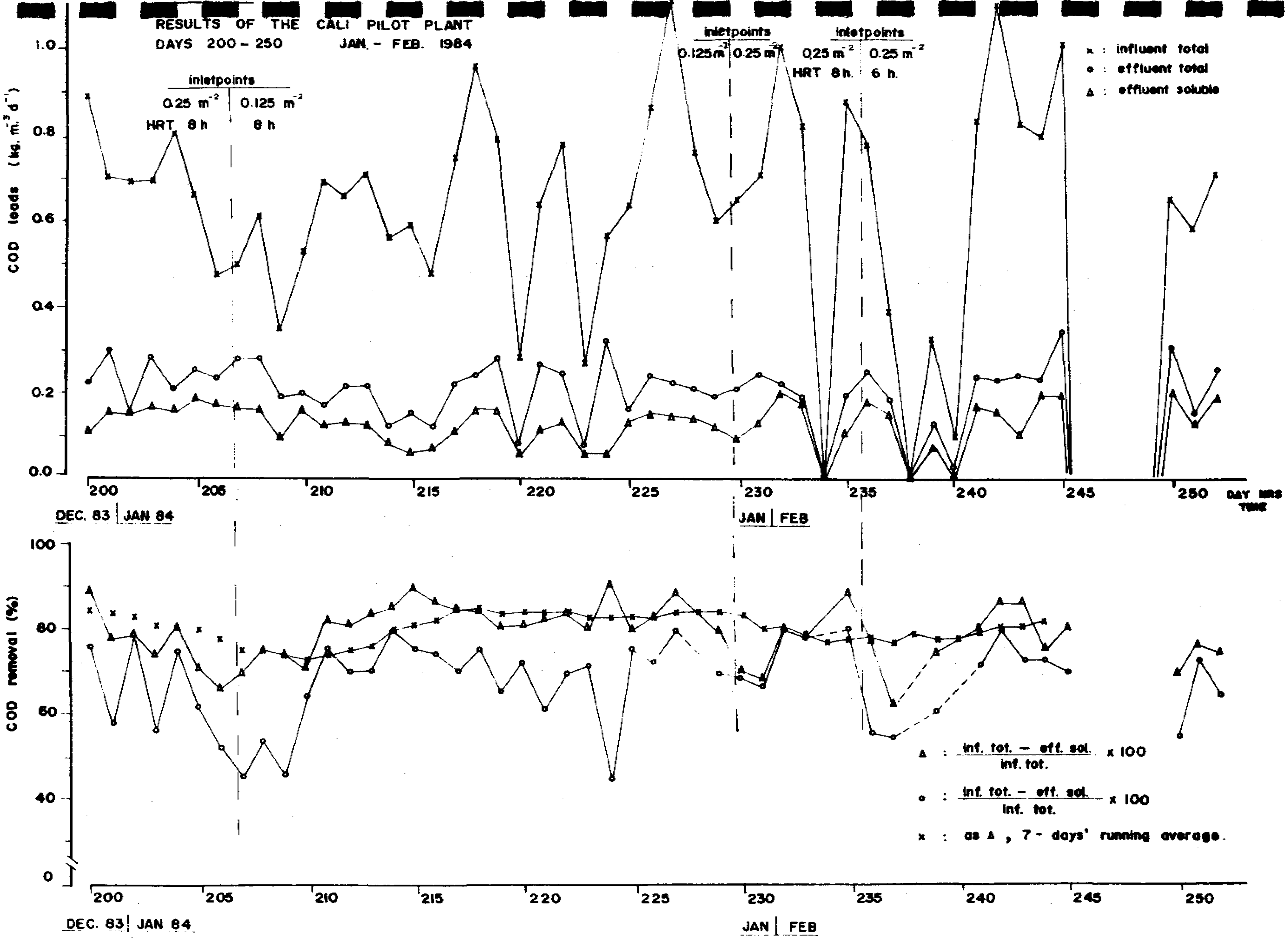
The results obtained have been summarized in Annex 2, 3, 4 and 5.

5.2 COD - loads and COD - treatment efficiency

The results in terms of COD-load applied to the reactor, COD-treatment efficiency based on raw influent-COD and filtered (settled) or unfiltered (unsettled) effluent - COD are shown graphically in Figure 5.1, 5.2, 5.3, 5.4 and 5.5, together with COD-loads (filtered and unfiltered) leaving the reactor. The days where some process parameter (number of feed inlet nozzles (lines) used, the hydraulic retention time applied) were altered are indicated in the figures.

5.3 COD - removal efficiency based on filtered (settled) effluent samples

Considering the results shown in Figures 5.1 - 5.5 it is evident that the plant performs quite satisfactorily, even when only two feed inlet nozzles are used. Based on weekly averaged data, the COD-reduction ultimately ranges from 80 - 85% (period 207 - 229, HRT=8 hours). In doubling the number of feed inlet nozzles from 2 to 4 (day 229), a slight but distinct drop in treatment efficiency occurs (period 229 - 236, HRT=8 hours). For the reason of this drop in efficiency can only be speculated. Considering the COD-loads (or influent-COD) the drop in efficiency certainly can not be attributed to a change in the strength of the waste water. A reasonable explanation for the phenomenon might be the occurrence of certain short-circuitings in the sludge bed above the feed inlet nozzles put in



RESULTS OF THE CALI PILOT PLANT
DAYS 200 - 250 JAN. - FEB. 1984
inletpoints
0.25 m⁻² | 0.125 m⁻²
HRT 8 h | 8 h
inletpoints
0.125 m⁻² | 0.25 m⁻²
inletpoints
0.25 m⁻² | 0.25 m⁻²
HRT 8 h. | 6 h.
x : influent total
o : effluent total
Δ : effluent soluble
COD loads (kg. m⁻³. d⁻¹)
DAY NRS TIME
DEC. 83 | JAN 84
JAN | FEB
COD removal (%)
Δ : (inf. tot. - eff. sol.) / inf. tot. x 100
o : (inf. tot. - eff. sol.) / inf. tot. x 100
x : as Δ , 7 - days' running average.

FIGURE 5.2

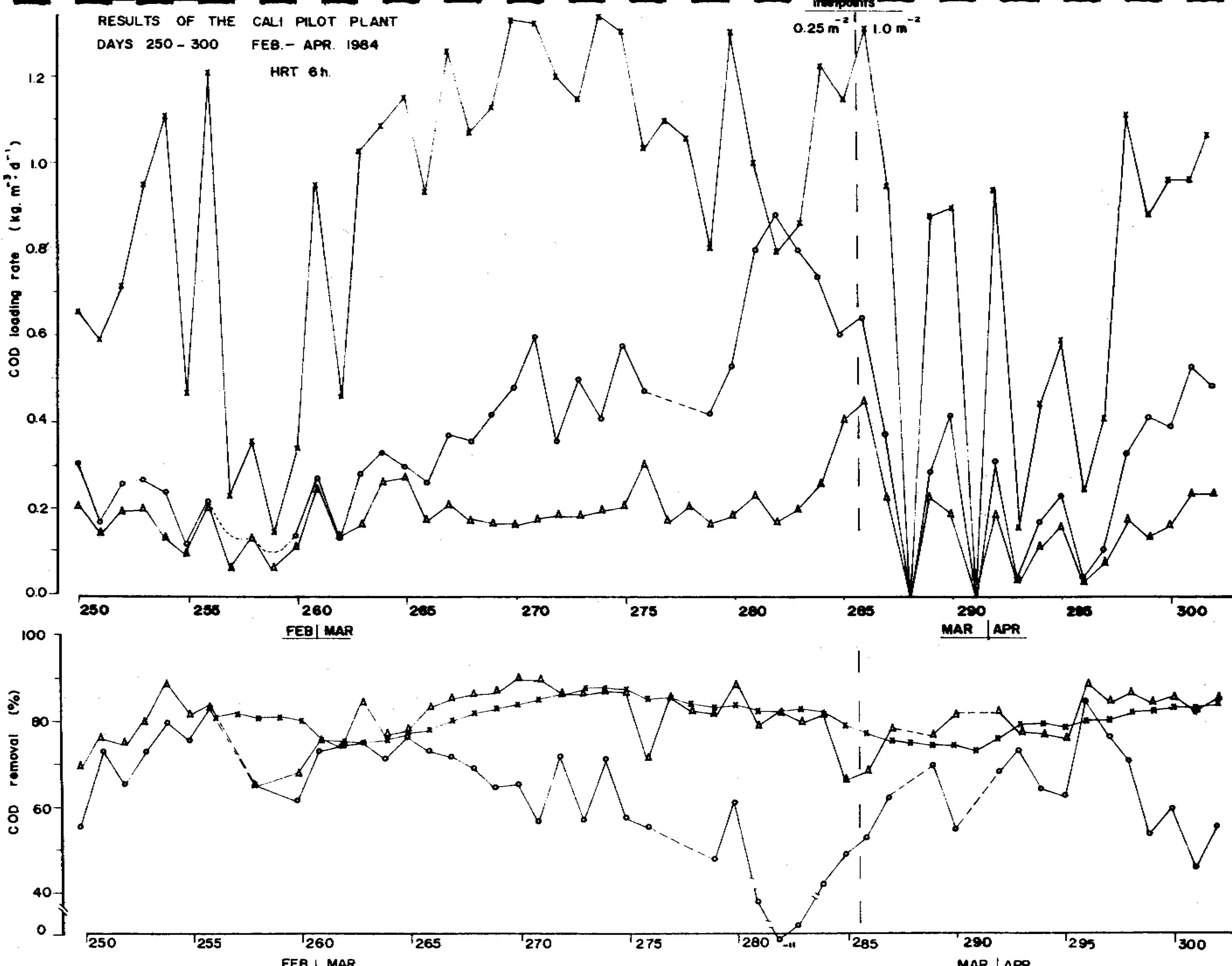
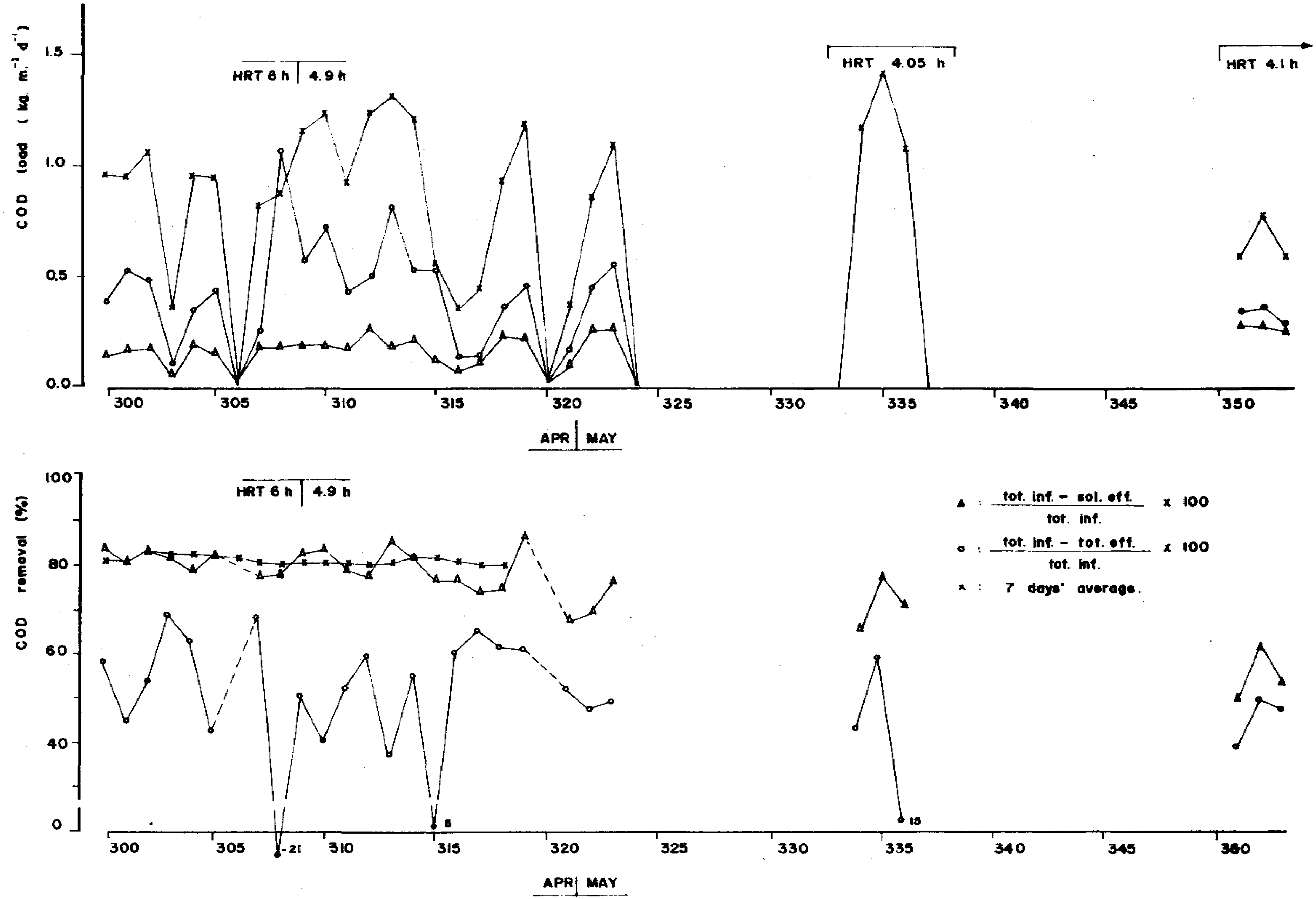

RESULTS OF THE CALI PILOT PLANT
DAYS 250 - 300 FEB.- APR. 1984
HRT 6 h.
0.25 m⁻² | 1.0 m⁻²
COD loading rate (kg. m⁻³ · d⁻¹)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
250
255
260
265
270
275
280
285
290
295
300
FEB | MAR
MAR | APR
COD removal (%)
0
40
60
80
100

FIGURE 5.3 RESULTS OF THE CALI PILOT PLANT
DAYS 300 - 350 APRIL - MAY 1984



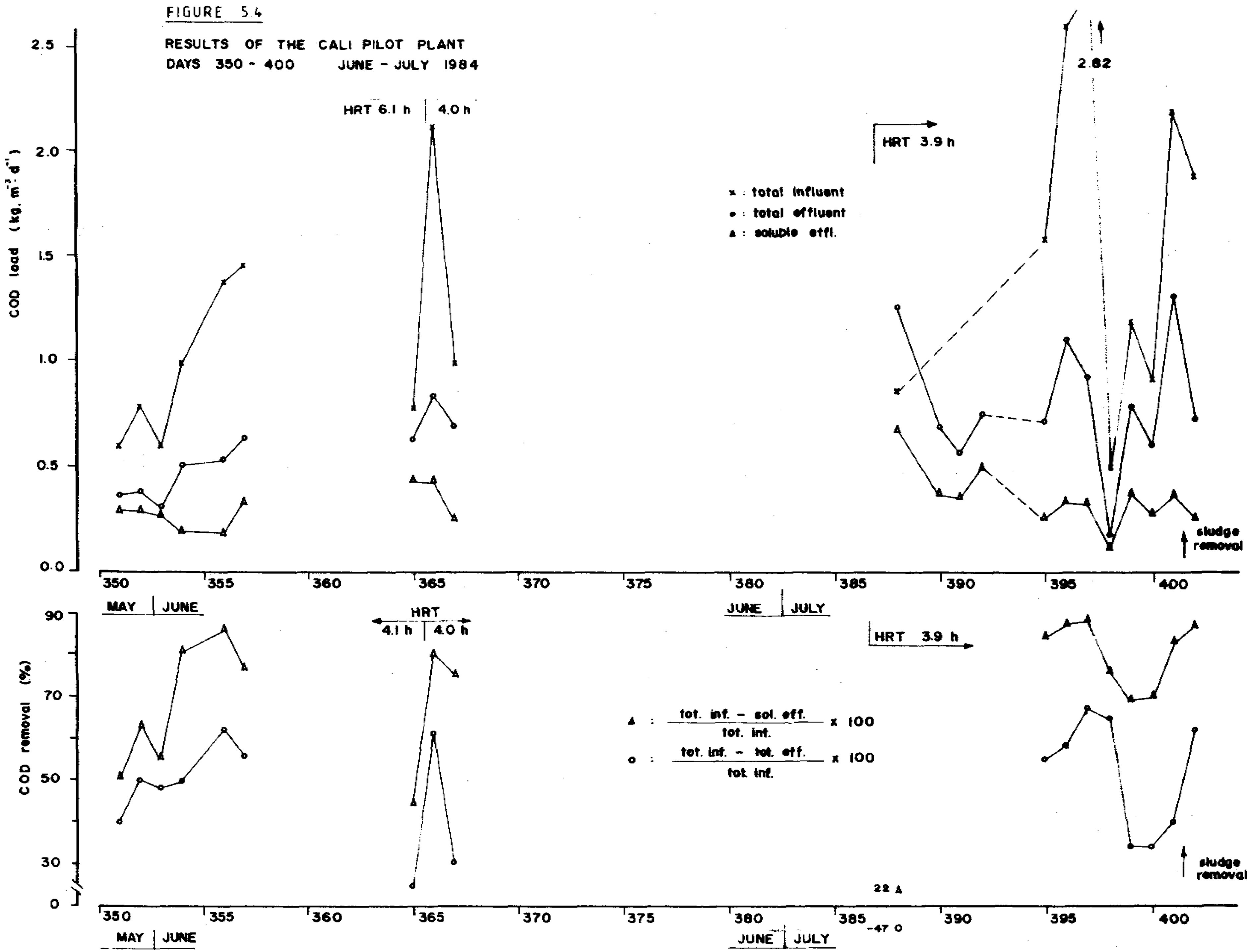
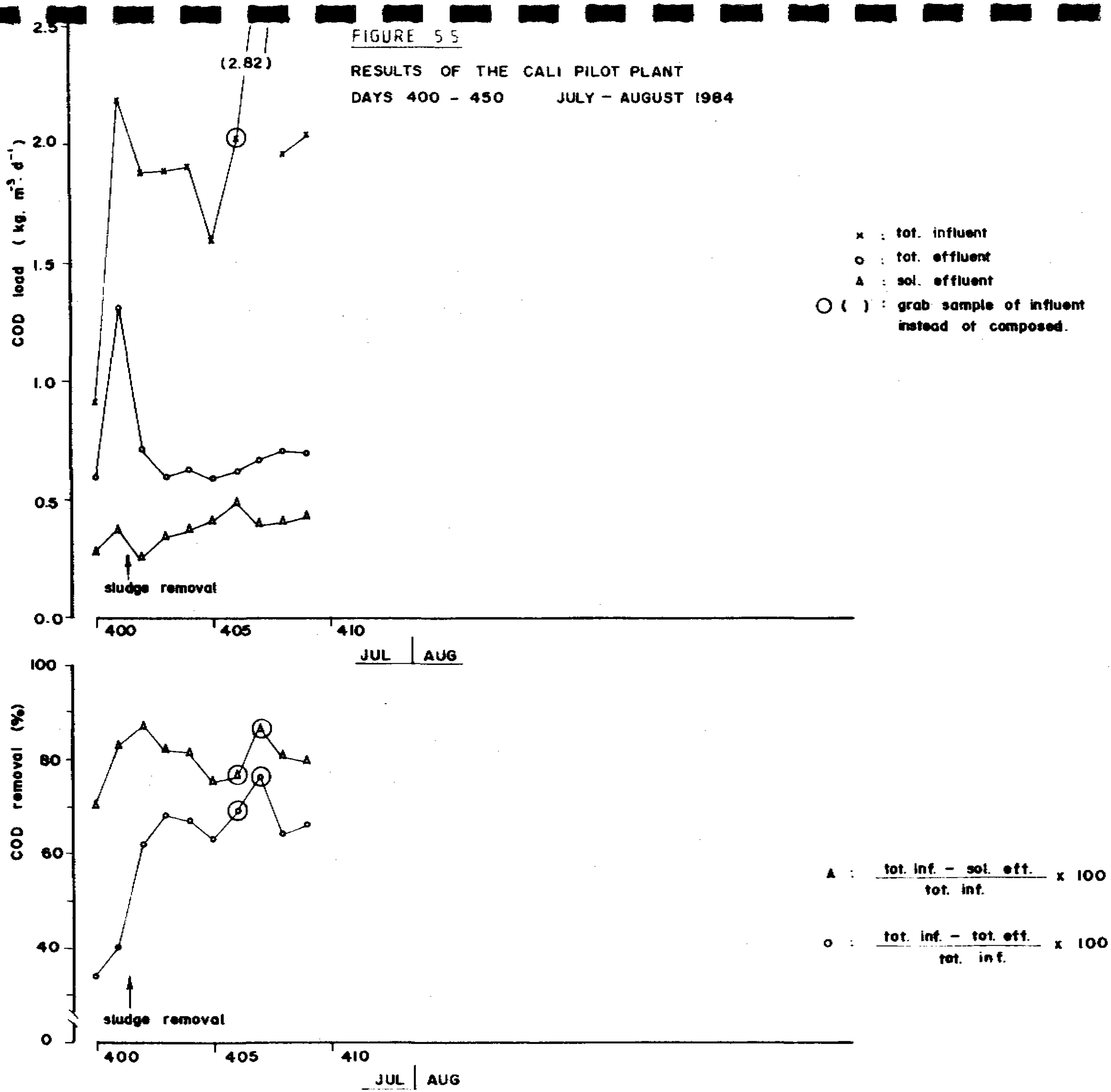


FIGURE 5.4
RESULTS OF THE CALI PILOT PLANT
DAYS 350 - 400 JUNE - JULY 1984
HRT 6.1 h
4.0 h
HRT 3.9 h
2.82
x : total influent
• : total effluent
▲ : soluble effl.
COD load (kg. m⁻³ d⁻¹)
sludge removal
MAY
JUNE
JULY
HRT
4.1 h
4.0 h
COD removal (%)
▲ : (tot. inf. − sol. eff.) / tot. inf. x 100
o : (tot. inf. − tot. eff.) / tot. inf. x 100
22 ▲
-47 o

FIGURE 55

RESULTS OF THE CALI PILOT PLANT

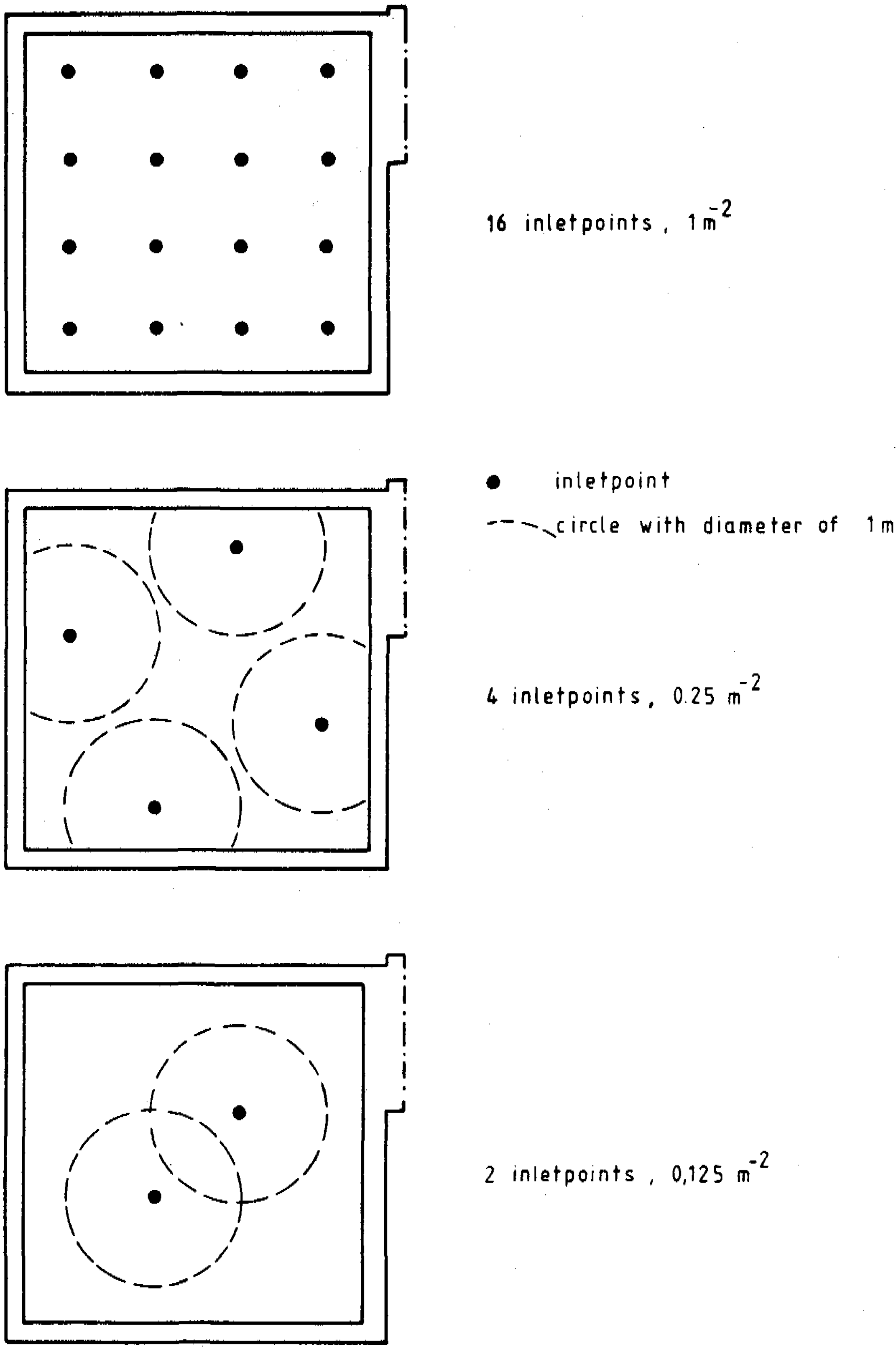
DAYS 400 - 450 JULY - AUGUST 1984



operation beyond day 229. Figure 5.6 shows schematically the position of the feed inlet pipes under the various conditions.

The performance of the plant remains quite satisfactory after increasing the hydraulic load to $4m^3.m^{-2}.day^{-1}$ (HRT=6 hours, period 236 - 309), to approx. 5 $m^3.m^{-2}.day^{-1}$ (HRT= 4.9 hours, period 309 - 324) and to approx. 6 $m^3.m^{-2}.d^{ay-1}$ (HRT=2hours, periods 334-337, 350-353, 365-367, 387-409). The treatment efficiency remains in the range 70 - 85%, except during periods of pump breakdowns and heavy rainfall, viz. more diluted wastewater, but this is also the case under conditions of lower hydraulic loads. The effect of the strength of the wastewater particularly becomes apparent from the calculated daily COD-reduction. In the weekly averaged COD-reduction value the effect of influent dilution obviously only is reflected in the case of prolonged periods of heavy rain, e.g. period day 287-297, although also several pump stops occurred during that period.

As a matter of fact over the whole period day 287-353 the influent COD is relatively low (compare also the influent data in Annexes 1, 2, 3, 4 and 5). Still the treatment efficiency remains close to 80%, except during period day 361-363, where - under conditions of heavy rainfall - the efficiency drops to 50 - 60%. The results in Figure 5.1 - 5.5 clearly show that the treatment efficiency always recovers immediately once the influent-COD (viz. loading rate) becomes at a higher level. Moreover the results provide some evidence of a slightly poorer treatment efficiency during the first day after a secondary start-up.



PATTERN OF INLETPOINTS OF THE UASB PILOT PLANT

FIGURE 5.6

5.4 COD-removal efficiency based on unfiltered effluent samples

Due to carry-over of suspended solids (SS) the treatment efficiency based on raw effluent samples remains 10 - 20 % behind the values based on filtered (settled) effluent samples. The results in Figures 5.1 and 5.2 show the existence of periods of alternative lower and heavier washs-out of SS-COD. However, starting from day 265 the process result detoriates clearly with respect to SS-removal, which at first sights might lead to the conclusion that the maximum loading potentials are determined by the SS-removal efficiency of the system. The reason for the detoriation in SS-removal of the reactor lies in the fact that the sludge blanket at that time already reached for the settler. At day 265 the blanket reached 1.75 m beneath the liquid surface area at day 268 this only was 0.55 - 0.9 m.
It will be obvious that a poor SS-removal will occur, once the blanket has reached the effluent weirs. At that time - but preferable some days before - sludge should be discharged from the reactor, unless a secondary settler system is put in series with the reactor. As the settleability of the SS in the effluent is very good, little if any problems (viz. additional expenses) will be encountered in the elimination of this matter from the treated wastewater. In order to be able to assess the development of the sludgebed/ blanket in the reactor under conditions that the reactor was completely filled up with sludge, it was decided to delay the discharge of sludge. Due to pumpdamages the plant could be operated only for a few days during the period day 315-384, but starting from day 388 again a prolonged period of more or less continuous operation could be accomplished. Sludge wash out remained heavy untill at

day 401 approximately 26.4 m^3 (880 kg TSS) sludge was discharged from the reactor. As expected, the SS-removal efficiency when restored immediately!

5.5 Treatment efficiency in terms of BOD

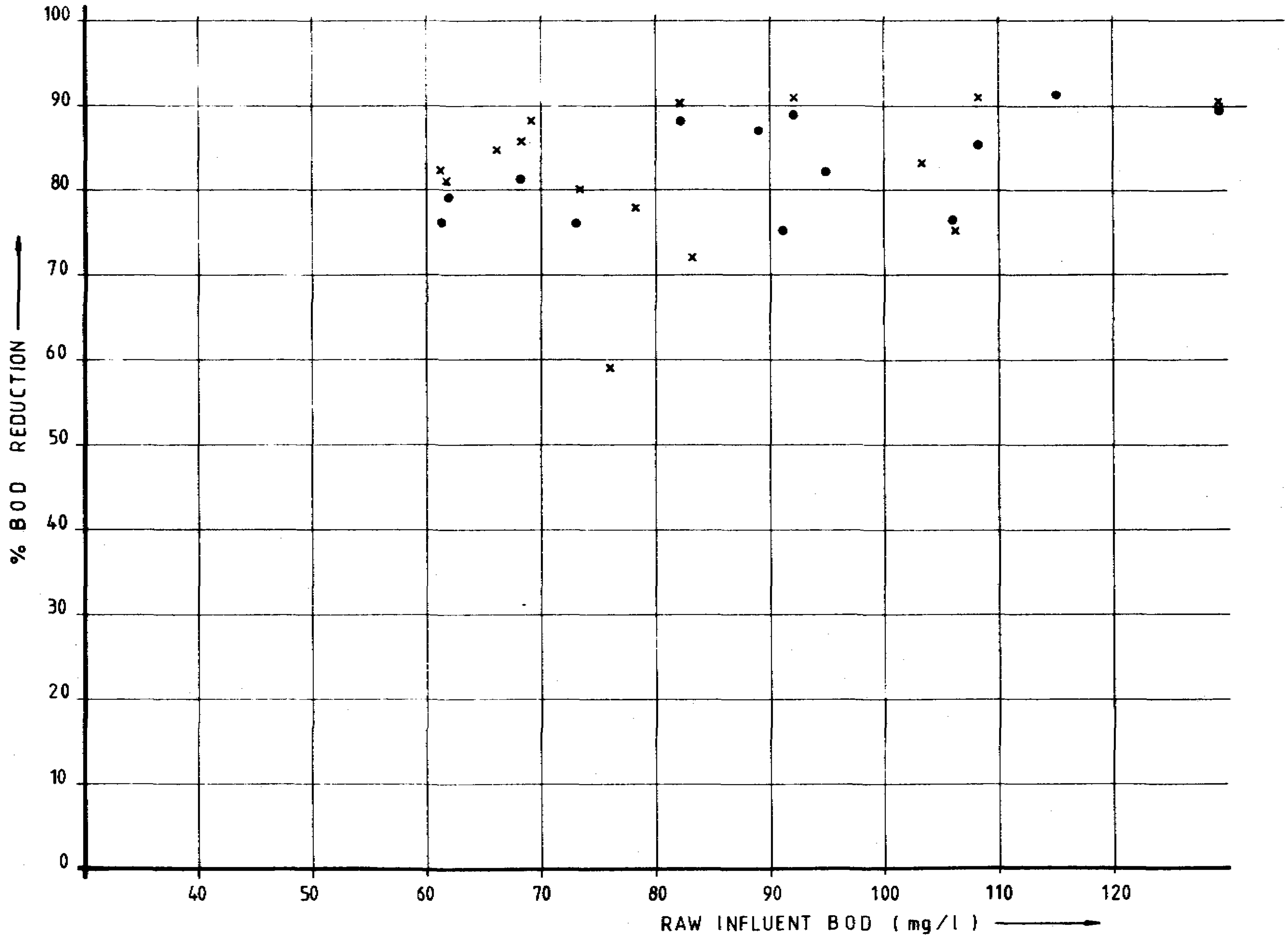
Analyses of BOD in raw influent and settled and filtered effluent samples were made once a week, and starting from day 283 also the BOD-analyses were made on raw effluent samples. The results of these measurements are presented in Annex 6.
Considering these results first of all it should be mentioned that the data look fairly consistent, although there are a few striking discrepancies, particularly in the COD/BOD - ratio, which should be attributed in either an inaccurate COD or BOD measurement.

As far as the COD/BOD - values of the influent concern it can be stated that over the whole line these values are significantly higher than found for domestic sewage in moderate climates, e.g. the COD/BOD ratio for domestic sewage of the village Bennekom (the Netherlands) is generally in the range 1.8 - 2.1. The higher values found for the Cali sewage can be explained on the basis of its appreciably higher temperature and - possibly - the longer retention time of the sewage in the sewerage system. As a result of both these factors a considerable break down of biodegradable compounds has already occurred in the sewer, anyhow to a significant higher extent than in the Bennekom situation. The relatively low soluble COD-fraction in the Cali-sewage forms another indication for the "high" bioactivity present in the sewer-system in Cali. Considering the COD/BOD values of the soluble fraction in the Cali-sewage it appears that they generally are higher than for the raw sewage, indicating a poorer biodegradability of the soluble fraction. Apart of a number of striking low values - presumably due to wrong analysis - the COD/ BOD-factors for the filtered or settled effluent samples is higher than for the raw influent, which is an obvious result of the biodegradation taking place in the digester. Indeed exceptionally good BOD-reductions are achieved in the pilot plant, once again pointing to its considerable potentials under tropical conditions. As mentioned above, the few relatively low COD/BOD-values (or high BOD-values) presumably should be attributed to faulty analyses, probably of the BOD-measurement. As in the case of the COD-reduction little if any clear effect becomes apparent in the BOD-reduction from the applied different hydraulic loads. Moreover, the results from Annex 6 indicate also (compare Figure 5.7 where the BOD-reduction values have been plotted versus the raw influent BOD) little if any effect of the strength of the sewage.

5.6 SS - removal efficiency

As already explained above, the SS-effluent concentration in terms of COD is strongly dependant on the position of the top of the sludge blanket. As a matter of fact the efficiency of the system in the SS-removal only can be evaluated from the data collected under situations where the top of the blanket remains well below the effluent weirs. Instead of the SS-COD-values, obviously the available TSS-values and VSS-values can be employed for this purpose, because there should exist a close relation between these three parameters.

FIGURE 5.7



BOD REDUCTION (RAW INFLUENT AND FILTERED (×) AND SETTLED ( ) EFFLUENT)
IN RELATION TO RAW INFLUENT BOD

In order to assess this relationship all the available data for influent and effluent have to be "digested" for this purpose. The concerning elaboration of the data will be made in the Final Report. For this report the results of VSS and TSS-analyses presented in Annex 1 through 5 suffice, and in fact exclusively those which meet the condition that the sludge blanket is well below the effluent weir, consequently only those obtained over the period January, February and the first week of March 1984, and those beyond 18th July 1984. During these periods a very satisfactory SS-removal is achieved, viz. ranging from 65 - 81% except during week 27/7 - 3/8 1984, where only 43% SS-removal was achieved. The latter presumably can be attributed to the sharply increasing gas production during that period. Insufficient data are avaialble yet to explain the poor SS-removal efficiency during that week.

5.7 Gas production

The gas production in terms of average daily gas production, is presented in Figure 5.8 over the period day 190 - 416 (end of November 1983 - beginning of August 1984), together with the HRT applied and the number of feed inlet lines used. The results show little if any increase of the gas production over the period December 1983 - end April 1984, despite the fact that the HRT was decreased corresponding to an increase in the COD-load of 20 - 40% (compare Figure 5.1, 5.2 and 5.3). Only in July 1984, when a HRT of 4 hours was applied for a prolonged period of time the gas production responded with the increased loading rate, viz. the gas production reached approximately 800 l/hour - which means about a doubling - at a organic

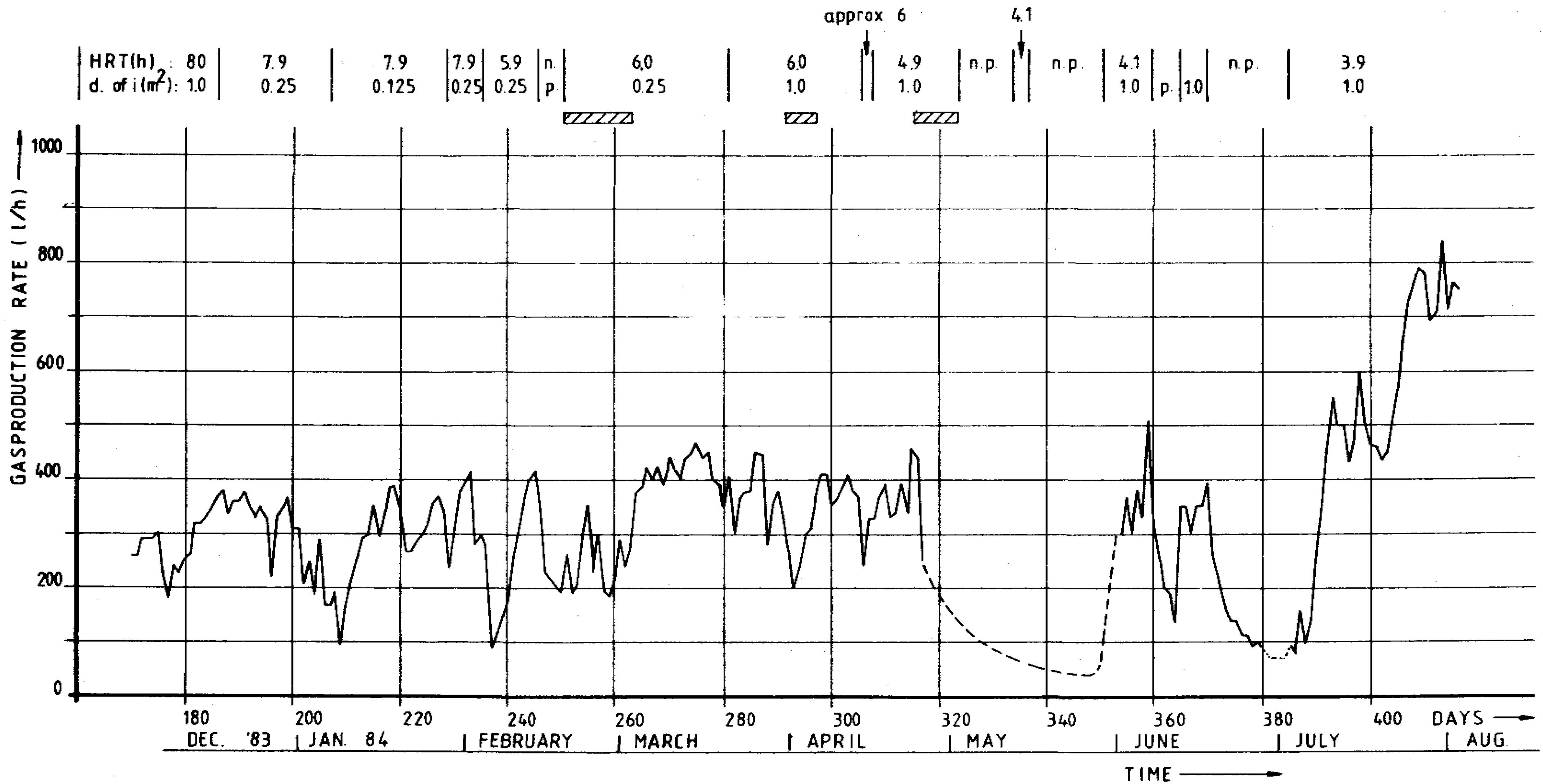


FIGURE 5.8

HRT hydraulic retention time

d of i density of inletpoints

np no pumping

▨ period with many pumpstops

DAILY AVERAGE OF GASPRODUCTION RATE

DECEMBER 1983 - AUGUST 1984

load of approximately 2.5, which also corresponds to roughly a doubling.

During periods of feed interruption the gas production drops down but it takes a number of days before it attains a very low value, e.g. the period day 238 - 240, 245 - 249, 357 - 364, and particularly the period day 368 - 387. The amount of gas produced during periods of feed interruption represents a direct indication of the total amount of biodegradable matter retained in the reactor. In all cases the gas production increases sharply once the feeding is resumed. The figures of the gas production concern the net measured total gas production (CH_4, CO_2, N_2), the amount of dissolved CH_4 in the effluent solution has not been accounted for. So far insufficient reliable information is available about the gas composition to allow the calcualtion of COD-balances. The results of the Gascope and Orsat-apparatus still do not correspond sufficiently.

5.8 Sludge hold-up in the reactor

The development of the sludge bed/blanket has been followed by determining TSS and VSS-profiles at several days over the experimental period. So, in addtion to the profiles presented in Progress Report No. 3 (Figure 5.7, 5.8, 5.9, 5.10, 5.11 and 5.12) various profiles are avaialbe now. Those measured at day 378, 401 and 430 are presented in Figure 5.9, 5.10 and 5.11, and - as far as TSS concerned - presented in Table 5.1 below.

Table 5.1

TSS - content over the height of the reactor as measured at day 378, 401 and 430.

position of sampling part (m)		depth below effluent weir (m)	TSS-concentration $(kg.m^{-3})$ day 378	day 407	day 430
3.60		0.50	30.0	28.7	0.7
3.10	settler	1.00	33.6	34.3	22.2
2.60		1.50	36.8	35.1	27.1
2.00			44.6	38.4	32.6
1.80			44.5	37.7	32.9
1.60			42.5	37.8	35.0
1.40			43.9	37.8	35.2
1.20			41.8	39.9	35.7
1.00			45.3	40.5	38.5
0.80			52.2	47.9	40.4
0.60			56.6	72.5	47.9
0.40			61.5*	106.5	106.3
020			68.8*	120.0	114.8

*unreliable sampling

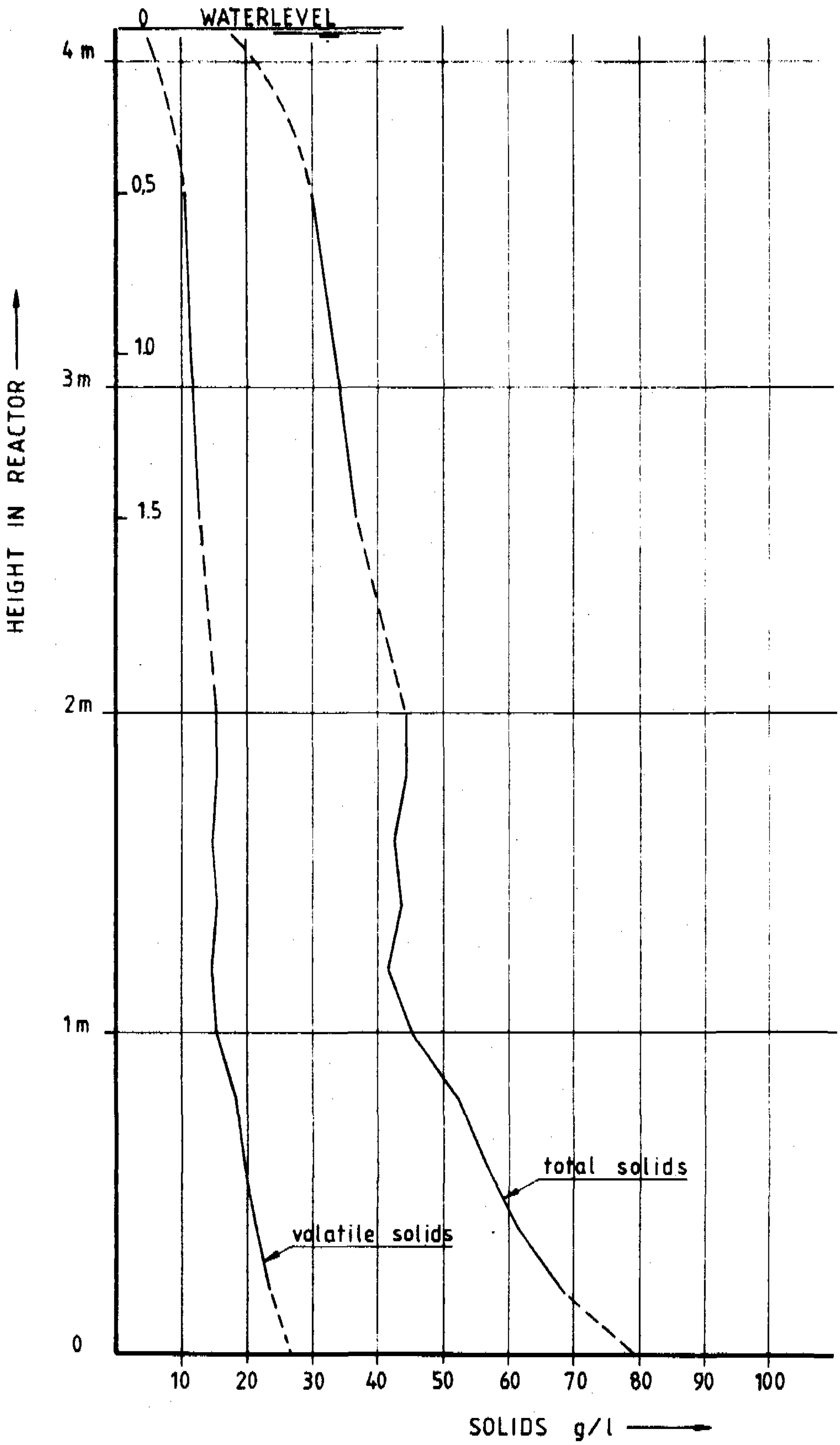
Compared to the profiles determined at day 182 (Figure 5.11, Progress Report No. 2), the height of the sludge bed (i.e. the dense part of sludge bed) did not increase. However, the less dense part of the sludge bed (indicated as sludge blanket) increased significantly in height, and clearly extended into the settler; considering the heavy washout of sludge since day 265, it should be near the effluent weir. At day 401 (july 19) 26.4 m^3 sludge (TSS-content 33.5 $kg.m^{-3}$) was discharged from sampling part 7, located 1.40 m above the bottom of the reactor. As a result the sludge blanket retired and the SS-removal efficiency restored completely. However, considering the position of the blanket in the settles at day 430, it is clear that the system is almost ready for a new discharge of excess sludge.

The results in Figure 5.9, 5.10 and 5.11 reveal that the TSS-content of the blanket tends to decrease at due course. In view of the high hydraulic load applied ($6m^3.m^{-3}.d^{-1}$, corresponding to a superficial velocity of app. $1m.hour^{-1}$) this slight decrease in sludge hold-up is not surprising. On the other hand it would be important to assess the steady state condition of the sludge blanket TSS-content at this hydraulic load, because it ultimately determines the potentials of the system. The results reveal that the sludge is fairly uniformly distributed over the entire height of the blanket.

5.9 Sludge characteristics

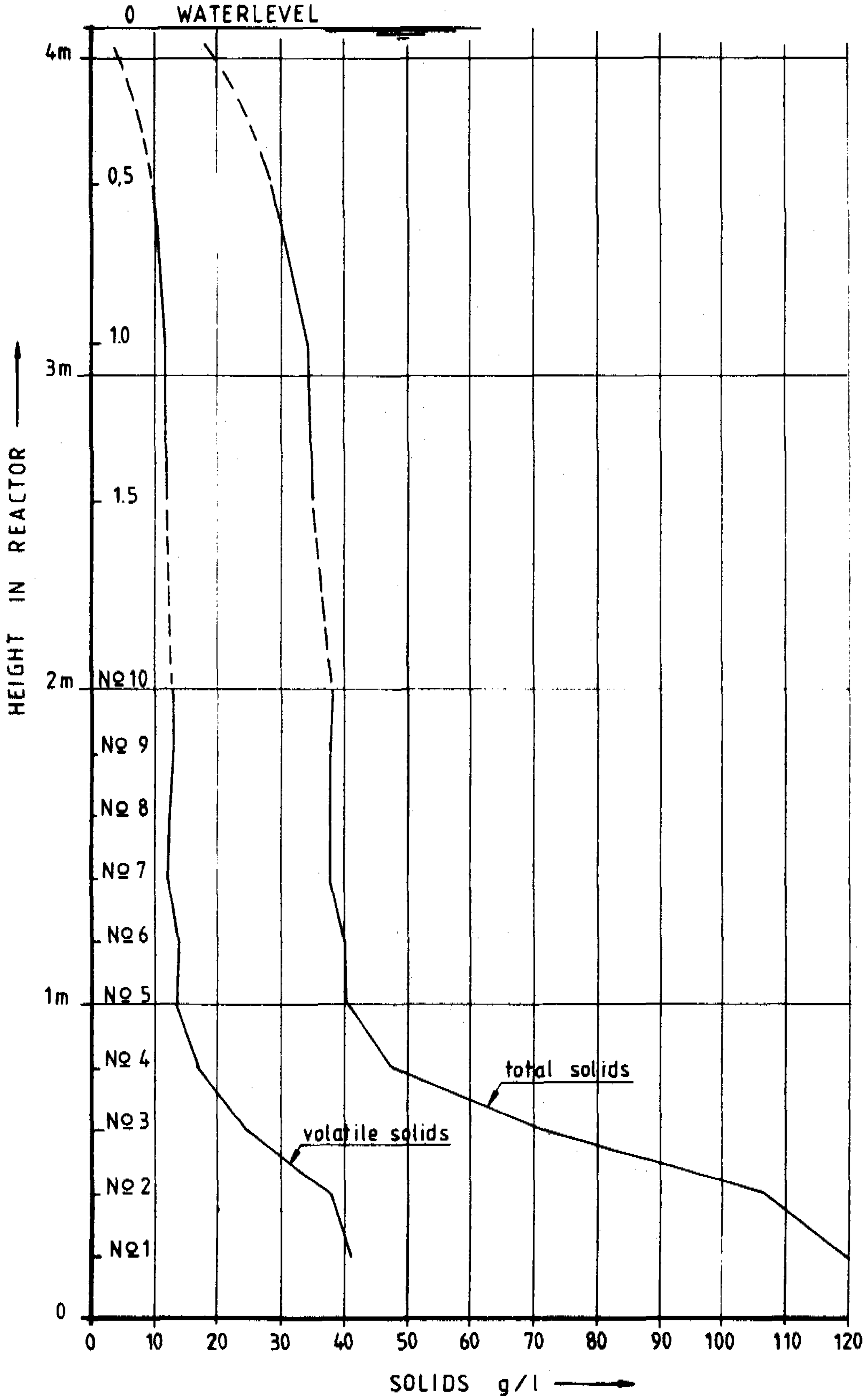
Specific activity:

Various specific activity measurements have been made. The results of these measurements will be reported in detail in the reports of the research assistants, and will be presented and discussed in the Final Report. The data available so far indicate a sharp increase of the specific methanogenic activity. At day 368 the average activity of three sludge samples amounted to 0.32 ±0.06 of COD. $gVSS^{-1}.\ d^{-1}$, which really is considerably higher than expected.



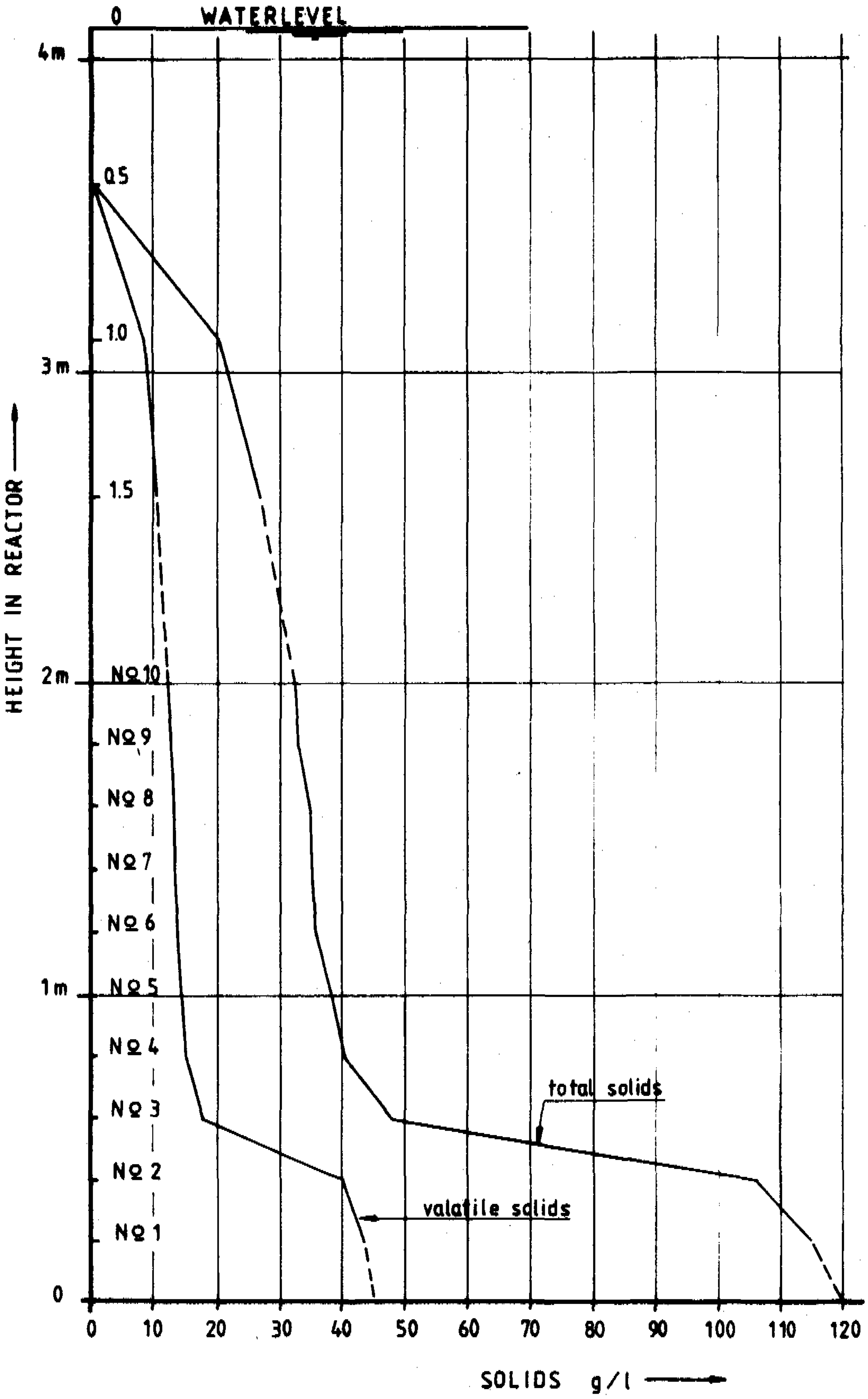
SLUDGE PROFILE DAY 378 (JUNE 26/84)

FIGURE 5.9



SLUDGE PROFILE DAY 401 (19/07/84)

FIGURE 5.10



SLUDGE PROFILE AFTER SLUDGE WITHDRAWAL DAY 430 (17/08/84)

FIGURE 5.11

Ash-content (VSS-content)

The ash content of the sludge remains high, indicating that the sludge is highly stabilized. However, considering the slightly lower values determined at day 430, there apparently occurs a gradual accumulation of biodegradable matter in the sludge at high loading rates. The results also reveal a surprising homogenity in ash content over the total height of the sludge bed/blanket. It will be evident that the nature of the sludge present in the effluent resembles closely the sludge retained in the reactor.

Anyhow, the washed out sludge deviates significantly from the SS present in the raw waste. More information about that will become available in the next months.

Sludge settleability

The settleability of the sludge is extra ordinary good, as already can be concluded from the high TSS-content of the sludge bed/blanket. Detailed information will be provided in the Final Report.

Sludge stability

As already pointed out before the sludge can be considered as highly stabilized, although at high loading rates the content of biodegradable matter tends to increase slightly. Detailed information concerning the stability of the sludge will become available in the next months.

5.10 Dynamic behaviour of the UASB-plants

Considerable emphasis has been devoted to assess the dynamic behaviour of the UASB-plant by performing liquid residence distribution measurements under the various conditions applied, particularly with respect to the number of feed inlet lines. As the elaboration of these results is difficult and time consuming, the results of these investigations can not be discussed in this report yet.

6. SOCIO - ECONOMIC STUDIES

6.1 Introduction

The evaluation of the socio-economic feasibility of the UASB-process for (domestic) wastewater treatment in Colombia, has to be restricted within this study to the Valle Department. The pilot-plant is situated in the capital of this department, Cali (1,4 million inhabitants). The total number of inhabitants within the Valle Department amounts to 3.2 million.
The economic level of the Valle Department is relatively high; together with the Antioquia Department and Bogotá and surroundings, it is the richest part of Colombia.

This study gives a short outline of those aspects playing a major role in the introduction of (domestic) wastewater treatment:

- political (official policy and legislation)
- organisational (framework for operation, maintenance and administration)
- economical (costs of the systems)
- social acceptance.

The conclusion with respect to the feasibility of the UASB-process for domestic wastewater treatment is very positive, given the technical results from the pilot-plant in Cali and the evaluation of the costs of the system.

(Cali)

Maria 50 10 34

(Primera)

* usted tiene datos sobre el nº de plantas de tratamiento

22 y (23) (lunes) martes miercoles

The standards set by the Government, are easily met by the system, which can be considered for Colombia - as a complete treatment system, and not only as a pre-treatment system. There is no system that can compete with the combination of a high-efficiency of waste removal and low capital investments and running costs.

In the Valle Department also industry has to conform to the effluent requirements set to wastewater flows. Here, the possibilities and willingness is higher than at the public level. As in the Valle Department many industries have organic wastewater flows (sugarcane factories, breweries, slaughterhouses, distilleries etc.), the UASB process is in many cases technically applicable, and attractive for its low investments and running costs.

6.2 Review of organisations, involved in infrastructure

For cities above 2500 inhabitants, the National Institute of Municipal Development (INSFOPAL) coordinates, advises, supervises and provides financing for the Sanitary Works Enterprises (nowadays EMPOS), except for the Departments Valle and Antioquia which have ACUAS; EMPOS are more dependant from the national level than ACUAS are).
The shares of ACUAVALLE S.A. are divided over the Departmental Government (57%), the National Government (42% through INSFOPAL) and Municipalities (1%).
ACUAVALLE manages 36 drinking water systems, of which 29 have complete treatment (sedimentation, filtration and chlorination) and laboratory facilities, for 2 systems groundwater is used with desinfection, 3 systems only have desinfection and 2 systems are without any treatment at all.

Given the difficult financial position of ACUAVALLE, priority is given to maintenance and improvement of the existing systems. Especially the occurrance of many leaks in the distribution systems needs attention.
ACUAVALLE manages 28 sewerage systems, of which 23 are separate and 5 are combined systems. The systems are old and 30 to 50% is in bad condition. About 70% of the urban population has a sewerage connection.

In the Valle Department 7 Public Municipal Enterprises (EMPRESAS) operate water supply and sewerage systems in the principal cities. The EMPRESAS also provide services such as solid waste collection and disposal, public markets, telephone and electric power. Together, the EMPRESAS of the Valle Department have about 2 million inhabitants under their jurisdiction.

The National Institute of Health (INAS), through its Health Service Sections (SSS) is responsible for communities below 2500 inhabitants as well as for the dispersed rural population. The "Division Saneamiento Ambiental" of the SSS carries out a programme of "Saneamiento Basico" which includes water supply and drainage.

Activities such as research, design and establishment of criteria for systems are carried out by INAS in Bogotà. Decisions are taken at the regional level though most times the directives of Bogotà are followed.

The Valle Department is divided in 9 "Zonas Regionales". In 1977 of each zone, very detailed statistics and diagnosis have been made about the tehcnical, geographical and socio-economical circumstances. Detailed data are available but will not be elaborated in further detail now.

Practically every community has a Community Action Committee for coordinating community activities. If a request of a village for INAS assistance in installing water supply systems is approved, the construction of the works will be carried out with the assistance of the community. The system is turned over to the community for administration, operation and maintenance under the Administrative Committee. The Committee appoints and pays an operator (fontanero) and a collector to collect the water revenues. In this way, the community has to pay not only the running costs but also its share of the investment costs (20%).
From the survey of 1977 it follows that of the 969 villages in the Valle Department, only 138 are suitable for construction of a sewerage system.
At this moment 77 systems are constructed, though in the last 3 years no activity at all has taken place.
In dispersed populated villages and land, a pit-latrine programme is carried out.
About 30 to 35% of the rural population has access to officially supplied drinking water. Generally, quality is bad and control and maintenance is absent in most cases.

Besides INAS, also the Comité de Cafeteros and CVC are working in the rural sanitation field.

The role of the CVC

During the last 20 years, the increasing centralism of decision making of the public administration and the concentration of economic activities in Bogotà has made the region's problems more acute. The Valle Department has an effective instrument to fight this tendency: the Autonomous Regional Corporation of Vall del Cauca, the CVC, set up in 1954.

The area of influence comprises 2,2 million ha, situated in the Valle Department. In general, its principal objective is to contribute to the overall development of the biophysical and human resources in this zone.

The CVC has basic programmes in electrification, land suitability, agricultural and pastoral development, and the management and conservation of replaceable natural resources.

There are special programmes for Buenaventura and, more recently, the Programme for Rehabilitation of the Pacific Coast/Nariño/Cauca (PLADEICOP).

The CVC prides itself on its technical-professional, and not party-political, recruitment of personnel (2500 employees); stability is great, especially at the higher levels. In general, the relative autonomy of the CVC from the official political system makes its position rather exceptional in Colombia.

Income from services in 1979 accounted for 69% of total income.

The Pollution Control Section - equiped with modern laboratory facilities - carries out a programme as described in the paragraph on water quality control (6.3).

In some cases CVC projects are carried out in the area of "basic needs": housing, health, education. If requested, the Pollution Control Section provides studies and design for sewerage and - making use of the opportunity - wastewater treatment (septic-tank with infiltration beds in general). The project supervises the construction which generally is carried out by the local community. Control and maintenance of these systems is well organised.

The division of municipalities and villages in the Valle Department has been given in table 6.1.

Table 6.1

INHABITANTS	ACUAVALLE	EMPRESAS	MUNICIPIOS	TOTAL
2.000 - 5.000	9		3	12
5.000 - 10.000	11			11
10.000 - 15.000	7			7
15.000 - 20.000	1			1
20.000 - 25.000	3			3
25.000 - 30.000	3			3
50.000 - 100.000	1	4		5
100.000 - 200.000		1		1
150.000 - 200.000	1	1		2
Cali 1.500.000		1		1
	36	7	3	46*

* 42 municipalities
4 villages

Source: ACUAVALLE 1983 (December)

Summarized:	5.000	-	15.000	inhabitants	:	18
	15.000	-	30.000	inhabitants	:	7
	50.000	-	200.000	inhabitants	:	8

6.3 Water quality control

The Valle Department is the only department in the country where an anti-pollution policy is formulated and is being carried out.

The CVC started in 1973 - after 5 years of pre-studies - with the "Programme of Pollution Control of the Water Resources", culminating in 1976 in the formulation of: "Acuerdo 014", anticipating the national law "Ley 09, Sanitaria Nacional" (1979).

This Ley 09 still is not made official.

The main river in the Valle Department is the Cauca with a flow between 46 and 1074 m^3/sec. and a length of 500 km in the region under jurisdiction of the CVC.

Acuerdo 014 sets standards for the quality of the receiving waters (dissolved oxygen, temperature, toxics, pesticides, heavy metals, pH and pathogens).

Any "wastewater disposal" (whether from industry or munipalities) has to be announced, qualified and quantified. Thereby CVC is authorized to visit and take samples where and whenever they wish.

For existing disposals, treatment plans have to be formulated (e.g. by official consultants) and judged by CVC.

Standards for effluents are categorized by branch (see Annex 8, 9). Industries have to pay for their disposal until the treatment works to be realized by themselves are ready (1990) - requirements are removal of 80% of BOD and 90% suspended solids.

A "Carga Combinada"* forms the basis for calculations; expressed in kg/day the bigger factories (paper and sugar cane) produce each around 100.000 (The penalty is $ 0,05 per kg/day which is very low).

Since CVC controls the electricity networks, they can stop energy - supply when industries do not cooperate.
Treatment plans are reviewed by CVC and if necessary changed; if it appears later that standards are not met then a) by bad construction work, the contractor is responsible, or b) by bad design, CVC will assist in improvents.
From industrial side the cooperation is considered to be good. CVC expects that within the coming 10 years the industrial water pollution will be reduced considerably.
More problems are expected with public organizations, where a strong resistance exists against the CVC requirements.

$$\text{* Carga Combinada} = \frac{2\ \text{BOD} + \text{COD}}{3} + \text{Susp. solids (kg/day)}$$

Domestic wastewater must be treated (from 1985 on): removal of 50% of susp. solids and 35% of BOD. This will be the responsibility of the public entities.
Urban extensions ("urbanizaciones") that can not connected to the old sewerage system if any, have to build a treatment plant to be connected to their new sewerage system.
It is predicted that the share of domestic wastewater (except for Cali) in the total pollution will be

doubled in 1990 (from 20 to 40%). Measured absolutely, this share also increases (from 70 to 93 tons of organic matter per day) due to rapid growth of these cities.

6.4 Organisational aspects

As stated in Chapter 6.2, in Colombia and especially in the Valle Department, an infrastructure exists of public and private organizations in charge of drinking water supply and sewerage works. Domestic wastewater treatment should become part of this infrastructure. Legislation is formulated and in the Valle Department already made operational.
Considering the Valle Department, the organizations (Empresas, ACUAVALLE and Health Service Section) do have, in general, sufficient personal and in general there is no shortage of drinking water. However, the quality of the supplied water often is questionable. As all organizations have their own way of maintenance and control, there does not exist a "clear" insight in the proper functioning of these systems. Most of the lower personnel do not have an adequate training.
It is considered a big step forward that an official reglementation is formulated now for drinking water supply.* Here, the Ministry of Health formulates standards and procedures for design, operation, maintenance and control of drinking water plants.
Moreover, in the Valle Department, a "convenio" of all organizations working in the field of water supply as well as the CVC and Valle University, developed a 30-month programme to improve drinking water quality in the Valle Department.**

In this programme, strategies are formulated to standardize and improve control of plants and drinking water. As is required in Decreto 2105, this control will be under the jurisdiction of the Ministry of Health through its regional Health Service Sections. Furthermore, the programme organizes training courses for all levels of personnel of all organizations.
Existing laboratories of all organizations will have to cooperate. A new central reference laboratory will be installed, which must have a funtion for whole south-east Colombia.
Because of the fact that for a large part use can be made of already existing infrastructure, the costs of this programme are low, whereas the expected improvement in the quality of drinking water is relatively high.

The plans and developments described above are of importance for the possibilities of a large-scale introduction of domestic wastewater treatment systems. For a proper functioning of these systems, a well organised maintenance and control are essential. In the above given structure of improved coordination and control, wastewater systems can be implemented.
Thereby, in the Valle Department exists a growing potential of young sanitary engineers, coming from the Valle University.

* as part of Ley 09: Decreto no. 2105, 26 july 1983.

** desarrollo del programa nacional de calidad del agua en el departamento del Valle del Cauca; Cali, march 1984.

6.5 Economic aspects

The chance of introduction of a wastewater treatment system is in the first place determined by its initial investment costs. In most cases, the investment costs are paid by the Government, while costs of maintenance and administration etc. have to be paid by the consumers.

Of the EMPRESAS, EMCALI is the only one which is preparing the construction of a wastewater treatment plant for its city. This large-scale project costs huge amounts of money. Feasibility studies now carried out will cost around 220 million pesos. The financial situation of EMCALI is very critical, depending heavily on foreign loans (high debts and interest rates).

At ACUAVALLE the willingness exists - for years already an engineer is assigned to the area of domestic wastewater - but for a lack of financial means no more real activities have taken place. A practical consideration, which is used by political decision makers is the fact that the main pollutor of the river Cauca, Cali (1,5 million inhabitants) first has to build their treatment plants!

6.5.1 Construction costs

Small scale plants

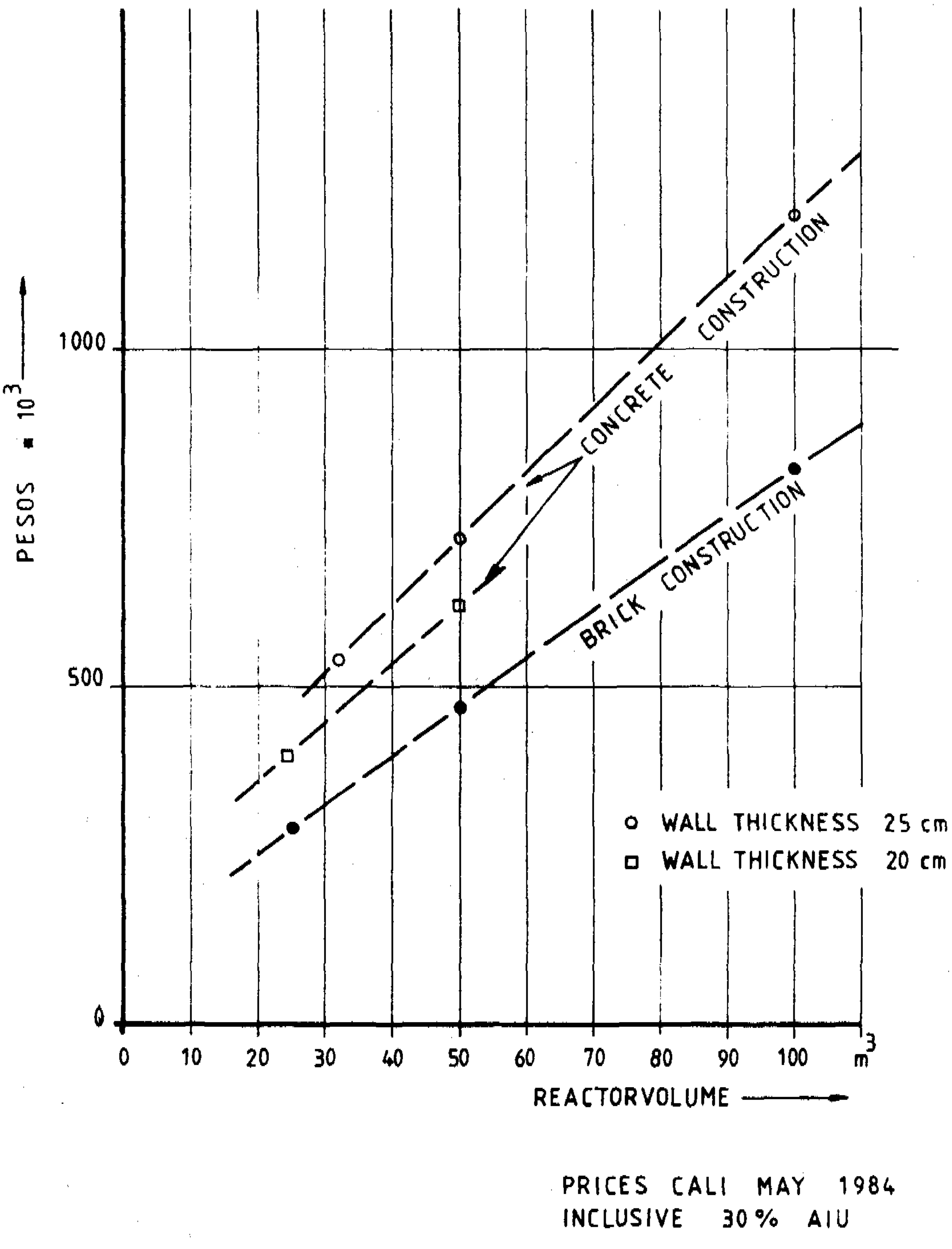
Cost estimates have been made of simple small scale reactors which can be used in rural situations. A simplification of the design is formed by the use of aluminium baffles for the sedimentation part of the reactor.

Gas is not collected but is directly released into the atmosphere.

Figure 6.1 shows the costs of construction (labour and materials). In rural situations, especially in the mountains, transport costs can greatly influence the costs of construction. Therefore, these prices only serve as a guidance to compare the costs with costs of other treatment systems like septic-tanks or Imhoff-tanks, lagoons etc. In most cases the local population will participate in the construction of the plant. The costs of labor, which is about 10% of the shown total costs, therefore can be neglected.
In a lot of cases in rural areas of the Valle del Cauca, due to the topographical conditions, use can be made of gravity for feeding the reactor and discharging the effluent, so pumping costs do not need to be considered if a comparison is made.

Table 6.2 shows a comparison of a preliminary estimate of actual total project costs for three different systems: septic-tanks, Imhoff-tanks and UASB-reactors. The total costs of UASB plants are only slightly higher than Imhoff-tanks, whereas the removal-efficiency of UASB-reactors is considerably higher.

Another actual example is the design of a 32 m^3 UASB-reactor for treating the wastewater of a hotel and surrounding holiday-houses at the lake Calima, nearby the village of Darien. The total work includes a bypass-chamber and piping (50 m in total) and connections. The total estimated costs are below $ 600.000. The reactor is designed for an average population of 475 persons.



CONSTRUCTION COSTS SMALL SCALE UASB PLANTS

FIGURE 6.1

Table 6.2

situation:	1750 inhabitants
	average flow: 3,24 l/sec.
system	**costs $ Col.**
1. 2 septic tanks (35 m^3 each)	900.000
2. Imhoff tank + sludge drying beds	1.200.000
3. 90 m^3 UASB	1.400.000

Table 6.3

city	hab.	temp. °C	HRT h.	cost of pre-studies (10%)	costs of pumps, gritchamber etc.	costs of UASB-reactors	total project costs (UASB)	cost of lagoons	total project costs (lagoons
1. Candelaria	30.000	23	6	1.525.000	1.000.000	14.250.000	16.775.000	25.000.000	28.600.000
2. Guacari	30.000	23	6	2.225.000	8.000.000	14.250.000	24.475.000	24.400.000	35.640.000
3. La Union	22.000	23	6	1.990.000	7.900.000	12.000.000	21.890.000	19.000.000	29.590.000
4. Roldanillo	32.000	23	6	2.225.000	7.500.000	14.750.000	24.475.000	25.200.000	35.970.000
5. Toro	18.000	23	6	1.630.000	5.800.000	10.500.000	17.930.000	13.800.000	21.560.000

Prices in Colombian pesos

Costs of lagoons and preliminary systems are based on calculations of ACUAVALLE; load 40g BOD/hab. day (May 1984)

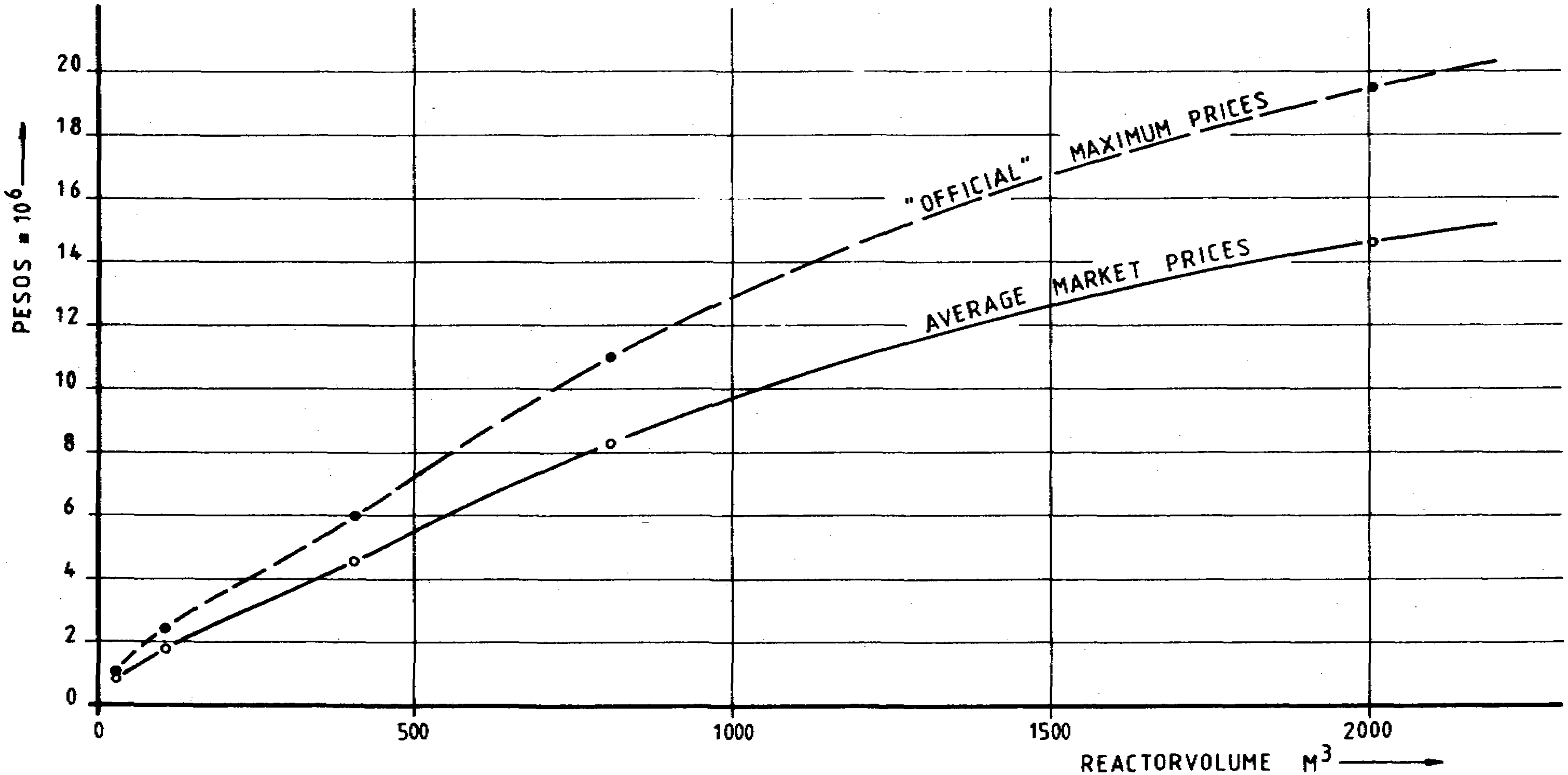
Sizes of UASB - reactors based on a load of 250 l/hab. day.

Reactors of 100 m^3 to 2000 m^3

Figure 6.2 shows curves of construction costs of bigger UASB-reactors. The upper line of the curve can be considered to be a maximum price, based upon official prices. The lower line are more realistic "market-prices" (see also Figure 6.3).

To estimate costs of UASB-reactors, some global designs have been made. The calculations consist of about 20 different items, including groundworks (cleaning, measurements, etc.). Gascollectors are made of concrete which appears to be a little bit cheaper than metal ones.
Besides, there exists a lot of experience in building in concrete in Colombia.
Prices can be influenced of course strongly by local and temporal differences. The case of the city of Neiva, where a 400 m^3 reactor was built for less than $ 3.000.000 shows for example the advantage of building the plant while the residential area itself is also under construction. All equipment and materials are easily available.
Therefore, to compare prices of different treatment systems, it is always necessary to check the list of items and unit-prices upon which the cost calculations are based.
The real costs will always differ from the official estimates.

FIGURE 6.2



CONSTRUCTION COSTS UASB - PLANTS

CALI, MAY' 1984

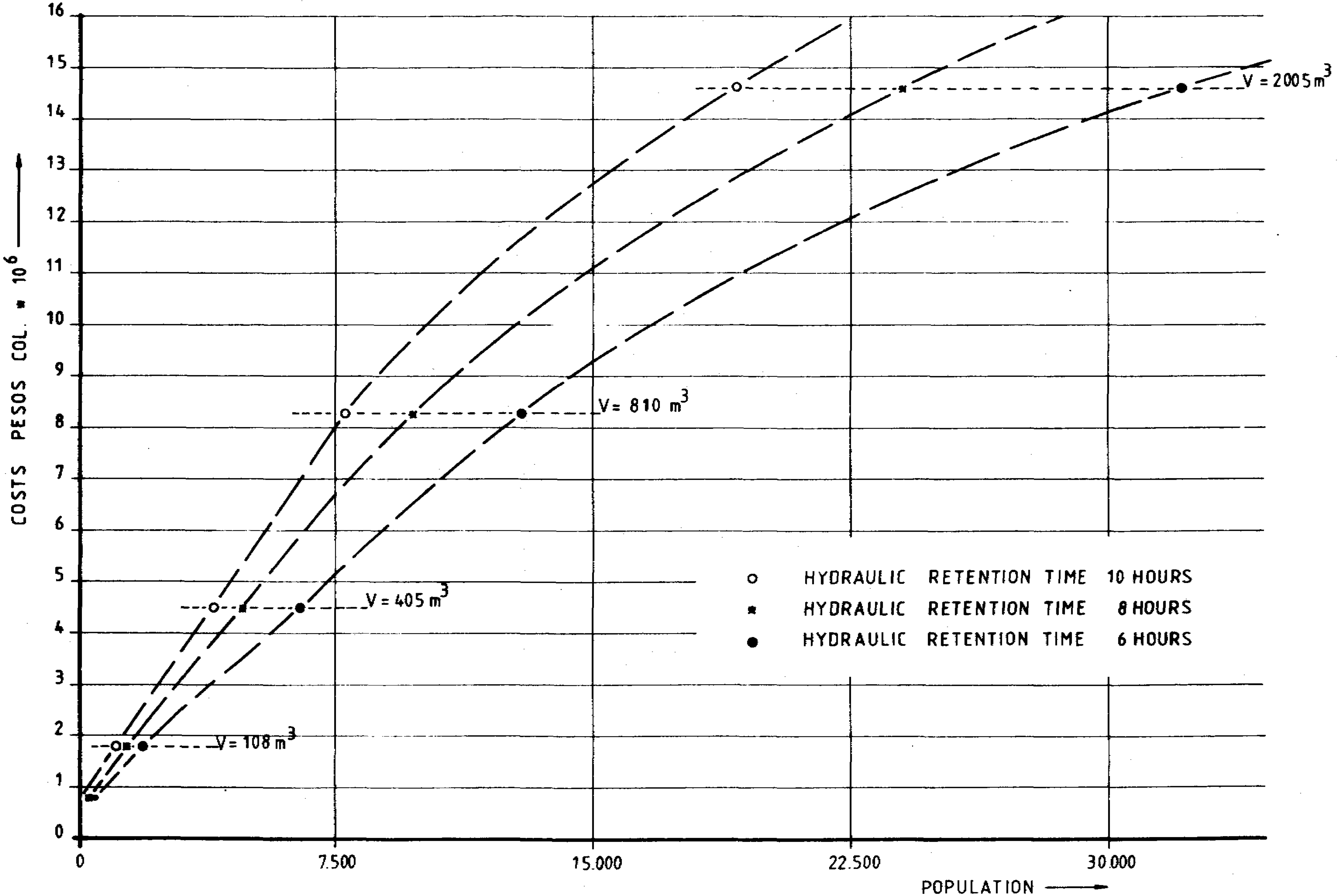


FIGURE 6.3

CONSTRUCTION COSTS OF UASB REACTORS

CALI , MAY 1984

6.5.2 Comparison with other systems

Lagoons

Table 6.3 shows estimated costs of lagoons (stabilisation lagoons) in some cities in the Valle del Cauca for treating domestic wastewater.
Comparing these data with costs of UASB-plants (see above) it appears that building costs of UASB plants are about 60% lower for systems of 30.000 inhabitants. Considering all the costs including in sewerage works (pumping, transport, design etc.) the total project costs for UASB are about 70% lower than the costs of a lagoon.

Activated sludge plants

Rough estimates indicate that the costs of activated sludge plants for treating the same amount of wastewater are about twice as high as for the UASB-system.
Activated sludge installations for domestic wastewater are designed with a hydraulic retention time of approximately 10 hours. This means that the reactor size is always bigger than UASB-plants, while the main cost component of UASB-reactors is formed by the tank, for activated sludge installations there are additional costs of sedimentation tanks, sludge recirculation and aeration systems.

6.5.3 Maintenance and operation costs

In principle, an UASB-treatment plant needs little maintenance. If sludge development is good, like in the case of the pilot-plant in Cali, sludge-washout will be very low and excess sludge removal has to take place every one or two months, depending on applied organic

loads. In general, a sand-trap and grit-chamber with screen has to be installed. These parts need more maintenance than the reactor itself. If pumping is necessary this also will need more operation and maintenance than the plant itself. Besides the sludge removal from time to time, the only operation work will be a daily check of a proper functioning inlet system and of the screen.
Therefore for daily routine of bigger installations, staffing with one operator with 2 ayudantes will be more than sufficient. Small scale plants should be checked once a day if possible.

As a typical example of a possible application of an UASB-wastewater plant, a middle-big town in the Valle (30.000 inhab.) can be taken.

This town will fall under the jurisdiction of ACUA-VALLE. In this situation there already exists a technical and organisational infrastructure formed by the local drinking water treatment plant. In general there is one operator with 1 to 3 "ayudantes" and a laboratory staff of 3 persons in charge of these plants (depending on size and kind of treatment plant).

Taking the same building up of costs as is the average for drinking water plants of ACUAVALLE, the yearly running costs will be approximately as follows:

The total capital costs of the project are taken to be 25 million col. pesos (This inlcudes design, pre-studies, sewage-connections, grittrap, civil works, pumping station and UASB-reactor).
The yearly running costs will be as follow:

A. DIRECT COSTS

-	Labor	1 operator	$ 445.000
		2 ayudantes	$ 585.000
		additionals	$ 235.000
		Subtotal labor	$ 1.265.000
-	Operation and maintenance		$ 260.000

INDIRECT COSTS

-	Central service and admin. (Cali)	$ 1.860.000

DEPRECIATION	$ 335.000
Total A	$ 3.720.000

B. Like "A" but inclusive of guards, being $ 730.000**, gives:

Total B $ 4.450.000

*Costs per m^3 treated effluent:	A: $ 1.7	(30.000 inhabitants
	B: $ 2.0	donation 200 l/inhab. day)
*Annual costs per inhabitant	A: $ 124	
	B: $ 148	
*Annual costs per connection:	A: $ 875	(ca. 7 inhab. per
	B: $ 1000	connection)

C. Yearly running costs inclusive investment costs***

Interest:	22%	
Period of payment:	7 years	
Capital costs:	$ 25.000.000	
Average costs per year (over 7 years)		$ 7.143.000
Running costs "A"		$ 3.720.000
	Total	$ 10.863.000
*Costs per m³ treated effluent:		$ 5.0

These calculations only give a raugh idea of the costs that might be expected of a washwater treatment plant.

Notes:

*Use is made of ACUAVALLE computerdata of all expenses of the month April 1984. The expenses made for 33 drinkingwater systems are taken as the basis for an average building-up of costs of one treatment system.

The indirect costs of Cali are rather high. They include costs like technical staff, direction, administration, computersystem, laboratory, research etc.

If services of ACUAVALLE are extended with waste water treatment, the indirect costs will raise less than proportional - this is not assumed in the above made calculations; there are all new costs lead to a proportional increase of the indirect costs.

**Guards, assuming 3 persons with net-salary of $ 12.500/ month or $ 20.250/month inclusive taxes.

***Taking ACUAVALLE calculations of ZARZAL-sewerageworks costs as example.

****Production costs drinkingwater in the Valle Department: $ 8 - 13/m³.

6.6 Social aspects

Given the great social differences in Colombia, it is difficult to evaluate these aspects.

In urban parts (in the Valle Department 80%), the city-policy depending on departmental and national politics, decides public activities.

In general, tariffs for public services are low and adjusted to the different social levels of the population.

E.g. in Cali, the price of a m^3 drinking water is $ 3 for the lowest income groups while it is $ 30 for the highest. The price for sewerage is 50% of the price paid for drinking water. In an average city, the total price for public water services won't raise considerably when effluent will be treated. The fact that only running costs are charged and no investment costs plays a role in this. Problems in the area of payment of bills is not expected when wastewater treatment is introduced.

In general, people admit the importance of an anti-pollution-campaign. Thereby, rivers are commonly used by many (poor) people for washing, bathing and sometimes even drinking.

Clean surface waters will influence the living conditions of these groups.

In rural areas, village participation is very common.

In general people cannot afford anything, so money for investments will have to come from outside (see Annex 10).

Water tariffs differ from 50 to 200 $/month per house connection. This rather small amount already gives many problems and bills seldom are paid. Therefore maintenance and control do not take place.
Though considered to be important, priority in many cases is given to other needs than wastewater treatment (e.g. better housing, drinking water and food, street pavements, seweragesystems of latrine-pits).

6.7 Upscaled plant design

During the reporting period a start has been made with the upscaling of the design of UASB plants. Since criteria for pollution load per capita and hydraulic load may differ from place to place, it is assumed to be better not to relate the capacity to a certain number of population equivalents but to a certain volume of the bioreactor.
Criteria for the preliminary design which is added to this progress report are:

- Gravity flow to the reactor. In some cases pumping of influent will be required.
- Installation of a sandtrap with a flow velocity of 0.30 m/s.
- Installation of an automatic cleaned fine screen (1.5 - 2 cm). Since this is a vulnerable part of the plant an other solution will be looked for.
- Dividing of the bioreactor into 4 compartments in order to phase the plant capacity and to be as flexible as possible in operation and maintenance. The extra cost for the four separation walls will be partly compensated by savings on other parts of the construction.

- One inlet per 4 à 5 m^2.
- Separate outlets for effluent, inert bottom materials and excess sludge.
- Hydraulic retention time of 8 hours.
- Hydraulic load of 150 - 200 l/capita/day over 10 hours.
- Water depth 5m.
- Two alternatives will be investigated for construction of the gas collectors: in concrete and in iron.

The design of the upscaled UASB plant will be compared with the design of a facultative stabilisation pond and an activated sludge plant of the same capacity. This comparison will be presented in the Final Report. The investment costs for this upscaled design have been estimated at some $ 11 million, which is slightly higher than according to Figure 6.2 and 6.3. Detailed cost estimates will be presented in the Final Report.

7. TRANSFER OF KNOW-HOW

7.1 One-day course on UASB - systems

On April 16 1984, a one-day course was given by Messrs. Rodriguez, Yspeert, Schakel and Schellinkhout. The course was meant for personnel of the sanitary divisions of CVC, EMCALI and Univalle. Some 30 persons attended the course. Main items that were presented, were principles and process of anaerobic digestion, construction of UASB- and other anaerobic systems, organization and results of the research on the Cali pilot plant, hydraulic behaviour of the plant, and development and caracteristics of the sludge in the plant.

7.2 Univalle and CVC

In may 1984, three Colombian students started a research on the influence of the elements nickel, lead, chronium and cadmium on the methanogenic activity of sludge from the pilot plant.
In april 1984, Dr. Rodriguez started a study on the treatability of the wastewater of a yeast factory (vinasses). In this research two Colombian students participate.

After his participation as assistant engineer for the research project, Mr. Yspeert started working for a period of 3 months for CVC. His main task was to make an inventory of industrial pollution within the CVC area and to select those industries which produce waste water which can be treated with the UASB process.

Moreover, Mr. Yspeert initiated treatability tests of different types of wastewater. A report on his activities will be presented in the Final Report.

7.3 Seminar

A two days seminar preceeded by a one-day trainingscourse will be held on October 17/19 1984. The papers will be presented by teammembers. Besides, Mr. Celso Savelli Gomes from Brazil has been invited to present the experience from abroad. The training course will be organised by Univalle with assistance of the local team. The two-days seminar will be organised by Univalle/Haskoning. Some information on the seminar has been given in Annex 11.

8. PLANNING OF PERSONNEL AND BUDGET

8.1 Dutch staff movements during reporting period

The Resident Engineer, Mr. Schellinkhout, spended his vacations from February 27 to March 18, 1984. During his absence daily maintenance and control of the pilot plant as well as additional experiments were carried out by Messrs. Schakel and Yspeert, under responsibility of Mr. Rodriguez. Their work gave full satisfaction.

During May 1984 the resident engineer spent much time on the preparation of the construction of the post-treatment treatment systems, as described in Chapter 4. This implied that insufficient time was left for reporting and other regular tasks. In the same period he was in charge of the daily operation of the pilot plant, which included the performance of the BOD analysis.

On April 4, 1984 Mr. Yspeert terminated his work for the project. Still he has to complete a (preliminary) report about his studies on sludge bed behaviour and development, and of the anaerobic filter as well. At the moment Mr. Yspeert is working with CVC, performing a study to the feasibility of treatment of industrial waste water by the UASB-process, and giving guidance to research to the treatability of coffee fermentation water (aguamiel).

On April 5, 1984 Mr. Schakel finished the task of monitoring the pilot plant. Now he is working on a study to the socio-economic feasibility of treatment of domestic-wastewater by the UASB-system. Preliminary designs were made for standard types digesters, using cheap building materials and a simple construction.

The project director, Mr. Louwe Kooijmans visited the project from March31 to April 6, 1984 and from August 10 to 15, 1984. The progress of the project was discussed, a detailed planning was made for the post-treatment programme and the delivery of additional equipment to be bought and the arrangements were made for the organisation of the seminar.

The specialist on anaerobic treatment, Mr. van Velsen visited Cali from march 27 to April 2, 1984. Progress and planning were discussed (see Van Velsen's Report - in Dutch).
On May 31 1984, Mr. Heynekamp arrived to assist in the project. He is mainly in charge of the UASB pilot plant and of one of the post-treatment systems, the intermittent sandfilters.

On June 18 1984, Mr. Wildschut arrived. He is in charge of the post-treatment systems.
Both Mr. Heynekamp and Mr. Wildschut were well prepared for their job from a professional point of view.
A handicap for both is their poor knowledge of the spanish language. However, this is still better now.

Haskoning's process engineer Mr. van Drooge visited Cali from May 26 to June 16 1984 and supervised the construction of the post-treatment installations. When he left all installations were almost ready for operation.

8.2 Staff Univalle

The staff of Univalle on the project is still according to the description given in paragraph 6.3 of the first Progress Report.

8.3 Planning of staff requirements till the end of the project

The bar chart of personnel required for the project till the end of the project has been given in Figure 8.1.
The following short term visits have been foreseen:

Mr. van Velsen	- 17/9 - 28/9/1984 (post-treatment)
	- 10/12- 21/12/1984 (final report)
Mr. Louwe Kooijmans	- 10/10 - 24/10/84 (seminar + progress)
	- 10/12 - 21/12/84 (final report)
Mr. Lettinga	- 16/10 - 24/10/84 (seminar)
Mr. Savelli Gomez	- 16/10 - 21/10/84 (seminar)

8.4 Budget control

The budget control presented in Annex 12 is related to the original cost estimate and the additional budget for the project extension.
The project is financially under control, although some expenses differ considerably from the cost estimates.

Figure 8.1 Planning of personnel 01.09.84 - end of project

Colombia
------- Netherlands, temp
_______ local staff, temp

Editing Final Report

Personnel	Man weeks Neth.	Man weeks Col.
HASKONING		
Project director	4	3
Mech. Engr.	2	
Process Engr.	3	
Civil Engr.	4	
Design Engr.	3	
Agricultural University of Wageningen		
Specialists Anaerobic Treatm.	4	5
Resident Engr.		21
Ass. Engineer I		21
Ass. Engineer II		21
University Del Valle		
Col. Counterpart Engr.		pm
Techn. Personnel		pm
Laboratory Personnel		pm
INCOL		
Civil Engineer		2
Spec. Brazil Seminar		pm

Week nr.: Sept.'84 36 37 38 39 | Oct.'84 40 41 42 43 | Nov.'84 44 45 46 47 48 | Dec.'84 49 50 51 52 | Jan.'85 1 2 3 4

ANNEXES

ANNEXES

ANNEX 1 OPERATION SCHEDULE USAB REACTOR

PERIOD DATE		DAY NOS.	HRT (h)	INLETPOINTS No. (units)	density (m^{-2})	REMARK
1983	Nov 25 - Dec 17	165 - 186	8.0	16	1	
	Dec 18 - Jan 6	187 - 206	7.9	4	0.25	
1984	Jan 7 - Jan 28	207 - 228	7.9	2	0.125	
	Jan 29 - Feb 4	229 - 235	7.9	4	0.25	
	Feb 5 - Feb 14	236 - 245	5.9	4	0.25	
	Feb 15 - Feb 19	246 - 250	∞		No pumping	
	Feb 20 - Mar 2	251 - 261	6.1	4	0.25	Many pumps stops
	Mar 3 - Mar 20	263 - 280	6.0	4	0.25	
	Mar 21 - Mar 30	281 - 290	6.0	16	1	
	Mar 31 - Apr 6	291 - 297	6.0	16	1	Many pumps stops
	Apr 7 - Apr 14	298 - 305	6.0	16	1	
	Apr 15 - Apr 17	306 - 308	Appr.6	16	1	
	Apr 18 - Apr 23	309 - 314	4.9	16	1	
	Apr 24 - May 2	315 - 323	4.9	16	1	Many pumps stops
	May 3 - May 11	324 - 332	∞		No pumping	
	May 12 - May 15	333 - 336	4.1	16	1	
	May 15 - May 29	337 - 350	∞		No pumping	
	May 30 - Jun 7	351 - 359	4.1	16	1	
	Jun 8 - Jun 12	360 - 364	∞		No pumping	
	Jun 13 - Jun 16	365 - 368	4.1	16	1	
	Jun 17 - Jul 2	369 - 384	∞		No pumping	
	Jul 3 - Aug 16	385 - 424	3.9	16	1	

ANNEX 2 REUSLTS OF THE CALI PILOT PLANT - JAN-FEB 1984

TABLE 1 COD-VALUES $(g.m^{-3})$

PERIOD	REMARK	RAW INFLUENT		FILTRATED INFLUENT		RAW EFFLUENT		FILTRATED EFFLUENT	
		$\bar{x}$	o	$\bar{x}$	o	$\bar{x}$	o	$\bar{x}$	o
21/1 - 28/1	1	248	58	104	25	77	16	41	9
29/1 - 3/2	2	250	48	110	23	68	6	60	11
4/2 - 10/2	3	185	67	67	25	62	15	39	4
11/2 - 14/2	3	235	32	93	18	65	12	42	9
15/2 - 18/2	4	-	-	-	-	-	-	-	-

TABLE 2 COD-LOADING RATES $(g.m^{-3}.d^{-1})$

PERIOD	REMARK	RAW INFLUENT		FILTRATED INFLUENT		RAW EFFLUENT		FILTRATED EFFLUENT	
21/1 - 28/1	1	0.70	0.25	0.29	0.09	0.22	0.07	0.14	0.05
29/1 - 3/2	2	0.76	0.15	0.26	0.13	0.21	0.02	0.18	0.03
4/2 - 10/2	3	0.47	0.34	0.18	0.14	0.16	0.11	0.10	0.02
11/2 - 14/2	3	0.94	0.13	0.37	0.07	0.26	0.05	0.17	0.04
15/2 - 18/2	4	-	-	-	-	-	-	-	-

TABLE 3 COD-REMOVAL (%)

PERIOD	REMARK	TOTAL*		DISSOLVED**	
		$\bar{x}$	o	$\bar{x}$	o
21/1 - 28/1	1	67	11	84	4
29/1 - 3/2	2	72	5	75	5
4/2 - 10/2	3	64	10	76	9
11/2 - 14/2	3	72	5	82	5
15/2 - 18/2	4	-	-	-	-

*total: raw influent to raw effluent

**dissolved: raw influent to filtrated effluent

ANNEX 2

TABLE 4 GASPRODUCTION

PERIOD	REMARK	AVERAGE DAILY PRODUCTION ($m^3.d^{-1}$)	PRODUCTION PER KG REMOVED COD (liters.kg COD^{-1})
21/1 - 28/1	1	7.5	244
29/1 - 3/2	2	8.1	271
4/2 - 10/2	3	4.8	242
11/2 - 14/2	3	3.8	203
15/2 - 18/2	4	4.9	00

TABLE 5 solids

PERIOD	REMARK	TSS INFLUENT ($g.m^{-3}$)		TSS EFFLUENT ($g.m^{-3}$)		VSS REMOVAL (%)	VSS INFLUENT ($g.m^{-3}$)		VSS EFFLUENT ($g.m^{-3}$)	
		$\bar{x}$	σ	$\bar{x}$	σ		$\bar{x}$	σ	$\bar{x}$	σ
21/1 - 28/1	1	150	81	40	18	73	85	49	14	12
29/1 - 3/2	2	112	51	37	11	67	50	20	16	12
4/2 - 10/2	3	226	76	42	10	81	93	28	21	4
10/2 - 14/2	3	158	45	55	10	65	93	19	29	9
15/2 - 18/2	4	-	-	-	-	-	-	-	-	-

ANNEX 2

TABLE 6 VARIOUS PARAMETERS (21/1 - 10/2)

PARAMATER	UNITS	INFLUENT		EFFLUENT	
		$\bar{x}$	σ	$\bar{x}$	σ
pH	units	6.9	0.1	6.6	0.1
T	^{o}C	24.4	0.3	24.3	0.5
Alcalinity	$eq.m^{-3}$	2.2	0.4	3.2	0.1
$NH_4^+ - N$	$g.m^{-3}$	9.5	0.8	14.3	2.4
N - org.	$g.m^{-3}$	6.4	0.9	2.3	0.4
NTK	$g.m^{-3}$	16.0	1.4	16.6	2.0
COD ÷ NTK	-	15.5	2.9	5.4	0.7

TABLE 7 BOD_5

DATE	REMARK	RAW INFLUENT VALUE ($g.m^{-3}$)	SETTLED EFFLUENT VALUE ($g.m^{-3}$)	REMOVAL (%)	FILTRATED EFFLUENT VALUE ($g.m^{-3}$)	REMOVAL (%)
19/1	1	73	17	77	15	80
27/1	1	129	13	90	13	90
2/2	2	92	7	92	6	94
10/2	3	68	13	81	9	86

REMARKS
1: HRT 8h. density of inletpoints 0.125 m^{-2}
2: HRT 8h. density of inletpoints 0.25 m^{-2}
3: HRT 6h. density of inletpoints 0.25 m^{-2}
4: Period of stand-still due to reconstruction works on the plant.

ANNEX 3

RESULTS OF THE CALI PILOT PLANT
FEB. - MAR. '84

TABLE 1 COD-VALUES ($g.m^{-3}$)

PERIOD	REMARK	RAW INFL.		FILTRATED INFL.		RAW EFFL.		FILTRATED EFFL.	
		$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
19/2 - 24/2	1	232	34	106	27	69	8	49	6
25/2 - 2/2	1	196	59	89	28	55	8	53	8
3/3 - 9/3	2	268	25	110	23	81	14	48	11
10/3 - 16/3	2	317	30	121	22	123	21	50	12
17/3 - 21/3	2	263	43	101	23	145	39	47	3

TABLE 2 COD-LOADING RATES ($kg.m^{-3}.d^{-1}$)

PERIOD	REMARK	RAW INFL.		FILTRATED INFL.		RAW EFFL.		FILTRATED EFFL.	
		$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
19/2 - 24/2	1	0.75	0.22	0.57	0.26	0.23	0.06	0.16	0.04
25/2 - 2/2	1	0.53	0.37	0.29	0.15	0.18	0.06	0.14	0.06
3/3 - 9/3	2	1.10	0.10	0.45	0.10	0.33	0.05	0.20	0.05
10/3 - 16/3	2	1.25	0.12	0.48	0.09	0.48	0.08	0.20	0.05
17/3 - 21/3	2	1.06	0.17	0.47	0.19	0.58	0.16	0.19	0.03

ANNEX 3

TABLE 3 COD-REMOVAL (%)

PERIOD	REMARK	TOTAL* x	TOTAL* σ	DISSOLVED** x	DISSOLVED** σ
19/2 - 24/2	1	69	8	78	6
25/2 - 2/3	1	70	8	71	8
3/3 - 9/3	2	70	4	82	4
10/3 - 16/3	2	61	7	84	6
17/3 - 21/3	2	43	16	82	3

* total: raw influent to raw effluent

** dissolved: raw to filtrated effluent

TABLE 4 GASPRODUCTION

PERIOD	REMARK	AVERAGE DAILY PRODUCTION ($m^3.d^{-1}$)	PRODUCTION FOR KG REMOVED COD ($liters.kg\ COD^{-1}$)
19/2 - 24/2	1	5.8	150
25/2 - 2/3	1	5.7	255
3/3 - 9/3	2	6.9	140
10/3 - 16/3	2	10.4	212
17/3 - 21/3	2	9.6	313

TABLE 5 SOLIDS

PERIOD	REMARK	TSS INFLUENT ($g.m^{-3}$)		TSS EFFLUENT ($g.m^{-3}$)		TSS REMOVAL (%)	VSS INFLUENT ($g.m^{-3}$)		(%TSS)	VSS EFFLUENT ($g.m^{-3}$)		(%TSS)
		$\bar{x}$	σ	$\bar{x}$	σ		$\bar{x}$	σ		$\bar{x}$	σ	
19/2 - 24/2	1	172	73	40	10	77	81	24	53	16	7	38
25/2 - 2/3	1	153	68	29	16	81	70	28	48	12	10	34
3/3 - 9/3	2	131	41	48	24	63	63	27	47	29	21	55
10/3 - 16/3	2	154	37	104	43	32	70	17	46	41	19	38
17/3 - 21/3	2	190	67	192	93	-1	86	22	53	46	26	27

ANNEX 3

TABLE 6 VARIOUS PARAMETERS (11/2 - 12/3)

PARAMETER	UNITS	INFLUENT		EFFLUENT		REMARK
		$\bar{x}$	σ	$\bar{x}$	σ	
pH	units	7.0	0.1	6.7	0.2	18/2 - 9/3
T	°C	24.8	0.2	24.8	0.8	13/2 - 22/3
alkalinity	$eq.m^{-3}$	2.4	0.2	3.3	0.2	
NH_4^+ - N	$g.m^{-3}$	10.2	1.7	13.2	3.3	
N-org	$g.m^{-3}$	7.5	1.4	2.3	0.7	
NTK	$g.m^{-3}$	16.8	0.9	14.8	2.7	
COD : NTK	-	13.7	2.2	4.3	0.8	

is thus a reasonable (average) domestic waste water ~~effluent~~ quality

TABLE 7 BOD_5

DATE	REMARK	RAW INFLUENT VALUE ($g.m^{-3}$)	RAW INFLUENT COD:BOD %	SETTLED EFFL. ($g.m^{-3}$)	REMOVAL (%)	FILTRATED EFFL. VALUE ($g.m^{-3}$)	FILTRATED EFFL. COD:BOD %	REMOVAL (%)
24/2	1	82	2.9	10	88	8	5.6	90
2/3	1	62	2.4	13	79	12	3.6	81
16/3	2	108	2.4	16	85	10	7.9	91

REMARKS: 1 HRT 6-h, many stops of the pump, 4 inletpoints
2 HRT 6-h, continuous feeding of influent, 4 inletpoints

$\bar{x}$: average value
o : standard deviation

ANNEX 4 RESULTS OF THE CALI PILOT PLANT MAR. - APR. 1984

TABLE 1 COD-VALUES ($g.m^{-3}$)

PERIOD	REMARK	RAW	INFLUENT	FILTRATED	INFLUENT	RAW	EFFLUENT	FILTRATED	EFFLUENT
		$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
22/3 - 30/3	1	252	46	121	31	147	50	64	25
31/3 - 6/4	1	208	56	114	41	58	11	40	3
7/4 - 13/4	1	250	21	120	33	100	18	44	5
14/4 - 17/4	2	228	8	102	18	162	90	47	5
18/4 - 20/4	3	225	27	108	15	117	25	40	1
21/4 - 27/4	3	227	33	103	25	116	51	48	6

TABLE 2 COD-LOADS ($kg.m^{-3}.d^{-1}$)

PERIOD	REMARK	RAW	INFLUENT	FILTRATED	INFLUENT	RAW	EFFLUENT	FILTRATED	EFFLUENT
		$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
22/3 - 30/3	1	0.90	0.36	0.43	0.20	0.52	0.26	0.23	0.12
31/3 - 6/4	1	0.40	0.29	0.18	0.10	0.12	0.11	0.08	0.06
7/4 - 13/4	1	0.90	0.23	0.41	0.10	0.37	0.12	0.16	0.04
14/4 - 17/4	2	0.68	0.38	0.29	0.18	0.46	0.40	0.13	0.08
18/4 - 20/4	3	1.11	0.13	0.52	0.07	0.58	0.12	0.20	0.00
21/4 - 27/4	3	0.80	0.47	0.40	0.04	0.43	0.22	0.18	0.07

ANNEX 4

RESULTS OF THE CALI PILOT PLANT MAR. - APR.1984

TABLE 3 COD - REMOVAL (%)

PERIOD	REMARK	TOTAL* $\bar{x}$	TOTAL* σ	DISSOLVED** $\bar{x}$	DISSOLVED** σ
22/3 - 30/3	1	40	29	75	6
31/3 - 6/4	1	71	8	79	5
7/4 - 13/4	1	60	9	83	2
14/4 - 17/4	2	30	38	80	3
18/4 - 20/4	3	48	5	82	2
21/4 - 22/4	3	50	20	78	4

* TOTAL: raw influent to raw effluent

** DISSOLVED: raw influent to filtrated effluent

TABLE 4 GASPRODUCTION

PERIOD	REMARK	AVERAGE DAILY PRODUCTION ($m^3.d^{-1}$)	PRODUCTION PER KG REMOVED COD (liter.$kgCOD^{-1}$)
22/3 - 30/3	1	9.2	378
31/3 - 6/4	1	6.9	383
7/4 - 13/4	1	9.3	273
14/4 - 17/4	2	7.6	543
18/4 - 20/4	3	8.7	258
21/4 - 22/4	3	8.3	349

ANNEX 4

RESULTS OF THE CALI PILOT PLANT   MAR. - APR. 1984

TABLE 5.1   TOTAL SUSPENDED SOLIDS

PERIOD	REMARK	TSS INFLUENT ($g.m^{-3}$)		TSS EFFLUENT ($g.m^{-3}$)		REMOVAL BASED ON TOTAL LOAD*	DAILY REMOVAL (%)	
		$\bar{x}$	σ	$\bar{x}$	σ		$\bar{x}$	σ
22/3 - 30/3	1	136	37	140	86	0	-20	95
31/3 - 6/4	1	123	54	49	10	60	64	7
7/4 - 13/4	1	153	28	105	35	31	31	20
14/4 - 17/4	2	136	20	221	165	-63	-83	154
18/4 - 20/4	3	101	12	125	44	-24	-24	45
21/4 - 27/4	3	133	83	120	75	10	-18	95

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* Total load is the load of TSS over the entire period in question.

ANNEX 4 RESULTS OF THE CALI PILOT PLANT MAR. - APR. 1984

TABLE 5.2 VOLATILE SUSPENDED SOLIDS

PERIOD	REMARK	VSS INLFUENT ($g.m^{-3}$)		VSS INLFUENT (%TSS)		VSS EFFLUENT ($g.m^{-3}$)		VSS EFFLUENT (%TSS)		REMARKS
		$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	
22/3 - 30/3	1	50	30	49	12	55	26	42	8	
31/3 - 6/4	1	61	25	48	10	13	8	30	11	
7/4 - 13/4	1	94	19	61	8	43	18	39	6	
14/4 - 17/4	2	78	15	57	7	80	57	37	2	
18/4 - 20/4	3	67	10	66	3	44	13	36	3	
21/4 - 27/4	3	91	43	55	10	48	27	36	6	21 - 25 APRIL

ANNEX 4

RESULTS OF THE CALI PILOT PLANT MAR. - APR. 1984

TABLE 6 VARIOUS PARAMETERS

PARAMETER	UNIT	INFLUENT x	INFLUENT σ	EFFLUENT x	EFFLUENT σ	REMARK
pH	units	no dates due to damage of pH-meter				
T	°C	24.9	0.6	25.2	0.3	
Alkalinity	$eq.m^{-3}$	2.3	0.15	3.1	0.25	
$NH_4^+ - N$	$g.m^{-3}$	7.3	1.5	11.0	1.6	17/3 - 31/3
N-org	$g.m^{-3}$	5.5	0.8	2.7	1.6	17/3 - 31/3
NTK	$g.m^{-3}$	12.8	2.1	13.7	0.1	17/3 - 31/3
$t\text{-}PO_4^{=}$	$g.m^{-3}$	1.7	1.0	2.2	0.7	

TABLE 7 BOD_5

DATE	REMARK (1)	RAW INFLUENT VALUE ($g.m^{-3}$) (2)	RAW INFLUENT $\frac{COD}{BOD_5}$ (3)	RAW EFFLUENT VALUE ($g.m^{-3}$) (4)	RAW EFFLUENT $\frac{COD}{BOD_5}$ (5)	η_{total} (6)	SETTLED EFFL. VALUE ($g.m^{-3}$) (7)	$\eta_{soluble}$ (8)
23/3	1	91	2.5	35	5.7	62	15	75
30/3	1	89	2.5	18	8.7	80	12	87
6/4	1	115	2.2	15	4.3	90	10	91
13/4	1	95	2.5	25	3.4	74	17	82

$$\eta_{total} = \frac{(2) - (4)}{(2)} \times 100\%$$

$$\eta_{soluble} = \frac{(2) - (7)}{(2)} \times 100\%$$

REMARKS 1: HRT 6h; 2: HRT approx. 6.5h; 3: HRT 4.9h;

* : average value

o : standard deviation

ANNEX 5

RESULTS OF THE CALI PILOT PLANT

Table 1 COD-VALUES ($g.m^{-3}$)

PERIOD	INFLUENT				EFFLUENT				
	total		soluble		total		soluble		remark
	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	
3/7- 6/7	144	--	103	--	211	--	113	--	1
7/7-12/7	--	--	--	--	107	13	65	10	2
13/7-19/7	305	99	119	29	143	38	55	7	3
20/7-27/7	306	20	124	35	106	7	62	10	3
3/7- 3/8	314	37	145	40	125	14	59	8	

Remarks:
1. data of 1 day
2. no influent data available
3. sludge silled at 19/7

$\bar{x}$ average value of period

σ standard deviation over period

Table 2 COD-loads ($kg.m^{-3}.d^{-1}$)

PERIOD	INFLUENT				EFFLUENT				
	total		soluble		total		soluble		remark
	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	
3/7- 6/7	0.86	--	0.61	--	1.25	--	0.67	--	1
7/7-12/7	--	--	--	--	0.66	0.08	0.40	0.07	2
13/7-19/7	1.68	0.82	0.60	0.18	0.80	0.34	0.29	0.08	
20/7-27/7	1.87	0.14	0.76	0.21	0.61	0.12	0.38	0.06	3
30/7- 3/8	1.89	0.18	0.87	0.22	0.75	0.11	0.36	0.05	

Remarks:
1. data of 1 day
2. no influent data available
3. sludge spilled at 19/7

$\bar{x}$ average value of period

σ standard deviation over period

Table 3 COD-removal (%)

PERIOD	total $\bar{x}$	total σ	soluble $\bar{x}$	soluble σ	remark
3/7- 6/7	-47	--	22	--	1
7/7-12/7	--	--	--	--	2
13/7-19/7	50	13	80	7	
20/7-27/7	65	2	81	4	3
30/7- 3/8	60	7	81	3	

Remarks: 1. data of 1 day
2. no influent dat available
3. sludge spilled at 19/7

total: $$\frac{\text{total infl. COD - tot. effl. COD}}{\text{tot. infl. COD}} \times 100$$

soluble: $$\frac{\text{total infl. COD - sol. effl. COD}}{\text{tot. infl. COD}} \times 100$$

Table 4 TOTAL SUSPENDED SOLIDS

PERIOD	TSS INFLUENT ($g.m^{-3}$) $\bar{x}$	TSS INFLUENT σ	TSS EFFLUENT ($g.m^{-3}$) $\bar{x}$	TSS EFFLUENT σ	REMOVAL BASED ON WEEKLOAD (4) % (5)	DAILY REMOVAL % $\bar{x}$	DAILY REMOVAL σ	REMARK
3/7- 6/7	79	--	146	--	-86	-86	--	1
7/7-12/7	--	--	61	15	--	--	--	2
13/7-19/7	176	84	150	94	15	11	54	
20/7-27/7	201	61	56	16	72	69	17	3
30/7- 3/8	190	25	109	17	43	41	14	

Remarks: 1. data of one day
2. no data of influent available
3. sludge spilled at 19/7
4. Weekloads are the sum of TSS influent and effluent respectively
5. daily removal is TSS infl. on one day compared with TSS effl. on the same day
average value
standard deviation

Table 5 VOLATILE SUSPENDED SOLIDS

PERIOD	VSS INFLUENT ($g.m^{3}$)		INFLUENT (% TSS)		VSS EFFLUENT ($g.m^{3}$)		EFFLUENT (%TSS)		REMARKS
	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	
3/7-7/7	37	--	14	--	47	--	50	--	1
7/7-12/7	--	--	26	6	--		43	3	2
13/7-19/7	94	41	61	34	55	7	42	2	
20/7-27/7	130	47	21	12	58	11	37	21	3
30/7- 3/8	49	28	42	16	50	11	38	10	

Remarks:
1. data of one day
2. no influent data available
3. sludge spilled at 19/7

average value

standard deviation

Table 6 VARIOUS PARAMETERS

PARAMETER	UNIT	INFLUENT		EFFLUENT		REMARK
		$\bar{x}$	σ	$\bar{x}$	σ	
pH	units	--	--	--	--	1
T	°C	246	0.4	24.8	0.4	
NH_4+-N	$.m^{-3}$	13.2	1.7	18.1	1.1	
N-	$.m^{-3}$	3.3	1.7	2.2	0.7	
NTK	$.m^{-3}$	16.6	2.5	20.3	1.7	
t.PO_4	$.m^{-3}$	0.80	0.77	1.05	0.34	
alkalinity	$.m^{-3}$	2.6	0.1	3.0	0.4	

Remarks:

average value over July 1984

standard deviation

poor performance of pH meter

RESULTS OF JULY 1984

HRT 4 hrs.

Table 7 BIOCHEMICAL OXYGEN DEMAND

DATE	TOTAL BOD_5 $(g.m^{-3})$	INFLUENT $\frac{COD}{BOD_5}$	TOTAL BOD_5 $(g.m^{-3})$	EFFLUENT $\frac{COD}{BOD_5}$	(1) %	FILTRATED BOD_5 $(g.m^{-3})$	EFFLUENT $\frac{COD}{BOD_5}$	(2) %	REMARK
13/7	69	3.7	27	4.2	61	8	5.0	88	
18/7	66	3.0	17	7.7	74	10	5.9	85	
27/7	76	4.4	37	3.0	51	31	2.3	59	
3/8	103	3.0	34	3.9	67	17	3.1	83	

(1) $$\frac{BOD_{total\ infl.} - BOD_{total\ effl.} \times 100}{BOD_{total\ infl.}}$$

(2) $$\frac{BOD_{total\ infl.} - BOD_{filtr.\ effl.} \times 100}{BOD_{total\ infl.}}$$

Results vary significantly from results of period January - April 1984

ANNEX 6

BDO ANALYSIS

DATE 1984		HRT h	RAW INFLUENT BOD_5	RAW INFLUENT $\frac{COD}{BOD_5}$	RAW EFFLUENT BOD_5	RAW EFFLUENT $\frac{COD}{BOD_5}$	(%)	FILTRATED SETTLED EFFLUENT BOD_5	FILTRATED SETTLED EFFLUENT $\frac{COD}{BOD_5}$	(%)	REMARKS	
6/1	206	8	61	2.52	-	-	-	11	4.82	82	7	F
id								15	-	75		S
13/1	213	8	106	2.24	-	-	-	27	1.52	75	8	F
id								25	-	76		S
19/1	219	8	73	3.56	-	-	-	15	3.47	80	8	F
id								17	-	77		S
27/1	227	8	129	2.87	-	-	-	13	3.46	90	8	F
id								13	-	90		S
2/2	233	8	92	2.92	-	-	-	6	2.92	94	7	F
id								7	-	92		S
10/2	241	6	68	3.07	-	-	-	9	4.67	86	7	F
id								13	-	81		S
24/2	255	6	82	2.90	-	-	-	8	5.63	90	7	F
id								10	-	88		S
2/3	262	6	62	2.40	-	-	-	12	3.58	81	7	F
id								16	-	79		S
16/3	276	6	108	2.42	-	-	-	10	7.90	91	7	F
id								16	-	85		S
23/3	283	6	91	2.35	35	5.69	62	15	-	75	6	S
30/3	290	6	89	2.52	18	5.72	80	12	-	87	6	S
6/4	297	6	115	2.23	15	4.20	90	10	-	91	6	S
13/4	304	6	95	2.51	25	3.44	74	17	-	82	6	S
1/6	353	4	83	2.07	27	3.27	68	25	3.32	72	6	F
15/6	367	4	78	2.30	54	2.32	31	17	2.60	78	6	F
13/7	395	4	69	3.71	27	3.71	61	8	5.00	88	6	F
18/7	400	4	66	3.02	17	7.71	74	10	5.90	85	6	F
27/7	409	4	76	4.40	37	3.02	51	31	2.25	59	6	F
3/8	410	4	103	3.04	34	3.88	67	17	3.06	83	6	F

REMARKS:

1 total influent BOD

2 total effluent BOD

3 $\frac{\text{total infl.BOD - total eff.BOD}}{\text{tot. inl. BOD}}$

4 soluble effleunt BOD after decanting or filtration see F and S

5 $\frac{\text{total inf.BOD - soluble eff.BOD}}{\text{tot.inf. BOD}}$

6 density of inletpoints: 1 m^{-2}

7 density of inletpoints: 0.25 m^{-2}

8 density of inletpoints: 0.125 m^{-2}

F filtration/filtrated effluent

S decanting/settled effluent

ANNEX 7

HACH-COD ANALYSIS METHOD

BLANKS AND STANDARDS (260784 - 100884)

- BLANKS - 2 ML DISTILLED WATER (1x distilled)
- STANDARD SOLUTION for 150 mg COD/liter
  $(8H_5 KO_4)$ 127,5 mg KHpH 1 liter
  (M=204,32) (standard methods page 499 §4d)

RESULTS:

BLANKS		STANDARD	(150)	
0*	1	150	149	
		102 (100)	98 (100)	
		50 (50)	49 (50)	
0*	3	155	155	
		98 (100)	102 (100)	
		51* (50)	56 (50)	
-10*	-10	150	152	
0*	2	148	150	
0*	0	151	153	
		148	148	other pipet
0*	-10	151*	153	
-10*	22	150	150	
0	0*	155	155	
- 5	0*	153	150	
-10[1]	0	153[1]	155	
- 5[1]	-	155[1]	-	

* adjustment
[1] average adjustment

ANNEX 8

Pollution units

In general, little information is available about organic waste load and waterconsumption/production per inhabitant.
These values strongly depend on geographical and socio-economical circumstances*.
Average values, commonly used, are:

Organic load	40 - 50 g BOD/inhab. day or 125 g COD/inhab. day
Water consumption	250 l/inhab. day
Water-delivery	200 l/inhab. day (80% return of consumption).

The maximal concentration in domestic wastewater therefore will be about 625 mg COD/l. The actual value of course depends of the type of sewerage system and above mentioned circumstances. At the pilot-plant in Cali, measured values are in the range of 250 to 300 mg COD/l.
Infiltration water can be taken to be 10 to 25% of the average inhabitant water-delivery for average population densities.

Until better data are available, for each treatment plant design, the local situation should be considered carefully to estimate the expected wastewater flow and concentration. However, uptill now, the rough data given above are used in allmost every design.

Further, it is very common to calculate populations from the number of houses. The value used is 6 or 7 persons per house.

* Data of Valle University give for the city Jamundi (20.000 inhabitants in 1978) the following data:

1977: 34 g BOD/inhab. day

1978: 26 g BOD/inhab. day

CVC studies give the value of 37 g BOD/inhab. day for low socio-economic strata.

how strict will they be applied

ANNEX 9

Standards for water pollution control in the "Cauca"-riverbasin under jurisdiction of CVC - Acuerdo No. 14; 1976

Three kinds of treatment:

- Preliminary treatment: 80% reduction of sand and floating material.
- Primary treatment: reduction of 50% of suspended solids (SS) and of 35% of BOD.
- Secundary treatment: reduction of 90% of SS and of 85% of BOD.

The percentages are determined on a basis of the mass of removed pollutant in the specified year.

Requirements for different braches:

- EMCALI
  a. Preliminary tr. after 1981
  b. Primary tr. after 1985
  c. Secundary tr. after 1990.

These treatments concern all waste water from Cali (incl. industry).

- Paper-industry
  a. Before 1981: pre-treatment 80% sand and pH within 5 and 9.
  b. Before 1985: SS-reduction of 50%, BOD-red. of 17%
  c. Before 1990: maximum 45 kg BOD per ton produced per product

- Other industries: After 1985:
  80% - reduction of acids, sulfur, fats and toxics (if considered necessary)
  50% - reduction of SS and 80% of BOD.

- Yumbo and surroundings:
  After 1985:
  sec. treatment with a capacity of 2500 kg DBO/day.
  After 1990: another one
  After 1981: preliminary tr.

- Sucarcane factories:
  use vinasses for irrigation
  30% BOD reduction of the part drained.

- Cities after 1985: 50% reduction of SS and 35% of BOD and satisfy the standards for dissolved oxygen in receiving surface waters.

ANNEX 10

Population (1 x 1000)

	Colombia			Valle del Cauca		
	1973	1982		1973	1982	
Totaal	22.862	29.672		2.373	3.068	
Urban	13.410	17.644	(60%)	1.804	2.331	(76%)
Rural	9.142	12.029		569	736	

Estimates for 1983: Colombia 30.241.000 inhabitants
Valle 3.124.900 inhabitants

Source: DANE

Income-distribution cities Valle Department

$ Col./month	number	Rel. %
6540 - 10559	150.992	55
10560 - 16079	57.289	21
16080 - 23339	35.896	13
23340 - 32579	16.096	6
32580 - 57959	11.593	4
57960 and more	3.764	1
	275.630	

Source: Indicadores Socio-economicos; CVC.

(For comparison, middle-income standard-living-packet costs 40.000 - 45.000 pesos a month); low-income: 15 - 18.000 a month; 1982, DANE data).

ANNEX 11

PROGRAMA DE COOPERACION COLOMBO-HOLANDES

REF.: CURSO DE ENTRENAMIENTO Y SEMINARIO SOBRE TRATAMIENTO ANAEROBICO DE AGUAS RESIDUALES POR MEDIO DE REACTORES DE FLUJO ASCENDIENTE TIPO UASB

Cali - Nimega, 15 de Mayo de 1984

Dentro del Convenio de cooperación técnica internacional entre el Gobierno Holandés y el Gobierno Colombiano se tiene un programa piloto que investiga la aplicación de un proceso anaeróbico de flujo ascendente a través de un manto de lodos (proceso UASB) para el tratamiento de las aguas residuales domésticas en condiciones tropicales y sub-tropicales.

Como parte del programa de cooperación se tiene previsto un curso y un seminario de transferencia de tecnología en sistemas anaeróbicos con énfasis en los resultados obtenidos durante la operación de un reactor UASB de 64 m^3 que está trabajando en Cali desde junio de 1983.

Adjunto estamos enviando un formulario de aplicación para el seminario y el curso corto. Como sólo se tienen cupos limitados para ambas actividades, le solicitamos que devuelva el formulario de aplicación antes del 30 de junio de 1984. La selección de candidatos se hará el mes de julio y antes del 15 de agosto de 1984 se recibirá los formularios definitivos.

Atentamente,

Ir. JAAP LOUWE KOOIJMANS	Ing. GUILLERMO RODRIGUEZ P.
Coordinador Internacional	Coordinador Nacional

UNIVERSIDAD DEL VALLE

FACULTAD DE INGENIERIA

DEPARTAMENTO DE PROCESOS QUIMICOS Y BIOLOGICOS

SECCION DE SANEAMIENTO AMBIENTAL

Profesor Guillermo Rodríguez Parra

Apartado aéreo 25360
Cali

CALI – VALLE

COOPERACION TECHNICO COLOMBO – HOLANDES
HASKONING – UNIVERSIDAD DEL VALLE – UNIVERSIDAD DE AGRONOMIA DE WAGENINGEN

Curso de entrenamiento y seminario sobre tratamiento anaerobico de aguas residuales pro medio de reactores de flujo ascendente tipo UASB

CALI – Octubre 17-18-19 de 1984

OBJETIVOS

A. Curso corto

- Informar sobre sistemas anaeróbicos como el proceso UASB; Filtros Anaeróbicos; Procesos de Película Fija, etc.
- Establecer criterios de diseño para diferentes industrias.
- Presentar metodologias para la iniciación de estudios de tratabilidad a nivel de laboratorio y piloto.

B. Seminario

- Dar a conocer la experiencia adquirida con un reactor UASB de 64 M3 en el tratamiento de aguas residuales domésticas en condiciones tropicales.
- Presentar resultados específicos en el tratamiento de aguas residuales industriales utilizando la tecnología UASB en Holanda; Colombia y Brazil o Cuba.
- Presentación de resultados de postratamiento (e.g., Filtros anaeróbicos; Filtros Percoladores; Filtros intermitentes de arena; lagunas de estabilización y para el pulimiento final del efluente.

PARTICIPANTES

Son bienvenidos los profesionales del Sector Salud; de Empresas Públicas Municipales; Corporaciones de Desarrollo; Agencias de Control; Profesores Universitarios; Consultores y Representantes de las Industrias.

CUPO

Curso de Entrenamiento: 50 personas
Seminario: 75 personas

FECHA

Curso de Entrenamiento: Octubre 17/84
Seminario: Octubre 18-19/84

VALOR

Curso de Entrenamiento: $5000
Seminario: $3000

SEDE

Universidad del Valle
Melendez Cali Valle

FORMA DE PAGO

Curso de Entrenamiento: Departamento de Procesos Quimicos y Biológicos

Seminario: Ing. A. Schellinkhout

Los Cheques deben ser separados por actividad y enviados al Apart. Aéreo 25360 Cali.

COORDINACION

Nacional: Dr. Guillermo Rodríguez
Internacional: Ing. Jaap Louwe Kooijmans

EXPOSITORES

Dr.Ing. Gatze Lettinga, Holanda
Ing. Guillermo Rodríguez, Ph.D. Colombia
Ing. Jaap Louwe Kooijmans, M.Sc., Holanda
Ing. Aris Schellinkhout, M.Sc., Holanda
Experto latinoaméricano

HASKONING – UNIVERSIDAD DEL VALLE – UNIVERSIDAD DE AGRONOMIA DE WAGENINGEN (HOLANDA)

CURSO DE ENTRANAMIENTO Y SEMINARIO SOBRE TRATAMIENTO ANAEROBICO DE AGUAS RESIDUALES POR MEDIO DE REACTORES DE FLUJO ASCENDENTE TIPO UASB

Formulario de Aplicación

Curso .... ☐
Seminario .... ☐
Ambos .... ☐

Nombre(s) ....
Entidad donde Trabaja .... Ciudad .... Tel. ....
Dirección Postal ....
Firma .... Fecha ....

PROGRAMA TENTATIVO DEL CURSO Y SEMINARIO DE TRATAMIENTOS ANAEROBICOS – CALI, COLOMBIA

CURSO CORTO: Oct. 17/84 NUMERO MAXIMO: 50 PERSONAS
SEMINARIO: Oct. 18-19/84 NUMERO MAXIMO: 75 PERSONAS
LUGAR: CALI – Colombia

8:00- 9:00 Inscripción.
9:00- 9:15 Discurso de bienvenida por Sr. Rector de la Universidad del Valle.
9:15- 9:30 Inauguración. Embaj. de Holanda. Dr. Eduardo Roell.
9:30- 9:40 Palabras del Sr. Gerente de EMCALI.
9:40-10:00 Receso.
10:00-11:00 Introducción del Proyecto Piloto en Cali. Ing. J. Louwe Kooijmans.
11:00-13:00 Conceptos básicos del proceso UASB. Dr. G. Lettinga.
13:00-14:00 Almuerzo.
14:00-14:45 Descripción del reactor y Metodología Investigativa. Ing. A. Schellinkhout.
14:45-17:00 Visitas al reactor UASB y Laboratorio UNIVALLE.

Octubre 19/84

8:30- 9:30 Presentación de resultados. Planta Anaeróbica. Ing. A. Schellinkhout.
9:30- 9:45 Receso.
9:45-10:45 Presentación resultados del postratamiento. Dr. G. Rodríguez.
10:45-12:15 Aplicación del proceso UASB para Aguas Residuales Industriales. Dr. G. Lettinga.
12:15-13:00 Almuerzo.
13:00-14:30 Resultados práticos para una industria colombiana. Dr. G. Rodríguez.
14:30-16:00 Resultados práticos en Latinoamérica.
16:00-16:15 Receso.
16:15-17:00 Mesa Redonda.
17:00-17:10 Clausura. Ing. J. Louwe Kooijmans / Decano. Facultad de Ingeniería – UNIVALLE.
17:10-18:30 Cocktail de clausura. Ofrecido por HASKONING Ingenieros Consultores Reales Nijmegen Holanda e INCOL LTDA. Cali.

HASKONING
Royal Dutch Consulting
Engineers and Architects

Annex 12

Toelichting bij budget bewaking

Ook in het eerste half jaar van 1984 is het uitgaven patroon binnen de budget planning gebleven. Doordat het project verlengd werd tot eind 1984, waarvoor een aanvullend budget van dfl. 328.000 ter beschikking werd gesteld, werd het noodzakelijk het werkplan te herzien. Hierdoor is het moeilijk om de uitgaven ten laste van het oorspronkelijke budget en die ten aanzien van de verlenging duidelijk te scheiden.

Zonder in detail in te gaan op de bestedingen en te verwachten uitgaven per kosten post is te verwachten dat de totaal uitgaven t/m indiening van het eindrapport ook binnen het budget zullen blijven.

- De salariskosten blijven praktisch op het geraamde bedrag. Veel tijd blijkt nodig te zijn voor begeleiding rapportage en equipment leveranties.

- De post laboratorium uitrusting wordt zeer ruim overschreden deels door te lage ramingen, deels doordat veel niet voorziene aanschaffingen moesten worden gedaan ten einde de voortgang niet in gevaar te brengen.
  Getracht zal worden de recentelijk aangeschafte flygt influentpomp aan het eind van het project te verkopen.

- Belangrijke besprekingen zijn er geweest o.a. op uitzendkosten, huisvesting en bouw proef installatie.

Nijmegen, 31 augustus 1984
Coll.: JLK/BW

Annex 12

Budget bewaking

Activiteit nr. 015672

t/m week 26, 1984

		Begroting t/m eind 1984		Besteding t/m week week 26, 1984		Raming bestedingen t/m eind project	
		mm	besteding	mm	besteding	mm	besteding
1.	Voorbereidingskosten						
	Salariskosten		41.742		42.461		
	Bijkomende kosten		3.633		2.956		
	Spaanse vertaling		977		977		
	Reiskosten buitenland		1.422		1.390		
			47.744		47.784		
2.	Uitvoeringsfase						
2.1.1	Salariskosten Nederland						
	Projectleider	1.75	49.133	1.463	40.063	1.25	35.622
	Werktuigbouwkundige	1.25	28.642	--	--	0.50	10.406
	Civiel ingenieur	2	44.744	0.7	12.038	1.25	21.496
	Procestechnoloog	2	40.348	1.123	29.119	0.75	13.009
	Bouwkundig tekenaar	1	18.229	0.04	423	0.75	13.672
	Specialist L.H.	1.75	20.415	0.75	8.755	1	11.660
	Ir begeleiding L.H.	3	25.849	2.93	27.741	--	--
	Bijkomende kosten	--	15.003	--	5.750	--	7.300
2.1.2	Salariskosten Colombia						
	Projectleider	1.75	54.419	1.72	48.993	1.25	39.423
	Werktuigbouwkundige	1.25	29.569	0.29	5.985	--	--
	Procestechnoloog	3.50	59.343	4.21	68.317	0.50	9.625
	Spec. anaer. zuiv. L.H.	2	23.320	0.56	7.339	1.5	17.490
	Ir onderzoeker L.H.	25	230.549	19	173.016	6	54.800
	Lokaal INCOL						
	Besteks voorbereiding		6.000		4.963		--
	Toezicht op uitvoering		7.425		7.328		--
	Ass. upscaling		20.900		--		20.900
	Totaal salariskosten		673.888		439.830		255.403
2.2	Reis- en verblijfkosten						
2.2.1	Uitzendingskosten		13.857		1.061		1.000
2.2.2	Vliegtickets Int.		85.360		52.765		38.000
	Verzekering bagage		1.120		200		300
	Overvracht		9.500		1.684		3.000
2.2.3	Vliegtickets Lokaal		3.600		--		--
2.2.4	DSA Short Term		90.154		63.330		31.704
2.2.5	Huisvesting + utilities		88.082		38.002		18.000
	L.A. Schellinkhout		20.537		12.089		4.950
	L.A. studenten		14.000		7.000		18.000
2.2.6	Locaal transport						
	Aanschaf auto		20.000		28.624		--
	Running costs		18.700		6.413		6.100
2.2.7	Reis- en verblijfkosten Counterpart		9.000		6.091		--
2.2.8	Furniture costs L.H. Ing.		17.000		8.500		--
	Kledingtoelage		3.676		2.196		1.500
2.3	Materiaal en chemicaliën						
2.3.1	Bouw proef installatie		110.000		69.700		--
2.3.2	Laboratorium uitrusting		86.000		117.273		15.000
2.3.3	Transport en verzekeringen		10.000		--		--
2.3.4	Onderhoudskosten Inst.		10.000		7.421		3.000
2.3.5	Extra chemicaliën		16.000		4.224		12.000
2.3.6	Wijzigingen installatie (incl. nieuwe pomp)		14.000				35.000
2.4	Verspreidingskosten						
2.4.1	Seminar		20.000		872		25.000
2.4.2	Rapportage + verspreiding		30.000		6.380		25.000
2.5	Onvoorzien		60.782				
	Tel. telex Colombia				1.997		500
	Studenten, lokaal personeel				3.448		2.000
	Airport taxes				312		200
	Reserve onvoorzien						50.147
	Totaal		1.473.000		927.196		545.804