CSIR

DIVISION OF WATER TECHNOLOGY
WATER, WASTE AND EFFLUENT PROGRAMME

Report to the

WATER RESEARCH COMMISSION

on

# THE EVALUATION AND IMPROVEMENT OF THE ANAEROBIC DIGESTION ULTRAFILTRATION (ADUF) EFFLUENT TREATMENT PROCESS

by

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and

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| ADUF | Anaerobic digestion/ultrafiltration |
| ADS | Anaerobic digestion/settling |
| BOD | Biological oxygen demand |
| CIP | Clean in place |
| COD | Chemical oxygen demand |
| EDTA | Ethylene diamine tetraacetic acid |
| GRP | Glass reinforced polyester |
| HRT | Hydraulic retention time |
| ID | Internal diameter |
| MEMTUF | Trade name of low cost ultrafiltration system |
| MLSS | Mixed liquor suspended solids |
| MMCO | Molecular mass cut-off |
| OD | Outer diameter |
| PVC | Polyvinyl chloride |
| SLR | Space load rate |
| SRT | Sludge retention time |
| TA | Total alkalinity |
| TOD | Total oxygen demand |
| UASB | Upflow anaerobic sludge bed |
| UF | Ultrafiltration |
| VFA | Volatile fatty acids |
| WW | Wine Waste |

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# THE EVALUATION AND IMPROVEMENT OF THE ANAEROBIC DIGESTION ULTRAFILTRATION (ADUF) EFFLUENT TREATMENT PROCESS

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## BACKGROUND

Anaerobic digestion of industrial waste waters containing high concentrations of soluble and/or colloidal organic carbon has become an accepted method of treatment in recent years. This is attributable to the vast amount of research and development work that has been done to commercialize the concept, to stricter environmental regulations and enforcement policies, and to the increasing costs and decreasing availability of energy.

In designing high rate anaerobic digestion systems for soluble organic wastes, two of the essential features that must be incorporated are biomass concentration and biomass retention. High rate operation entails short hydraulic retention times, with maximum contact between the active biomass and the feed substrate. In the older, fully mixed anaerobic digestion systems, these requirements nearly always resulted in the loss of active biomass in the treated effluent from the digester, which reduced the efficiency of the process and frequently led to digester overloading and subsequent failure. To maintain a maximum active biomass concentration in a digester at the short hydraulic retention time required for economic operation, various system designs have been advocated. These designs either attempt to retain the biomass in the digester by immobilization on a retaining medium, by modifying the sludge to prevent its loss from the system, or by capturing the biomass lost from the digester in the treated effluent and by returning it to maintain a high concentration in the digester.

In recent years attention has been directed towards the use of membranes for biomass separation in biological treatment processes. A number of treatment systems have been developed overseas, employing solids retention in the treatment system by using membranes. Independent pilot-scale research into the use of locally manufactured ultrafiltration (UF) membranes for solid-liquid separation in the anaerobic treatment of wine distillery waste was commenced in 1987 at Distillers' Corporation, Stellenbosch, and continued at the Paarl sewage works during 1988. Significant differences, relative to overseas practice, in UF membrane design, support modules, and integration with the digester system prompted the development of what has come to be known as the ADUF process (Anaerobic Digestion Ultra Filtration) for the treatment of organic industrial effluents.

## OBJECTIVES

The ADUF process has been evaluated on pilot-scale on a number of organic waste effluents and at least two full-scale plants have been adapted to incorporate the ADUF concept. A number of problems have arisen with some of these applications of the ADUF technology and there are still some unanswered questions that should be addressed. Some of these have been identified and in an attempt to find practical solutions that would allow the ADUF process to attain its full potential the present evaluation was launched under the guidance of a Steering Committee, which was chaired by the Water Research Commission. The original aim was to address:

- Digester and overall plant design

- The reasons for the relatively poor performance of the anaerobic digestion process when coupled to the ultrafiltration process.

- Changes in the digester sludge characteristics caused by rapid pumping through the membrane system at relatively high velocities and the possible accumulation of biological debris and indigestible solids in the sludge.

- The effect of various feed substrates on the performance of the ADUF system.

## TEST APPARATUS

Three laboratory-scale anaerobic test units were designed and constructed. Two of these were identical ADUF units, comprising 72 litre digesters (50 litre operating volume) equipped with ultrafiltration modules containing 20 9 mm OD tubes, 400 mm long, connected in series. Polyethersulphone membranes with a molecular mass cut-off of 20 000 to 80 000 were used. The modules were designed to operate at low pressures of up to 400 kPa, with continuous applied inlet pressures of 150 to 250 kPa normally used. Variable speed Mono pumps were used to circulate the sludge from the digesters through the ultrafiltration units. The third digester had a total volume of 30 litres, an operating volume of 25 litres and employed an inclined cylindrical settling tank for sludge recovery. Special gas meters were constructed for the test units. This anaerobic digestion/settling unit would allow a direct comparison to be made between the two technologies.

It was foreseen that operating a laboratory-scale ADUF system would be fraught with problems. Scale effects make it impossible to realistically reproduce full-scale ADUF operation on a laboratory unit with a total anaerobic digester capacity of 50 litres.

The main problem is a consequence of the minimum linear flow velocity through the UF membrane tubes which is required to prevent excessive concentration polarization at the membrane surface with subsequent fouling layer build-up. The smallest available tubular UF membranes which are suitable for passing relatively viscous digester sludge have an outside diameter of 9 mm, with an average internal diameter of about 8,7 mm. This gives the tube an effective internal cross-section of 0,5945 $cm^2$. To maintain a linear velocity of 2 $m.s^{-1}$ across the membrane surface in a single tube (eg. a single pass series train) would require a pumping rate of 7,13 $\ell.min^{-1}$ through the membrane tube. Assuming that a 50 $\ell$ digester is coupled to this UF array, it would mean that the entire contents of the digester is pumped through the UF unit once approximately every 7 minutes, or 8,5 complete digester turnovers per hour.

It was thought that the excessive pumping rate may affect the sludge characteristics due to mechanical damage of the sludge structure and may cause short-circuiting of some undigested or partly digested feed substrate into the UF module, which would probably result in a poor quality final effluent.

## RESULTS AND CONCLUSIONS

The tests were run for 268 days. During the first 221 days the feed substrate used was spent wine waste. During the next 25 days the units were run on blends of spent wine waste and beer brewery effluent and eventually on pure beer brewery waste for the final 23 days. The test was stopped at this stage as the finances had been exhausted and the indifferent results obtained did not warrant extending the test any further.

Numerous breakdowns and other problems occurred during the test. The generation of large quantities of foam in the ADUF digesters caused severe problems and restricted the space and biological load rates that the units could handle. The foam often clogged the gas pipes, water traps and meters, and resulted in loss of solids from the ADUF systems.

The overall performance of these laboratory-scale units was poor. Although all three units maintained a COD reduction of more than 98% while operating under steady state conditions (not during periods of instability), the load rates that could be maintained were poor. The ADUF units averaged a space load rate of approximately 2.5 kg $COD.m^{-3}.d^{-1}$, whereas larger pilot and full-scale ADUF plants have operated at rates of 11 to 15 kg $COD.m^{-3}.d^{-1}$ at hydraulic retention times of less than one day. The biological (or sludge) load rates were equally poor, averaging less than 0.15 kg $COD.kg^{-1}$ $VS.d^{-1}$, whereas other larger units have attained 0.5 to 0.7 kg $COD.kg^{-1}$ $VS.d^{-1}$.

A very high rate of flux loss occurred on both the ADUF ultrafiltration units. Cleaning procedures with warm water effected a temporary flux increase of approximately 10%. Over the test period total flux decline rates of 3.4 $\ell.m^{-2}.d^{-1}$ and 2.9 $\ell.m^{-2}.d^{-1}$ for ADUF1 and ADUF2 occurred, which were far too high for economic operation, especially if the low load rates that were attained are considered.

There was no indication of any short circuiting of raw or partly digested feed into the final effluent from the ADUF plants. Build-up of intractable solids was also not evident, although this condition may have been masked by the frequent sludge losses and addition of sludge from a full-scale digester.

The operation on the beer brewery waste was inconclusive as the waste was very weak during the time that the test was carried out (3 to 6 $g.\ell^{-1}$ COD) and the duration of the run was too short. The alkalinity in the digesters dropped markedly, as expected, during this phase of the test, as the feedstock consisted essentially of carbohydrates and very little protein. Nitrogen in the form of urea was added to counteract this deficiency, but the test was terminated before a meaningful gain in alkalinity had been established.

During this evaluation using small scale test units, the ADUF process did not perform better than the anaerobic digester equipped with an inclined settling tank with regard to most aspects, except that all suspended solids normally lost in the final effluent was retained in the digester.

# THE EVALUATION AND IMPROVEMENT OF THE ANAEROBIC DIGESTION ULTRAFILTRATION (ADUF) EFFLUENT TREATMENT PROCESS

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CONTRACT REPORT TO THE

WATER RESEARCH COMMISSION

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# 1. INTRODUCTION

Anaerobic digestion of industrial wastewaters containing high concentrations of soluble and/or colloidal organic carbon has become an accepted method of treatment in recent years. This is attributable to the vast amount of research and development work that has been done to commercialize the concept, to stricter environmental regulations and enforcement policies, and to the increasing costs and decreasing availability of energy.

In the past anaerobic digestion was regarded as a sensitive, unstable process which was prone to frequent failure. The factors governing stability have been extensively investigated and many of the associated problems solved so that it is now possible to operate anaerobic systems at high space loading rates by implementing proper control measures.

In designing high rate anaerobic digestion systems for soluble organic wastes, two of the essential features that must be incorporated are biomass concentration and biomass retention. High rate operation entails short hydraulic retention times, with maximum contact between the active biomass and the feed substrate. In the older, fully mixed anaerobic digestion systems, these requirements nearly always resulted in the loss of active biomass in the treated effluent from the digester, which reduced the efficiency of the process and frequently led to digester overloading and subsequent failure. To maintain a maximum active biomass concentration in a digester at the short hydraulic retention time required for economic operation, various system designs have been advocated. These designs either attempt to retain the biomass in the digester by immobilization on a retaining medium, by modifying the sludge to prevent its loss from the system, or by capturing the biomass lost from the digester in the treated effluent and by returning it to maintain a high concentration in the digester.

Examples of modern systems are: fluidized bed, upflow anaerobic sludge blanket (UASB) reactors, anaerobic filters and rotating contactors. Few of these designs consistently produce a high quality final effluent free of suspended solids (i.e. with full biomass retention) at the high digester space load rates required for economic treatment.

In recent years attention has been directed towards the use of membranes for biomass separation in biological treatment processes. Dorr-Oliver developed and patented a Membrane Sewage Treatment System (MSTS) consisting of an activated sludge reactor followed by an ultrafiltration (UF) stage for solid-liquid separation (Bemberis, *et al.*, 1971). Application of MSTS to anaerobic operation led to the Membrane Anaerobic Reactor System (MARS), (Epstein, *et al.*, 1981 and Li, *et al.*, 1985). Anderson, *et al.* (1986a), reported laboratory studies on a two-phase anaerobic digester using porous polyethylene membranes for treating synthetic wastes. Bindoff, *et al.* (1987,1988), described the development of cross-flow microfiltration technology for the concentration of sewage-works sludge streams. Anderson, *et al.* (1986b) described results obtained with cross-flow microfiltration in anaerobic digestion.

Independent pilot-scale research into the use of locally manufactured ultrafiltration (UF) membranes for solid-liquid separation in the anaerobic treatment of wine distillery waste was commenced in 1987 at Distillers' Corporation, Stellenbosch, and continued at the Paarl sewage works during 1988. Significant differences, relative to overseas practice, in UF membrane design, support modules, and integration with the digester system prompted the development of what has come to be known as the ADUF process (Anaerobic Digestion Ultra Filtration) for the treatment of organic industrial effluents.

A survey was conducted on several pilot-scale and full-scale anaerobic digesters treating liquid industrial wastes in South Africa, using a small portable UF system, to assess the applicability of the UF membranes for phase separation of digester solids. Pilot-scale ADUF systems were subsequently tested on-site at a malting plant and at two paper and pulp mills. A full-scale ultrafiltration plant treating egg processing wastes was converted to the ADUF system.

A number of problems have arisen with some of these applications of the ADUF technology. Some of these have been identified and it was felt necessary that these problems should be addressed during a more directed research effort to allow the ADUF process to attain its full potential. In broad outline, the present investigation will examine:

- Digester and overall plant design
- The reasons for the relatively poor performance of the anaerobic digestion process when coupled to the ultrafiltration process.
- Changes in the digester sludge characteristics caused by rapid pumping through the membrane system at relatively high velocities and the accumulation of biological debris and indigestible solids in the sludge.
- The effect of various feed substrates on the performance of the ADUF system.

## 2. PROCESS DESCRIPTION

A simplified diagram of the ADUF process is shown in Figure 1. Two unit processes are combined, i.e. an anaerobic digester and an external ultrafiltration unit. The general features of each unit process and their integration as the ADUF process are described below:

### 2.1 Anaerobic Digester

The anaerobic digester is essentially a suitably sized tank and has neither internals, i.e. gas/liquid/sludge separators as encountered on UASB plants, nor any plastic or other packing as used in attached growth anaerobic filters. Sludge (biomass) is withdrawn from a collector near the top of the digester and pumped to the UF unit under a relatively low pressure. Return sludge from the UF unit enters the digester near its base. The return of the recirculating sludge from the UF loop provides sufficient mixing in the digester to enhance its performance.

The recirculating sludge passes through a heat exchanger (or a heating unit) before re-entering the digester to maintain an optimum digester temperature. Additives required for nutrient supplementation or pH control may be injected into the recycle loop if required. Gas production may be monitored by means of a totalizing gas meter.

### 2.2 Ultrafiltration Unit

Ultrafiltration is a physical process whereby the liquid fraction is separated from a solid/liquid mixture (Strohwald, 1986) by a membrane acting as a filter. Pores in the membrane allow liquid passage through the membrane wall (called the membrane flux), while the solid particles are retained at the membrane surface. In the UF system employed in the ADUF process, the membrane is in the form of a tube with the inner membrane surface forming the tube wall.

The digester sludge mixture is introduced into the tube at a relatively low operating pressure of 100 to 200 kPa. The membrane flux results from the pressure differential from the inside to the outside of the tube wall. The sludge mixture flowing along the tube, i.e. across the membrane surface, becomes progressively more concentrated as the filtrate is passed through the membrane wall.

In contrast to normal dead-end filtration in which the flow direction is perpendicular to the filter medium, the flow direction is parallel to the membrane surface, i.e. along the tube, which greatly reduces its tendency to foul the membrane . Because the transport of liquid through the membrane involves viscous porous flow, the flow rate (flux), the retention of solids and the tendency for the membrane to foul, will all be influenced by the physical structure of the membrane.

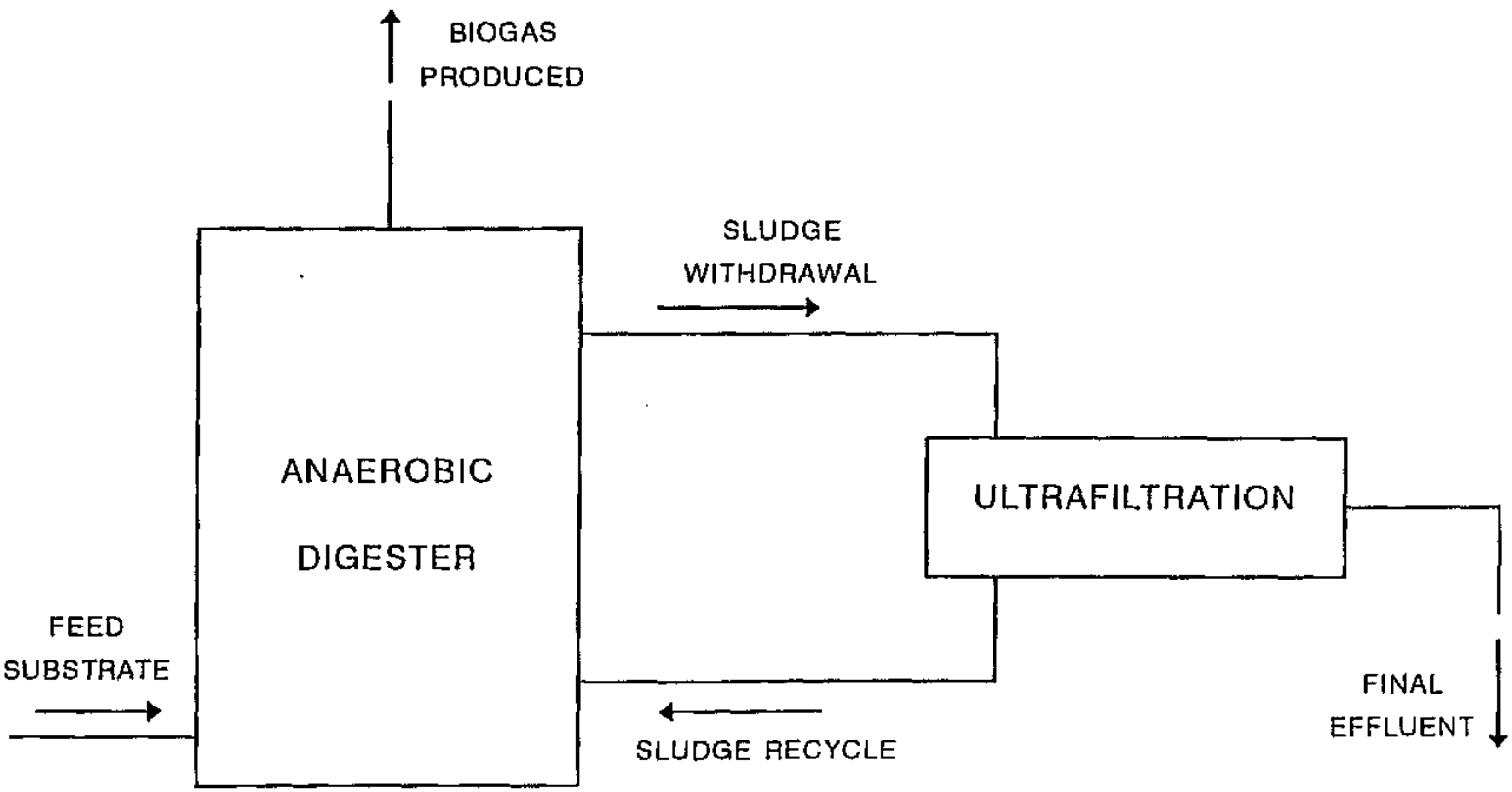


FIGURE 1: SCHEMATIC DIAGRAMME OF THE ADUF PROCESS

In the ADUF process, the liquid passing through the membrane (permeate) is the final effluent from the process, while the sludge, or biomass, containing the bacteria is recycled back to the digester with minimal activity or temperature loss.

Typical UF membranes possess an asymmetrical structure (see Figure 2). The top surface or "skin" is generally very thin (0.1 to 1.0 micron) and is supported by a substructure which is much more porous, thereby offering very little resistance to product flow through the membrane. The substructure supports the thin skin layer enabling it to withstand the pressure applied to perform the filtration process. In the tubular configuration used for the ADUF process, the membranes are cast on the inside of spirally welded porous polyester paper support tubes. The supporting polyester tube provides considerable added strength to the fragile membrane, facilitates easy handling of the membranes and enables them to withstand the moderate pressures required for the process.

Ultrafiltration involves the rejection of macromolecules or particles at the membrane surface with the rejection being governed by membrane pore size (0.001 - 0.1 micron). The ultrafiltration membranes employed have a molecular mass cut-off (MMCO) point of from 20 000 to 80 000.

Flux decreases with time as a fouling layer builds up on the membrane surface. The rate of flux loss depends on the nature of the fouling and on the fouling species involved. In theory, flux decreases in proportion to the inverse log of the retentate concentration. Flux regeneration can be effected by flushing the membranes with permeate or water under low pressure at increased linear velocity, or by employing chemical cleaning procedures. The UF membranes used in the ADUF process are made from polyethersulphone and can tolerate temperatures of up to 90°C and pH values of 0.5 to 13. Being of a synthetic nature, polyethersulphone membranes are compatible with a variety of digester feed substrates and cleaning agents. These membranes can also withstand high levels of chlorine.

Owing to the phenomenon known as concentration polarization, a gel layer, comprising macromolecular solids and colloids, forms on the membrane surface during operation. This layer acts as a secondary membrane, usually offering a high resistance to permeate flow. To maintain high flux rates when the solids content of the feed solution is high, the thickness of the gel layer must be limited. The gel layer thickness can be controlled by increasing the linear flow velocity across the membrane surface which increases the turbulence. The polarization layer is sheared off and an equilibrium fouling film thickness is established. The normal linear velocities employed vary from 2.0 to 3.5 $m.s^{-1}$. Higher linear velocities lead to higher flux rates, but at the expense of higher energy (pumping) costs.

### 2.3 Integration of the Anaerobic Digester with the Ultrafiltration Unit

In the ADUF process, ultrafiltration and anaerobic digestion are complementary processes: anaerobic digestion decomposes organics which would otherwise foul

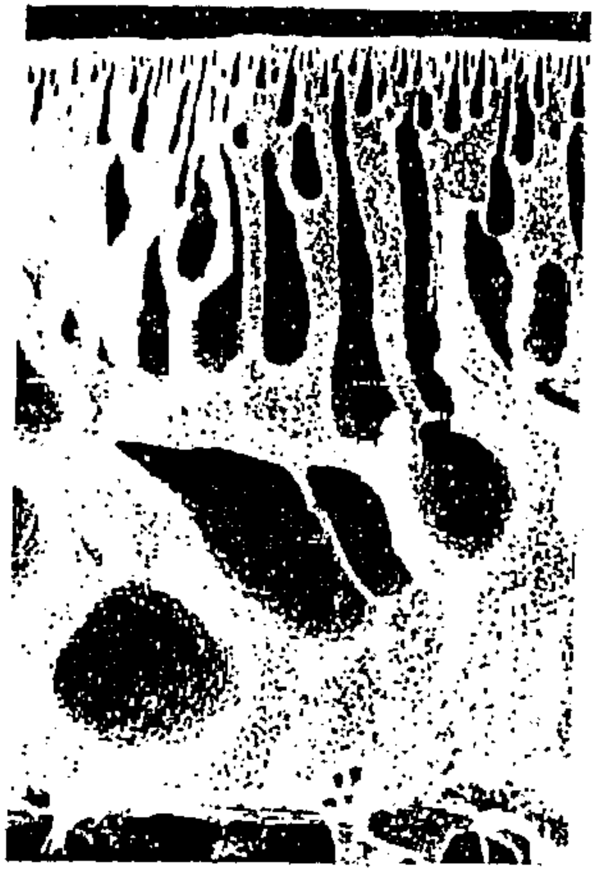

FIGURE 2: CROSS-SECTION OF A POLYETHERSULPHONE MEMBRANE
(MAGNIFICATION 700X)

the UF membranes while for their part these membranes serve to retain biomass which would otherwise be lost in the digester effluent. Parameters such as biomass concentration, operating temperature, digester space load rate, substrate degradability, flow velocity and pressure all affect the operation of the anaerobic digester and UF in different ways. Some of these parameters are synergistic in the integrated ADUF system, others are antagonistic. Great flexibility is achieved in the integration of the biological and physical functions of the digester and UF units. The ADUF process appears to be especially suitable for treating smaller volumes of concentrated waste as opposed to larger volumes of dilute waste. Selection of digester capacity and membrane area for processing a given waste should be based on pilot-scale studies, and a balance struck between digester cost and membrane cost.

Additional features of the ADUF process are:

- the process is completely enclosed. No undesirable odours should be detectable in the vicinity of the plant. This is especially important in sensitive areas, e.g. around food processing and beverage plants.

- no strict control of the sludge retention time (SRT) is necessary and permissible biomass concentration is governed by its influence on the permeate flux. The digester need not be a completely mixed system, and sludge withdrawal to and return from the UF unit may be implemented at different levels in the digester, as required, to promote efficient mixing.

# 3. LITERATURE SURVEY

## 3.1 Overseas Experience

The use of membrane filtration for biomass separation in aerobic biological systems was first reported by Smith (1970). During 1971 the Membrane Sewage Treatment System (MSTS) was patented for a combination of activated sludge and ultrafiltration (Bemberis *et al*, 1971).

Seven years later ultrafiltration was also combined with anaerobic digestion by Grethlein (1978). During this investigation, the anaerobic unit (a clear plastic septic tank of 106 litre capacity) was coupled to a membrane module consisting of two separate sections. The first section contained a cellulose acetate flat sheet membrane, while the second was a reverse osmosis ("Helicore") unit. This latter unit consisted of six porous tubes with the membranes wrapped around the outside of the tubes,the tubes being mounted in stainless steel pipes. The composition of the Helicore membrane and pore sizes of these membranes were not described.

BOD reduction rates (between 89 and 93%) and sludge production rates in the septic tank were found to be improved by the addition of the membrane filtration units. Both E. coli and turbidity levels were reduced to zero. Flux levels of between 400 and 600 $\ell.m^{-2}.d^{-1}$ were maintained with the flat sheet membrane without mechanical or chemical cleaning for a period of 1 500 hours. Linear velocities in the range 0.15 to 1.22 $m.s^{-1}$ were used.

In the Membrane Anaerobic Reactor System (MARS) described by Epstein *et al.* (1981), ultrafiltration was employed to replace the usual sedimentation step in a laboratory-scale study. Choate *et al.* (1982) discussed the incorporation of an ultrafiltration system into the flow regime of an anaerobic digester treating the effluent from a wheat flour processing plant. The plant was operating satisfactorily at the time of reporting, but increasing effluent COD due to low molecular, partly digested products were causing concern. Decreasing flux rates, falling from more than 25 down to 14 $\ell.m^{-2}.h^{-1}$), had to be restored regularly by chemical flushing.

Inoue (1990a), described experiments with a 10 $m^3.d^{-1}$ plant treating sewage. The BOD of the permeate effluent from the hollow fibre membrane filtration unit was reduced down to 20 mg/$\ell$. Although flux rates were described as "large" no further details were given. In another report by Inoue (1990b), the performance of an USAB reactor coupled to a flat plate membrane unit ( molecular mass cut-off equal to 30 000), treating a synthetic waste water, was discussed. The use of the UF module improved the substrate degrading performance significantly although granulation of the sludge was not affected. Flux had to be restored regularly by cleaning the membrane.

A bench-scale anaerobic bioreactor/ultrafiltration unit (the UF unit consisted of three thousand 1,4 mm diameter hollow fibres bundled together, giving a total membrane area of 10 $m^2$), digesting low strength soya-bean protein wastewater, was described by Yushina et. al. (1990). However, residual volatile fatty acids levels (acetic and propionic) which amounted to 67% of the COD found in the permeate, was deemed unsatisfactory and had to be improved. Space loading rates of more than 2 kg $BOD.m^{-3}.d^{-1}$ were achieved.

Hogetsu *et al.* (1992) described the treatment of wool scouring wastewater in a pilot- scale process using a fixed bed anaerobic digester (filled with polypropylene media) followed by an ultrafiltration module employing polyacrylonitrile hollow fibres (I.D. 1.4 mm) with a molecular mass cut-off of 13 000. Tests were carried out at both mesophilic (37°C) and at thermophilic (53°C) temperatures. The results obtained showed that without the UF module, the TOD (total oxygen demand) removal decreased sharply from about 90% to 30% in proportion to the increase in TOD loading rate from 3 to 45 $kg.m^{-3}.d^{-1}$. When the UF module was employed, the biomass retention was doubled and the effluent quality improved remarkably due to better filtration. At a TOD loading rate of 15 $kg.m^{-3}.d^{-1}$, at both temperatures, TOD removal increased from 45 to 90%, while grease removal increased from 37 to 99%. The study showed that 33% of the incoming SS was biodegraded when employing UF, while only 17% was achieved in the one pass through system (without the UF) at the same loading rate. During the first 40 days of operation, the flux of the UF module decreased from 37 to 23 $\ell.m^{-2}.h^{-1}$, and then gradually decreased further to 17 $\ell.m^{-2}.h^{-1}$ after 210 days of service.

### 3.2 South African Experience

#### 3.2.1 Pilot-plant Studies

**a) Wine Distillery Waste (Ross *et al.*, 1988b)**

Wine distillery waste (37 $kg.m^{-3}$ COD) has been treated in full-scale anaerobic plants at the Paarl and Stellenbosch sewage works for over 25 years (Heunis, 1986). Both upflow clarigester and contact-type plants are currently used for this purpose. These plants rely on clarifiers to concentrate and recycle the biomass back to the digester. Gravity separation restricts the digester mixed liquor suspended solids (MLSS) concentration from 15 to 20 $kg.m^{-3}$ and clarifier upflow velocities to 0.1 $m.h^{-1}$. The sludge has very poor settling properties owing to its diffuse (non-granular) and somewhat filamentous nature. Research has shown that settling and retention of this sludge becomes problematical at space load rates above 4 kg $COD.m^{-3}.d^{-1}$ as a result of residual gasification and consequent sludge rise in the clarifier compartment.

A pilot-plant comprising a digester and an external UF unit was commissioned at Distillers Corporation, Stellenbosch, during 1987. The 2.4 $m^3$ pilot-scale digester operated at a MLSS concentration of 30 $kg.m^{-3}$. Prior to the installation of the UF module, it could only be fed with wine distillery waste at a maximum space load rate of 3 kg $COD.m^{-3}.d^{-1}$ at 35° C. For evaluating the ADUF concept, a commercial Bintech UF tubular module with a total membrane area of 1.75 $m^2$ was introduced into the process and it was operated at an inlet pressure of 400 kPa. The high rate of sludge recirculation through the UF unit that had to be maintained to comply with a minimum linear velocity requirement of 2 m/s to limit fouling, resulted in a permeate volume (2.4 $m^3.d^{-1}$), which was well in excess of that of the substrate feed rate (0.3 $m^3.d^{-1}$) to the digester. The excess permeate had to be recycled back to the digester. Although the hydraulic load on the digester was increased considerably by recycling the excess permeate, the results obtained were still very good and may be summarized as follows:

- The extremely high initial flux of 1.5 $m^3.m^{-2}.d^{-1}$ at 400 kPa inlet pressure gradually decreased to 0.9 $m^3.m^{-2}.d^{-1}$ after 7 months' continuous operation. Temporary substitution of the original module by a new one also gave a flux of 0.9 $m^3.m^{-2}.d^{-1}$, indicating that the flux decline was not caused by membrane fouling but by changes to the digester contents, e.g. the MLSS in the digester had increased over the seven month period to 50 $kg.m^{-3}$ from an initial concentration of 30 $kg.m^{-3}$.

- No suspended solids were lost in the effluent (permeate), which was completely clear. Anaerobic bacterial counts before and after ultrafiltration clearly demonstrated one of the important advantages of ADUF, i.e. the recycling of bacteria (biomass) back to the digester.

- A build-up of biomass occurred in the digester, with a concomitant increase in permissible space load rate, notwithstanding the poor settleability of the sludge.

- During the study period, the space load rate increased from 4 kg $COD.m^{-3}.d^{-1}$ to 12 kg $COD.m^{-3}.d^{-1}$.

- The operating flux was successfully maintained for a period of several weeks before cleaning of the membrane was necessary.

- The degree of COD removal was 93% based on average feed and effluent concentrations of 37.0 kg $COD.m^{-3}$ and 2.6 kg $COD.m^{-3}$ respectively.

b) **Malt Plant Effluent** (Ross *et al.*, 1992)

This test was carried out over a period of 5 months at Southern Associated Maltsters (Pty) Limited, Caledon. The large volume of effluent produced by this industry was overloading the local municipal treatment works and the expansion of the malting plant which was in progress would create severe overloading.

A skid mounted pilot-plant comprising a 3 $m^3$ anaerobic digester and a 9,6 $m^2$ ultrafiltration unit, with all the necessary ancillary equipment, was used for the test.

The plant ran reliably for over 3 000 hours and on average treated 3 000 $\ell.d^{-1}$ of the malting plant effluent, reducing the COD from about 3500 $mg.\ell^{-1}$ to 800 $mg.\ell^{-1}$ (77% reduction). Further aerobic treatment, also carried out as part of the test, further reduced the COD to about 170 $mg.\ell^{-1}$. This residual COD proved to be intractable and could not be broken down further by biological processes.

The average space load rate for the digester was 5 kg $COD.m^{-3}.d^{-1}$, while a hydraulic retention of 18-hours was achieved. The results obtained with the UF unit varied considerably, but when the anaerobic process was functioning well, an average flux rate of 33 $\ell.m^{-2}.d^{-1}$ was attained (without chemical cleaning) at a linear velocity of 1,8 $m.s^{-1}$ and an inlet pressure of 500 kPa.

c) **Bagasse Slab Runoff** (De Villiers and Ross, 1990a)

An ADUF pilot plant, essentially similar to the one used on the malting waste described above, was tested over a period of 19 weeks at the SAPPI Stanger Mill. The bagasse slab runoff constituted some 49% of the total COD load of the various effluents emanating from the Stanger Mill. The COD of the bagasse slab runoff averaged 3 000 $mg.\ell^{-1}$ and comprised mainly residual sugars and some lignins. The plant was operated by the SAPPI personnel with bi-weekly supervision by a

CSIR appointed operator. An unfortunate aspect of the research programme was that the plant was non-operational during weeks 7 to 10 after commissioning, owing to membrane failure and subsequent replacement. Malfunctioning of the heating equipment and delays in replacing damaged parts had an adverse effect on the digestion process and steady state operation could not be attained.

When the plant was operating, the COD removal was very satisfactory and averaged approximately 80%. The final effluent had an average COD concentration of 500 $mg.\ell^{-1}$, down from 3000 $mg.\ell^{-1}$ and contained no suspended or colloidal solids.

The minimum hydraulic retention achieved was 1,2 days, and averaged a space load rate of 3,5 kg $COD.m^{-3}.d^{-1}$ under normal operation. Higher load rates were not possible during the contract period due to equipment malfunctions.

The UF membranes did not perform as well as on food wastes, such as wine distillery and malting plant wastes. The flux varied in the range 200 to 400 $\ell.m^{-2}.d^{-1}$, but the membranes tended to foul very rapidly. Cleaning was problematical, as alkaline washes dissolved the fouling material (lignins) but damaged the membranes. This problem was not resolved during the relatively short contract period.

No sensible design criteria could be generated during the contract period with respect to permissible load rates and membrane performance. The use of an ADUF plant was not recommended for this application.

d) **Paper Mill Bleach Effluent** (De Villiers & Ross, 1990b)

An ADUF pilot-plant, similar to the one used on bagasse waste, was operated for 19 weeks at SAPPI Ngodwana Mill. Up to 50% of the effluent organics and lignin derivatives, which can cause severe pollution of the environment, were removed.

This plant was also operated by the SAPPI personnel, with bi-weekly supervision by a CSIR appointed operator. The research was severely hampered by factors such as unavailability of feed, owing to strike action, mechanical breakdowns and failure of workshop services, non-availability of spares, etc. These breakdowns were very deleterious to the biological process and steady state operation for any meaningful period was not possible.

The COD removal varied from 64 to 90% and the maximum space load rate that could be achieved was 0,5 kg $COD.m^{-3}.d^{-1}$. The ultrafiltration flux varied in the range 100 to 300 $\ell.m^{-2}.d^{-1}$, which was very poor. As in the case with the Stanger ADUF application, it was found that cleaning the UF membranes with an alkaline solution dissolved the fouling material but damaged the membranes.

The ADUF process was not recommended for this application, but notwithstanding the poor results, the pilot-plant was purchased by SAPPI for further evaluation.

e) **Malt Brewery Effluent** (Strohwald and Ross, 1992)

Laboratory-scale investigations were conducted with brewery waste to which urea was added in order to correct a nitrogen deficiency. COD reductions of between 96 and 99% were achieved at a space loading rate of 15 kg COD. $m^{-3}.d^{-1}$. The COD of the final effluent (UF permeate) was generally below 100 mg.$\ell^{-1}$.

Fouling of membranes was not experienced and membrane flux remained stable. However membrane flux was significantly influenced by linear flow velocity, sludge concentration and metabolic conditions in the digester. Flux was optimized by maintaining the linear velocity at a point where the pressure drop equalled the maximum allowable operating pressure. Sludge concentration was reduced at the same time to a point where the maximum sludge loading rate was not exceeded.

f) **Chemical Distillery Effluent** (v d Westhuizen and Pakkies,1992)

Laboratory-scale experiments were carried out with chemically amended evaporator condensate as a feed substrate. A 5,5 $\ell$ anaerobic digester was coupled to a MEMTUF ultrafiltration unit fitted with polyethersulphone membranes of 40 000 molecular mass cut-off (MMCO).

A mean space loading rate of 9,4 kg COD.$m^{-3}.d^{-1}$ was achieved at a hydraulic retention time of 0,96 days, resulting in a COD removal rate of 96,7%.

The membranes performed well during the study but low linear flow velocities (0,08 $m.s^{-1}$) and fluxes (26 $\ell.m^{-2}.d^{-1}$) were used.

g) **Fruit Processing Waste** (Strohwald, 1993)

A major fruit processor in the Western Cape has been treating its factory effluent on site with UASB digesters, but has experienced digester overloading and sludge loss in the effluent during peak periods. A laboratory investigation into the possible application of the ADUF process to solve this problem was undertaken, using a 100 $\ell$ polyethylene reactor (active sludge volume 50 $\ell$) combined with a MEMTUF ultrafiltration unit. The latter was fitted with 9mm tubular polyethersulphone membranes of 40 000 MMCO (2 x 20 tube configuration), having a total area of 0.44 $m^2$. The UF permeate was recycled back to the digester, the excess being wasted. The concentrated biomass was returned to the digester after passing through a heat exchanger.

The results obtained over a period of 121 days of continuous operation showed that a mean space load rate of 1.46 kg COD.$m^{-3}.d^{-1}$ could be obtained at COD reduction rates in excess of 96% and a mean hydraulic retention time of 2.3 days.

Space load rates in excess of 1.5 kg COD.$m^{-3}.d^{-1}$ resulted in the deterioration of the COD reduction potential causing a sharp increase in the COD content of the UF permeate and the VFA/TA ratio, which was indicative of imminent digester failure. The ultrafiltration membrane flux could be maintained at an average value of 14.8 $\ell.m^{-2}.h^{-1}$ without the need for chemical cleaning. The membrane flux did, however, decline rapidly at MLSS values greater than 20 g.$\ell^{-1}$. Maintaining the MLSS below this value seems to be one of the prerequisites for limiting flux loss, as has also been shown in other ADUF applications (Strohwald, 1991). The linear flow velocity was shown to affect the flux directly. A flux increase of 20 to 30 $\ell.m^{-2}.h^{-1}$ can be expected for every metre per second velocity increase.

### 3.2.2 Full-Scale Application

a) Egg Processing Plant Effluent (Nel, 1991)

The egg processing plant of the Egg Board at Kraaifontein, Cape, produces some 120 $m^3.d^{-1}$ effluent. This effluent has a COD of 2 000 - 18 000 $mg.\ell^{-1}$, with an average COD of around 8000 $mg.\ell^{-1}$ and contains mainly egg protein, salt and caustic denatured protein produced during plant cleaning operations. Initial pilot-scale tests were carried out to establish the feasibility of anaerobic digestion of these wastewaters, as well as the recovery of useable solids by treating the wastewater by a tubular reverse osmosis plant (Roberts, 1987; Roberts and McGill, 1991). Both of these pilot- scale tests produced promising results.

An ADUF process was installed by Bintech (Pty) Limited at the Egg Board at Kraaifontein, by converting an existing rectangular balancing tank to an anaerobic digester. Total capacity of this anaerobic digester was 90 $m^3$ and the effective sludge volume 80 $m^3$. An ultrafiltration plant, previously used for protein recovery at the plant, was converted for use as part of the ADUF process. This unit was rearranged to comprise 57 trains of 2 modules in series. The 114 modules, having a total membrane area of 200 $m^2$, were food grade units fitted with 12.5 mm diameter tubular membranes.

The design specification for the ADUF process required treatment of 120 $m^3.d^{-1}$ effluent at an average of COD of 5 000 $mg.\ell^{-1}$ (a total of 600 kg $COD.d^{-1}$) to less than 500 $mg.\ell^{-1}$ COD to reduce the overloading problems at the receiving sewage works.

At the time of the report, the following points were noted:

1. After start up, it was found that the COD of the effluent was averaging 10 000 to 12 000 $mg.\ell^{-1}$ instead of the 5 000 $mg.\ell^{-1}$ specified. This caused severe overloading and the average flow handled was reduced to about 70 $\ell.d^{-1}$.

2. The UF system fouled rapidly and had to be cleaned frequently. It was found that a large build-up of apparently intractable or very slowly digestible material was accumulating in the system. By draining a large part of the digester sludge, the flux was restored to the required value to comply with the design specification, i.e. 600 $\ell.m^{-2}.d^{-1}$.

3. The draining off of the portion of the solids to get rid of the non-digestible portion caused a decrease in digester performance. Adding sludge from a domestic sewage digester restored normal operation.

4. At the date of this particular report, the plant was operating satisfactorily, but at regular intervals part of the sludge had to be removed, settled, the intractable fraction drained and the balance returned to the digester. It was suspected that the material which accumulated in the digester was a denatured protein produced during the cleaning operation. This problem was under investigation by the plant suppliers.

b) **Maize Processing Plant Effluent** (Ross *et al.*, 1992)

Pilot and subsequent full-scale ADUF studies were carried out on a maize processing effluent (15 kg $COD.m^{-3}$) at the Meyerton Mill of Messrs. African Products. The effluent is produced during the manufacture of cornflour, natural and modified starch, glucose syrups, dextrins, gluten and maize germ.

The results, after a 15 month period of full-scale operation, have illustrated the merits of the process for the production of a colloid-free effluent at a mean COD removal efficiency of 97%. A mean space load rate of 3 kg $COD.m^{-3}.d^{-1}$ was maintained during very large variations in the feed load. Permeate flux varied between 37 and 8 $\ell.m^{-2}.h^{-1}$ with a linear velocity of 1,6 $m.s^{-1}$ and at an inlet pressure of 450 kPa. Periodic cleaning of the polyethersulphone membranes with EDTA was however required after 13 months of operation. Digester suspended solids concentration was maintained at 21 $kg.m^{-3}$. A mean plant space load rate of 3 kg $COD.m^{-3}.d^{-1}$ guaranteed the reliability to withstand high COD shock loads during large variations in the feed load.

## 4. RESEARCH PROGRAMME

According to the original contract between Watertek and the WRC, the investigation would cover the following four objectives:

a) The re-design and upgrading of the ADUF process and its performance with primary attention to the digester phase;

b) A study of the effect of changes in digester sludge characteristics (due to the high velocity through the ultrafiltration membranes) on the process;

c) Long term semi pilot-scale studies at identified sites to investigate the effect of different feed substrates on the anaerobic process and ultrafiltration module;

d) Production of a final report covering laboratory studies and performance of the updated ADUF pilot-plant under realistic operating conditions and various types of effluent.

At the inaugural meeting of the Steering Committee held on 14 June 1991 a working program was accepted which allowed for:

- the construction of two laboratory-scale ADUF units and one normal anaerobic digester,
- start-up and stabilisation of these units,
- establishing performance criteria,
- determining sludge character changes during extended period of operation and
- re-construction of an existing pilot-plant for later use.

During the second meeting of the Steering Committee held on 16 June 1992 it was reported that the three laboratory digesters had been constructed but that many operational problems caused a substantial delay with the progress. A revised working program, which included the following tasks, was accepted:

- Start-up and acclimatization of three units on spent wine substrate.
- Evaluation of performance of three units (including optimised loading, prevention of short-circuiting, solving foam problems and build-up of intractable solids, operation on another substrate such as tannery waste).
- A study of the rheological characteristics of the sludges produced.

The investigation was, however, at this stage already hampered by limited funds.

# 5. EQUIPMENT AND METHODS

## 5.1 LIMITATIONS OF A LABORATORY-SCALE ADUF SYSTEM

It is relatively straightforward to evaluate a normal anaerobic digester with a settling system at a laboratory scale, although experience has shown that the results achieved are usually considerably better than could be obtained on a full-scale plant. Operating a laboratory scale ADUF system is, however, fraught with problems. Scale effects make it impossible to realistically reproduce full-scale ADUF operation on a laboratory unit with a total anaerobic digester capacity of, for example, 50 litres.

The main problem is a consequence of the minimum linear flow velocity through the UF membrane tubes which is required to prevent excessive concentration polarization at the membrane surface with subsequent fouling layer build-up. The smallest available tubular UF membranes which are suitable for passing relatively viscous digester sludge have an outside diameter of 9 mm, with an average internal diameter of about 8,7 mm. This gives the tube an effective internal cross-section of 0,5945 $cm^2$. To maintain a linear velocity of 2 $m.s^{-1}$ across the membrane surface in a single tube (eg. a single pass series train) would require a pumping rate of 7,13 $\ell.min^{-1}$ through the membrane tube. Assuming that a 50 $\ell$ digester is coupled to this UF array, it would mean that the entire contents of the digester is pumped through the UF unit once approximately every 7 minutes, or 8,5 complete digester turnovers per hour.

The excessive pumping rate may affect the sludge characteristics due to mechanical damage of the sludge structure and may cause short-circuiting of some undigested feed substrate into the UF module, which may result in traces of undigested feed in the final effluent. Excessive heat generation caused by friction may also be a problem during hot weather.

Simply increasing the digester volume is also not a valid solution to overcome this problem. If the digester volume is increased, the membrane area must be increased to maintain a set hydraulic load on the system. Increasing the membrane tube length to achieve this goal results in an increased pressure drop along the tube, with lower permeate (final effluent) flux and increased pressure requirements. At full-scale, parallel-series membrane arrays are used, but if for example, at laboratory scale two membrane trains are used in parallel, the pumping volume requirements are doubled. and digester turnover rate is doubled.

Assuming that, at best, a one day retention time will be achieved in the laboratory-scale 50 $\ell$ digester, it will require a 50 $\ell$ permeate volume to pass through the membrane daily. Assuming minimum flux rate of 10 $\ell.m^{-2}.d^{-1}$ and a single tube (series) membrane module, the membrane area required is 0,21 $m^2$. A total length of 7,68 m of 9 mm OD tubular membrane will be required. Typically a module having 8 x 1 m tubes in series would be employed. This would give a pressure drop of 50 to 100 kPa along the tube. The required inlet pressure would therefore have to be between 150 and 250 kPa.

## 5.2 LABORATORY - SCALE APPARATUS

In order to evaluate factors affecting the ADUF process properly it would have to be compared directly to an equivalent anaerobic digester/settling system, ie. a typical contact process, with both receiving the same feed substrate. To evaluate changes or improvements to the ADUF process it would be preferable to operate at least two experimental ADUF systems, the changes being made on one system, while the other (the digester/settling system) acts as a control.

Two identical ADUF units were built. To act as a control unit, a smaller anaerobic digester with a settling vessel was constructed (Referred to as the ADS unit).

### 5.2.1 ADUF LABORATORY SCALE UNITS (FIGURE 3)

a) **Anaerobic Digester**

- **Digester Vessel**

| | |
|---|---|
| Total Volume (including conical bottom) | 72 ℓ |
| Operating sludge volume | 50 ℓ |
| Diameter | 0,3 m |
| Height, cylinder only | 1,0 m |
| Construction material | PVC, 6 mm wall thickness |
| Insulation used | Glass wool, plastic covering |
| Conical bottom | 60° |

- **Heating system**

The sludge is heated by passing it through a 15 mm ID steel tube, wrapped with a silicone encased heating cord (90 Watt). The temperature is controlled by means of a RKC programmable controller coupled to a Pt100 sensor located through the sidewall of the digester. Additional heating is provided by means of another silicone encased heating cord (250 Watt) wrapped round the base of the digester.

A 20 mm glass wool insulating layer around the cylindrical section of the digester minimizes the heat loss. The set temperature of 35° C was easily maintained by this arrangement during late summer, but the heating and insulation was not sufficient to prevent temperature fluctuations of 2 - 3°C during winter.

- **Level control**

The operating level in the digester, giving a 50 ℓ average capacity, is maintained by diverting sufficient UF permeate back into the digester via a float valve. The rest of the permeate, approximately equal to the substrate feed volume, is run to waste.

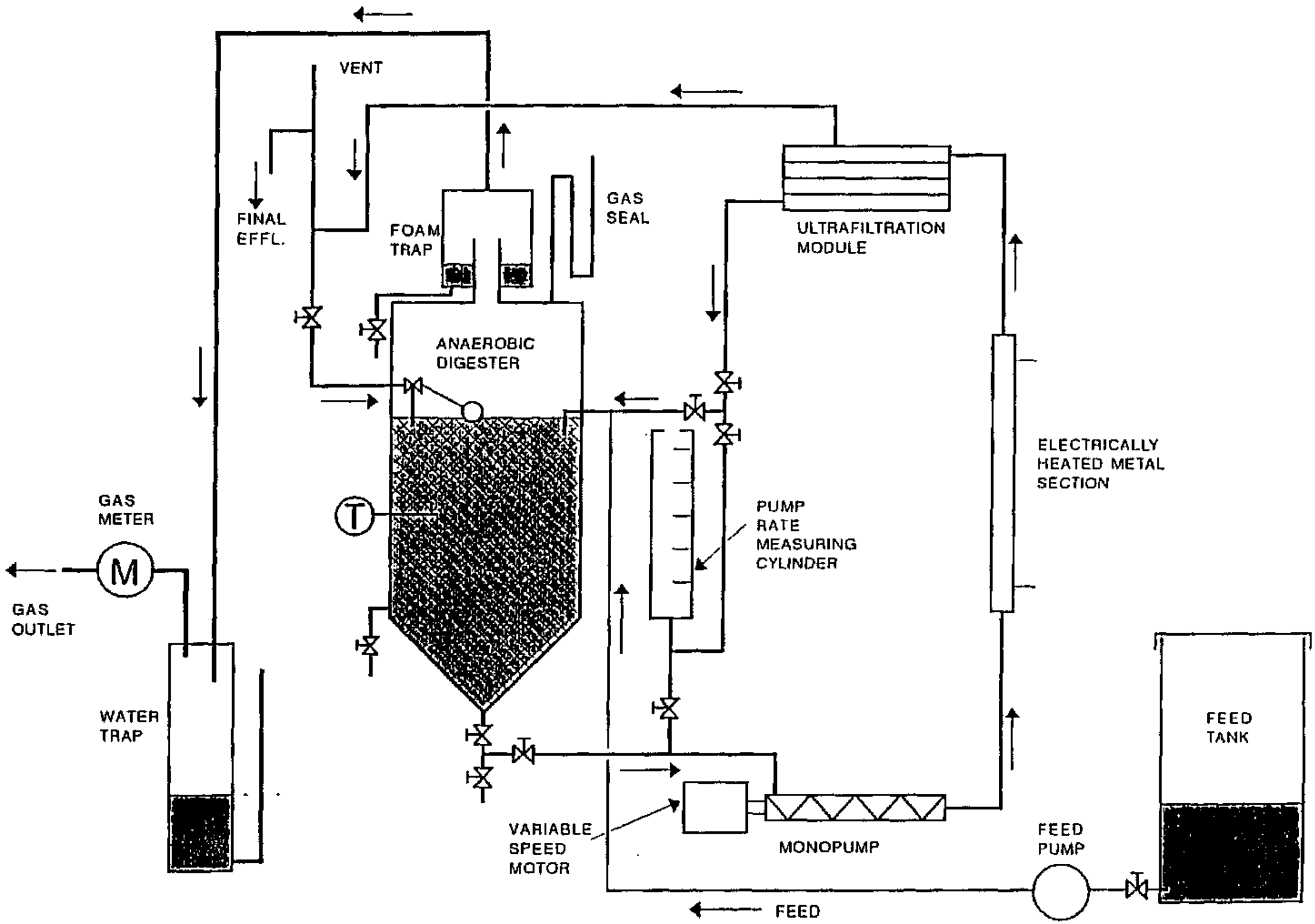


FIGURE 3: LABORATORY SCALE ADUF UNIT

- **Biogas Measurement**

The gas leaving the digester is cooled by passing it through a 10 mm stainless steel pipe, the condensate collecting in a water trap before the gas is passed to the measuring device.

A specially developed gas measuring unit is being used to monitor the biogas output. The measuring cell comprises two chambers separated by a flexible diaphragm. The chambers fill and empty alternately via four solenoid valves. A pressure sensor in each chamber activates a switching circuit which operates the appropriate solenoid valves. A counter registers the number of times the chambers are filled, each "filling" being 200 mℓ at a pressure of 40 mm water gauge.

- **Substrate Feed Pump**

The feed pump used for each digester is a Gilson peristaltic pump, operating with a 5 mm ID silicone tube. The speed of this unit is fully variable and it runs at a very stable speed once set.

b) **Ultrafiltration Unit**

The digester sludge mixture is introduced into the tube at a low operating pressure of 100 to 200 kPa. The membrane flux results from the pressure differential from the inside to the outside of the tube wall. The sludge mixture flowing down the tube, i.e. across the membrane surface, becomes progressively more concentrated as filtrate is passed through the membrane.

The UF modules used in the ADUF laboratory-scale units were manufactured by Bintech (Pty) Limited, Paarl. The more recent version using 9 mm tubes without the usual support structure, were selected as the most suitable. The smaller diameter tubes used in these units are capable of withstanding the relatively low pressures used in ultrafiltration. The small diameter and low hold-up volume of the membrane tubes make them more suitable for the low-volume laboratory units.

The membranes have a molecular mass cut-off point between 20 000 to 80 000 (nominally taken as 40 000 MMCO). The normal linear velocities employed may vary from 1.0 to 2.5 $m.s^{-1}$. Higher linear velocities lead to higher flux rates at the expense of higher pumping costs. Excess heat generation due to increased frictional losses will also be a problem at excessive linear velocities in these small laboratory ADUF units.

Design details of the UF module are as follows :

- **Ultrafiltration Module**

| | |
|---|---|
| Membrane type | 9 mm OD Tubular Polyether sulphone |
| Minimum membrane flux | 10 $\ell.m^{-2}.h^{-1}$ |
| Membrane area | 0,22 $m^2$ |
| Module configuration | 9 mm OD membrane tubes (20 in series, each 40 cm long) |

| | |
|---|---|
| Operating linear velocity range | 1 to 2 $m.s^{-1}$ |
| Required sludge flow rate | 3,6 - 7,2 $\ell.min^{-1}$ |
| Equivalent digester turnover time | 14 - 7 minutes |
| Pressure (operating) at inlet | 150 - 250 kPa |
| MMCO | 20 000 to 80 000 |

- **Ultrafiltration Pump**

| | |
|---|---|
| Pump Type | Mono C32M |
| Output (water) | 400 rpm 200 kPa 0,6 $m^3.h^{-1}$<br>600 rpm 200 kPa 1,0 $m^3.h^{-1}$ |
| Drive | 1,5 kW 6 pole motor, 1400 rpm, with 3:1 V-belt reduction drive, power provided by a Varispeed VC150D inverter drive unit. |

The motor/pump combination was chosen to provide adequate output for later small scale pilot units, as it can provide sufficient output to feed two 9 mm OD tubes in parallel at 2 $m.s^{-1}$. It also allows the Mono pump to operate at very low rotational speeds of between 200 and 600 rpm which will cause the minimum damage to the sludge structure. The speed is fully variable over this range by means of the inverter drive unit.

- **Linear velocity measurement in UF unit**

The linear velocity of the sludge passing through the membrane tubes of the UF module has to be maintained at between 1 and 2 $m.s^{-1}$ to limit fouling effects. The flow rate of the pump has to be monitored occasionally to make this determination. To do this, each ADUF unit is fitted with valves to enable the sludge from the UF unit to be bypassed to a transparent calibrated 5 $\ell$ cylinder. The time taken for eg. 3 $\ell$ sludge to be pumped into the cylinder is taken, then by opening another set of valves, the sludge is passed back into the pump outlet and into the digester via the UF module. It is, therefore, possible to accurately calculate the linear velocity of the sludge passing through the membrane tubes of the UF module.

### 5.2.2 ANAEROBIC DIGESTER/SETTLING LAB-SCALE UNIT (FIGURE 4)

The laboratory-scale anaerobic digester/settler does not have to be as large as the laboratory-scale ADUF units as it is not subject to the flow limitations

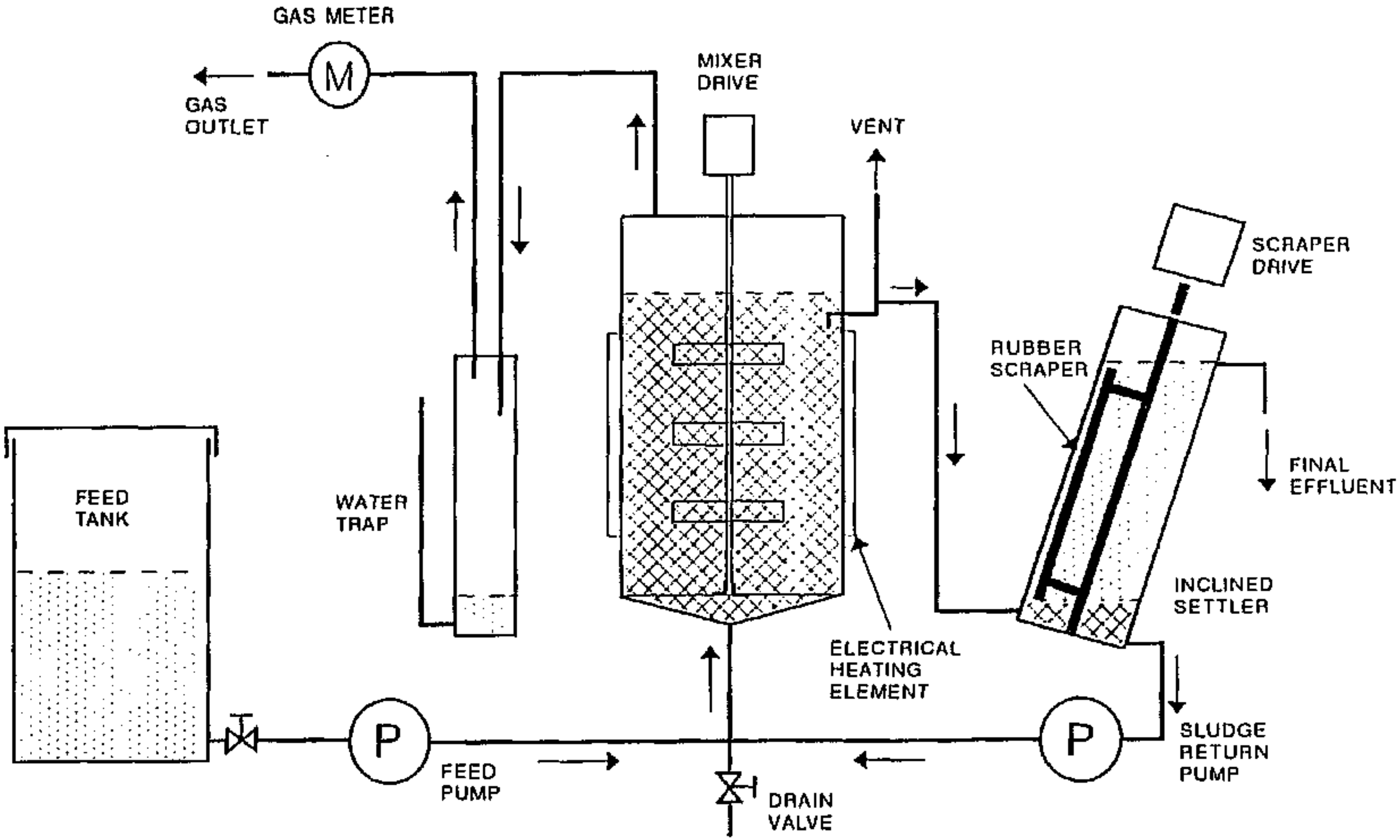


FIG 4: ANAEROBIC DIGESTER WITH SETTLING UNIT

imposed by the minimum available size of the ultrafiltration module tubes. It was therefore decided to use a 25 ℓ unit, with specifications as follows :

- **Digester**

| | |
|---|---|
| Total Volume,including conical ends | 30 ℓ |
| Operating sludge volume | 25 ℓ |
| Diameter | 0,25 m |
| Height (cylindrical part only) | 0,6 m |
| Mixing | Motor driven central shaft with paddles |
| Material | GRP |
| Insulation | Glass wool, plastic covered. |

- **Heating System**

The anaerobic digester is heated by means of silicone covered heating cord (250 Watt) wrapped round the unit for about one third of its height. A RKC programmable temperature controller coupled to a Pt100 sensor located in the sidewall of the digester regulates the temperature of the sludge in the digester. A layer of 20 mm glass wool wrapped round the cylindrical section of the digester is the only insulation provided.

- **Settling Tank**

An inclined cylindrical transparent PVC settling tank is used to thicken the effluent sludge from the digester. A rubber scraper, driven (intermittently, by time) by a 1 r.p.m. motor, keeps the walls of the unit clear of sludge. The specifications of the settling unit are:

| | |
|---|---|
| Total volume | 6,2 ℓ |
| Operating volume | 5,0 ℓ |
| Inclination | 30° from the vertical |

- **Sludge Return Pump**

Peristaltic pump, with intermittent operation by an adjustable timer.

- **Level control**

The digester overflows via an anti-siphon overflow system, which prevents any loss of biogas. The overflow sludge passes down a 12 mm ID tube to the base of the inclined settling tank.

- **Biogas Measurement**

A specially developed gas measuring system, similar to those employed on the ADUF units, is used to monitor the biogas production.

- **Substrate Feed Pump**

A Gilson peristaltic pump, using a 5 mm ID silicone tube, is used to feed the digester directly into the common sludge return inlet at its base. The feed pump operates intermittently, controlled by an adjustable timer.

## 5.3 FEED SUBSTRATE

The spent wine effluent used for the greater part of the tests was obtained from Distillers Company in Stellenbosch. Spent wine effluent was also obtained from Paarl Sewage Works when the distillery at Stellenbosch was not in operation. The COD strength of the spent wine varied between 25 to 50 $g.\ell^{-1}$ during the initial 56 days of operation. The further tests up to day 221 were carried out on diluted spent wine having a COD strength varying between 12 to 25 $g.\ell^{-1}$.

The feed substrate was changed from spent wine effluent to beer brewery waste effluent on day 222 after the later revision of the evaluation programme. The beer brewery waste effluent was obtained from Ohlssons Breweries in Newlands and had a mean COD strength of 2.5 to 3.0 $g.\ell^{-1}$. The digesters were fed on a mixture of spent wine and brewery waste effluents in order to make the transition from spent wine to beer waste as smooth as possible. This spent wine/beer waste mixture was fed in different ratios as shown in the table below:

| Day No. | Spent Wine Ratio | Beer Waste Ratio |
|---|---|---|
| 222 | 3 | 1 |
| 226 | 2 | 1 |
| 231 | 1 | 1 |
| 236 | 1 | 2 |
| 240 | 1 | 3 |

The digester was fed on pure beer waste effluent after day 240, until the end of the investigation.

# 6. OPERATION AND RESULTS

## 6.1 Hydraulic testing and start-up

After the three digestion units had been constructed, hydraulic testing with clean water was carried out on all three to ensure that the calculated volumes were correct, the required levels were maintained and that the assemblies were leak-free. Once these tests had been satisfactorily carried out and the necessary modifications made where required, the plants were filled with sludge obtained from the spent wine digesters at Paarl.

For the initial acclimatization period, all three digesters were fed with spent wine effluent obtained from the holding tank at the Paarl Sewage Works. The actual COD strength of the spent wine was not tested before feeding commenced. As it appeared to be quite weak, the initial feed rate to all three test units was over-estimated, which resulted in severe overloading, with space load rates of 4 to 8 kg $COD.m^{-3}.d^{-1}$. The feed rate was reduced when the analyses results became available, but apparently the digesters had already received a set-back, judging by the relatively low gas production rates of 0,29 to 0,38 $m^3.kg^{-1}$ COD.

During the first 13 days of operation, the analytical laboratory was not geared to do volatile acid and alkalinity determinations. The method finally adopted, after trying various others, was developed by Anderson and Yang (1992). The results shown in Appendix 1, Tables 1 to 3, reflect only the results obtained by this method, but converted from $meq.\ell^{-1}$ volatile acid and reported as $mg.\ell^{-1}$ acetic acid, the bicarbonate alkalinity being reported as $mg.\ell^{-1}$ $CaCO_3$ .

During the initial period (25 days) the volatile acids in ADUF1 and ADUF2 remained high, before dropping off to more acceptable levels of below 300 $mg.\ell^{-1}$. Considerable temperature fluctuations occurred initially while the digesters were not fully insulated. Day/night variations of up to 5° C occurred, and it was assumed that this had adversely affected the performance of the digestion process.

## 6.2 Problems with excessive foam production

Both ADUF units tended to undergo periods of severe frothing, for no apparent reason. The foam produced would eventually block up the gas outlet pipes and fill the water trap with extremely sticky, oily sludge, the consistency of which resembled molybdenum disulphide grease. It was suspected that the spent wine from Paarl was causing the foaming, as it had also been experienced at the Paarl Sewage Works where the "normal" anaerobic spent wine digesters had periodically undergone severe foaming episodes. Changing over to spent wine from the Stellenbosch distillery produced exactly the same results, with sporadic foaming episodes occurring for no apparent reason. This problem was not solved during this evaluation. The anaerobic unit with the settling tank (ADS) never produced foam, although it was operating at approximately the same load rate as the ADUF units.

## 6.3 Operation and results

### 6.3.1 General operation

Results achieved during the evaluation are reflected in Tables 1 to 3, and Figures 6 to 25.

It was decided that, when the digesters had stabilized sufficiently ADUF1 would act as the experimental unit while ADUF2 would be the control unit. The ADS would be used as a reference unit.

From day 97 ADUF1 was operated on an intermittent cycle (See section 6.3.2), while ADUF2 was fed continuously throughout the test period.

All three units were fed with blends of spent wine waste and beer brewery waste from day 226 and eventually on pure beer brewery waste from day 245, as described in section 5.3.

From the outset it proved to be difficult to achieve steady load conditions on all three units, as the COD content of the spent wine tended to change daily. The first batches obtained from Paarl varied between 25 and 37 g COD.$\ell^{-1}$, while the strength of the later spent wine from Stellenbosch went as high as 50 g COD.$\ell^{-1}$. This led to difficulties in feeding the small volumes required daily, so it was decided to dilute all the feed to half strength (Figures 6 to 8 reflect the changes in COD feed strength).

It was attempted to operate all three units at approximately the same space and biological load rates of 3 kg COD.$m^{-3}$.$d^{-1}$ and 0,2 kg COD.$kg^{-1}$VS.$d^{-1}$, but as can be seen from the fluctuations that occurred (Figures 12 to 16), this could not be achieved with any accuracy. The main cause for erratic loading was the variable strength of the feed substrate and the upsets caused by the severe frothing episodes of ADUF1 and ADUF2, which occurred periodically.

The effects of the initial overloading of ADUF1 and ADUF2 is clearly evident from the volatile acids and alkalinity plots shown in Figures 18 and 19. The ADS unit, which was not too seriously overloaded at the start, maintained a fairly steady level of alkalinity and volatile acids (Figure 20), except for a short period when it became overloaded when it was attempted to increase its feed rate slightly (from Day 27). It recovered after the feed was stopped for a few hours, then later (from Day 47) the feed rate was drastically reduced to allow it to recover fully. Approximately 400 g of $NaHCO_3$ was added (on day 66) to stabilize the alkalinity as this had dropped to a critically low level. This effectively raised the alkalinity to above the 2000 mg.$\ell^{-1}$ level, which was considered to be satisfactory.

The gas production of all three units was fairly erratic (Figures 21 to 23), but during periods of steady operation averaged 0,6 $m^3$.$kg^{-1}$COD. ADUF2 generally operated better and this is reflected in the steady gas production (Figure 20), while fairly large fluctuations occurred in the cases of ADUF2 and ADS (Figures 21 and 22). The gas composition was not determined owing to lack of suitable equipment, but assuming that the composition was 67% $CH_4$ and 33% $CO_2$, which is normal for anaerobic digesters operating on spent wine, this would mean that the units were producing about 400 $\ell$ methane per kilogram COD. This figure is considered to be normal for anaerobic digestion.

Initially both the ADUF units were operated at a UF inlet pressure of 150 kPa, with the Mono pumps turning at an extremely low speed of 150 to 180 rpm.

The ADUF1 exhibited a "stepped" flux decline over the total test period. A gradual flux decline occurred over the first 30 days of operation (Figure 24). In an attempt to restore the flux, the pressure was increased to 250 kPa, with no marked response. The UF unit was flushed with hot water (approximately 45 °C) during this period, but less than 10% increase in flux occurred. Reducing the pressure to 150 kPa did not appear to reduce the flux significantly, so operation was continued at this pressure, with the flux stabilising at approximately 30 $\ell.m^{-2}.h^{-1}$. up to day 66, when the heating pipe failed and the unit was stopped. On restarting (Day 70), the Mono pump was leaking and had to be stopped for repairs on day 77. These setbacks resulted in a lower average flux of approximately 25 $\ell.m^{-2}.h^{-1}$ at an inlet pressure of 150 kPa. An electrical short put the ADUF1 out of commission for a period of 11 days (Day 103 - 114) before the unit could be restarted, which resulted in a further slight deterioration of flux to approximately 24 $\ell.m^{-2}.h^{-1}$. After a further stoppage to replace the Mono pump packing (Day 146) the flux fell to approximately 15 $\ell.m^{-2}.h^{-1}$ while still operating at an inlet pressure of 150 kPa. A number of setbacks occurred between day 183 and 202, during which the entire digester content was lost 5 times in rapid succession, with the digester being refilled with fresh sludge from the Paarl spent wine digester on each occasion. After these setbacks the flux deteriorated to approximately 8 $\ell.m^{-2}.h^{-1}$, while operating at an inlet pressure of 150 kPa.

The UF unit on ADUF2 operated more erratically, showing a very large drop-off in flux during the first 20 days (Figure 25). On day 26, the UF unit was flushed with hot water (± 45 °C) for 15 minutes, with induced air bubbles, which produced virtually no improvements in flux. It was also noted that to maintain the required linear velocity of 1,6 m/s through the module required an increased amount of pressure as the test progressed. The pressure was increased to 230 kPa, and later to 250 kPa to maintain sufficient velocity through the UF unit, and also to provide sufficient heat transfer to the digester (the rate of heat transfer from the heated pipe section to the digester depends on the sludge flow rate through the external loop being maintained).

The sludge pump of ADUF2 slowed down during the night of day 47, (Figure 25) and when the operating pressure was re-established the next morning (250 kPa), the flux appeared to improve considerably. Why this occurred is not clear, unless the temporary relaxation of the membrane had a considerable cleaning effect. This phenomenon was not always evident after other pump stoppages. After an extended stoppage from day 111 to day 114 the flux did increase gradually to over 30 $\ell.m^{-2}.h^{-1}$ for a short period, in spite of the pressure having dropped from 250 to 190 kPa.

The pump operation became erratic from day 134 and on stopping and stripping the pump (Day 148) it was found that a plastic cap had become lodged inside the delivery end of the pump, causing fluctuations in the output. From then onwards a rapid drop in flux occurred, finally reaching a lower plateau where it fluctuated between 2 and 4 $\ell.m^{-2}.h^{-1}$, at an inlet pressure of approximately 190 kPa.

### 6.3.2 Intermittent feed of ADUF1

The first experiment to be carried out was to establish whether any short-circuiting of part of the feed, or some of the initial volatile acids produced, occurred through the membrane of the ADUF system. Ideally this would have required the re-circulating sludge to be diverted away from the UF unit directly to the digester during a feed cycle, as well as during a "digestion period" afterwards. This would have entailed switching the recirculating sludge flow by means of either a solenoid valve or a motorized valve. This option was considered to be impractical on these small scale units, so an alternative system was used, whereby the permeate would be diverted.

The modified ADUF1 unit is shown in Figure 5, the change being effected 40 days after initial start-up.

The operating mode was as follows :

- When the first timer (1) initiated the feed cycle and turned on the feed pump, the second timer (2) also started and opened the 3-way solenoid to divert all the permeate from the UF module back to the digester.
- When timer 1 stopped the feed pump (5 minutes), timer 2 operating the solenoid valve continued to allow the permeate to be diverted directly to the digester until 30 minutes had elapsed.
- At this point, timer 2 stopped, deactivating the solenoid valve, diverted the permeate to its normal circuit, part being bled off to waste, the rest returning to the digester. via the float valve to maintain the level. Timer 3 started as timer 2 stopped.
- Timer 3, which operates for a further period of 30 minutes, with the permeate bleeding off normally, eventually stops and restarts timers 1 and 2 to repeat the cycle.

This mode of operation prevents any raw feed from reaching the UF module. All feed substrate is retained in the digester and any pumped into the UF circuit is returned to the digester, either via the return sludge or via the return permeate.

From previous experience with ADUF pilot plant units, it was suspected that partly digested waste could theoretically be lost in the effluent. The COD results of ADUF's 1 and 2 obtained during this test (from day 41) does not support this theory. In both cases the COD of the effluent was below 1000 $mg.\ell^{-1}$, with the continuous feed unit (ADUF2) performing even slightly better than the test unit (see Appendix 1, Tables 1 and 2).

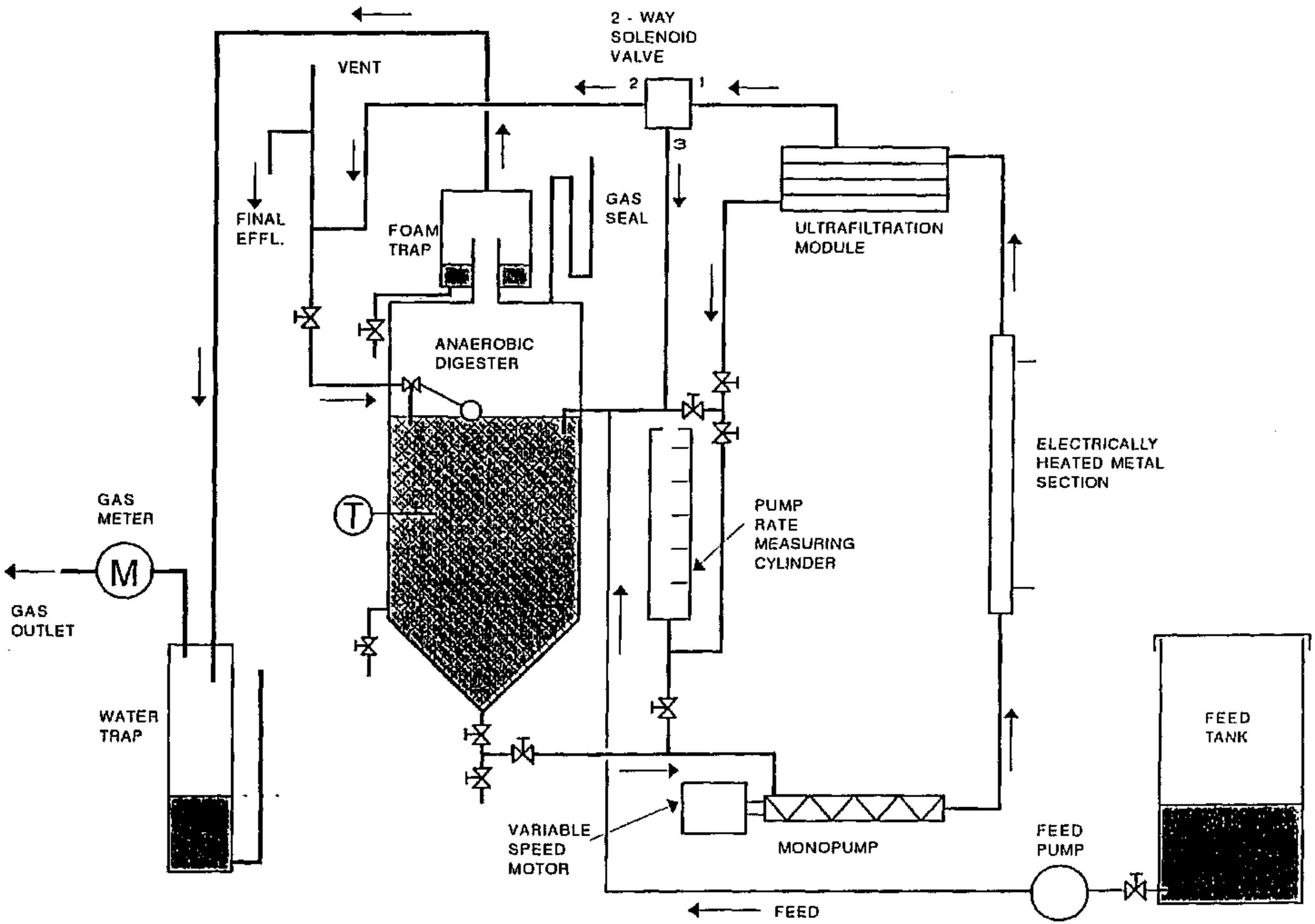


FIGURE 5: LABORATORY SCALE ADUF UNIT (MODIFIED)

During this test the load rates were relatively low in both cases. If it had been possible to operate at higher load rates, without foam interference, the situation may have been different. With the foaming causing problems throughout the experiment, it was not possible to determine this aspect conclusively.

### 6.3.3 Foam generation, causes and control

The problem experienced with foam generation in the ADUF digesters was not specifically researched as a separate experiment owing to a lack of time, but attempts were made to control this problem throughout the duration of the overall evaluation.

Severe frothing always occurred immediately after start-up when using fresh sludge from the Paarl spent wine digester. Spells of foaming occurred periodically afterwards, frequently when the feed load was increased, but often for no apparent reason. The anaerobic digester/settler unit, which used the same sludge for start-up and was fed the same substrate never suffered from this problem. It was therefore deduced that the ADUF process itself was responsible for the foam generation.

The most reasonable explanation, without any positive proof, is that the foam is generated either by the severe mixing action of the ADUF system which affects the biomass causing it to release polymeric substances which promotes the foam formation, or by the pressurizing of the sludge into the UF module and subsequent release of the pressure when the sludge is returned to the digester.

As both mixing and pressurization of the sludge are inherent processes of the ADUF system, it would be difficult to eliminate foaming, but it could be limited and controlled by proper design. It must be noted that the small ADUF test units had a very high mixing rate owing to the limitations mentioned earlier (Refer to Section 6.1). The problem is likely to be considerably less in large full-scale plants, but provision should be made to control foam loss into the gas system. The large foam traps installed on the test ADUF units (From day 67 on ADUF1 and day 76 on ADUF2) worked reasonably well, trapping considerable quantities of sludge which would have fouled up the gas meters and would have been lost from the systems.

The addition of a food grade anti-foam agent was tried on ADUF1 (Day 62) but this had no visible effect.

### 6.3.4 Digester solids management

As no sludge was lost in the effluent from the ADUF units, it was hoped that an estimate of the sludge accumulation in the digesters would be obtained, as well as the ratio of active to inactive biomass. Two factors completely hampered this aspect of the investigation:

(i) Initially considerable amounts of sludge was lost in foam escaping via the gas system, clogging the water traps and gas meters. The installation of foam traps alleviated this to some extent, but a significant amount was still lost on cleaning the traps, i.e. non-liquid sludge adhering to the trap surfaces which had to be washed off and could not be returned to the digester.

(ii) Sludge was frequently lost from the ADUF units owing to equipment failures e.g.

leaking pump glands, gas seal failures, fractured pipes etc. ADUF1 lost all its sludge on five occasions as a result of pipes being ruptured or blown off due to blockages, which required total sludge replacement from the Paarl spent wine digester. Sludge was lost in the effluent from the settling unit of the ADS system almost continuously. On a number of occasions gross sludge losses occurred from this unit due to failure of the sludge recycle pump and blockages in the system.

As a result of these operational problems, the solids content of the experimental ADUF and ADS units fluctuated considerably (Refer Figures 9, 10 and 11). Contrary to expectations, from these Figures it would appear as if the overall solids content of both the ADUF units tended to decline with time if all the sludge additions are discounted. Sludge losses from the ADS unit also resulted in a regular decline in the solids concentration (Figure 11). In all three units the volatile (probably active) to total solids ratio, as represented by the percentage volatile solids in the figures, showed a very slight increasing trend.

### 6.3.5 Changes in digester sludge (biomass) characteristics

No tests were performed to determine if any changes in sludge characteristics had occurred with time in the experimental units, owing mainly to financial and time limitations. The poor performance in terms of sludge retention in the experimental units also would have jeopardized any results obtained from the relatively expensive tests required to characterize the sludge samples and it was not deemed wise to proceed with these unless the tests units were operating in a stable mode.

### 6.3.6 Operation on a typical problem effluent

The original decision was to run the test units on a problem effluent such as abattoir waste or tannery waste. At this stage, however, owing to financial and time restrictions, it was decided to operate on a more conveniently available effluent. Beer brewery waste, obtainable from Ohlssons Brewery, Cape Town, was selected, as this was definitely causing expensive disposal problems for the company.

From day 222 blends of spent wine effluent and beer brewery was fed to the test units, as described in section 6.3, to acclimatize the digesters to the new feed substrate. By day 245 all three units were operating on pure beer brewery waste.

It was realized that the brewery waste contained large amounts of carbohydrate and very little protein or nitrogen, so it was anticipated that at some stage the nitrogen content would have to be supplemented by adding urea to the feed.

All three test units performed reasonably well during the conversion to brewery effluent, but as expected the alkalinity levels decreased rapidly. The waste was also very weak which resulted in very low loading rates. The digesters all showed signs of incipient failure by day 235 and urea was added to the feed (100 mg.$\ell^{-1}$) to attempt to stabilize the process. The ADS unit, which was already showing signs of digestion failure immediately after the changeover to brewery waste, continued to deteriorate and failed completely. ADUF1 showed a general drop in performance i.e. reduced COD removal and an increase in volatile acids before the test was terminated. ADUF2 continued to run well, with only a slight reduction in COD removal.

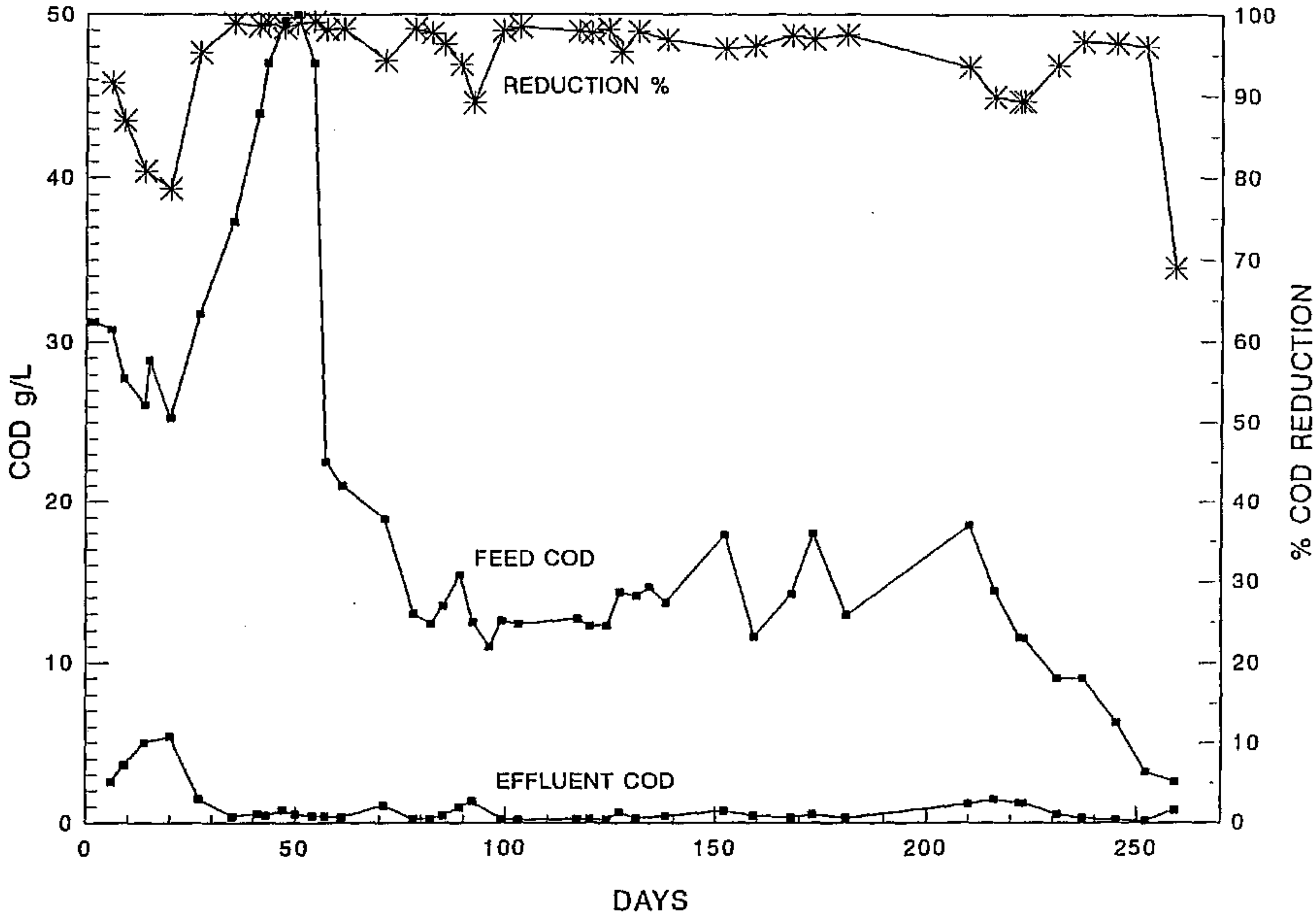


FIGURE 6: ADUF 1 - COD vs TIME

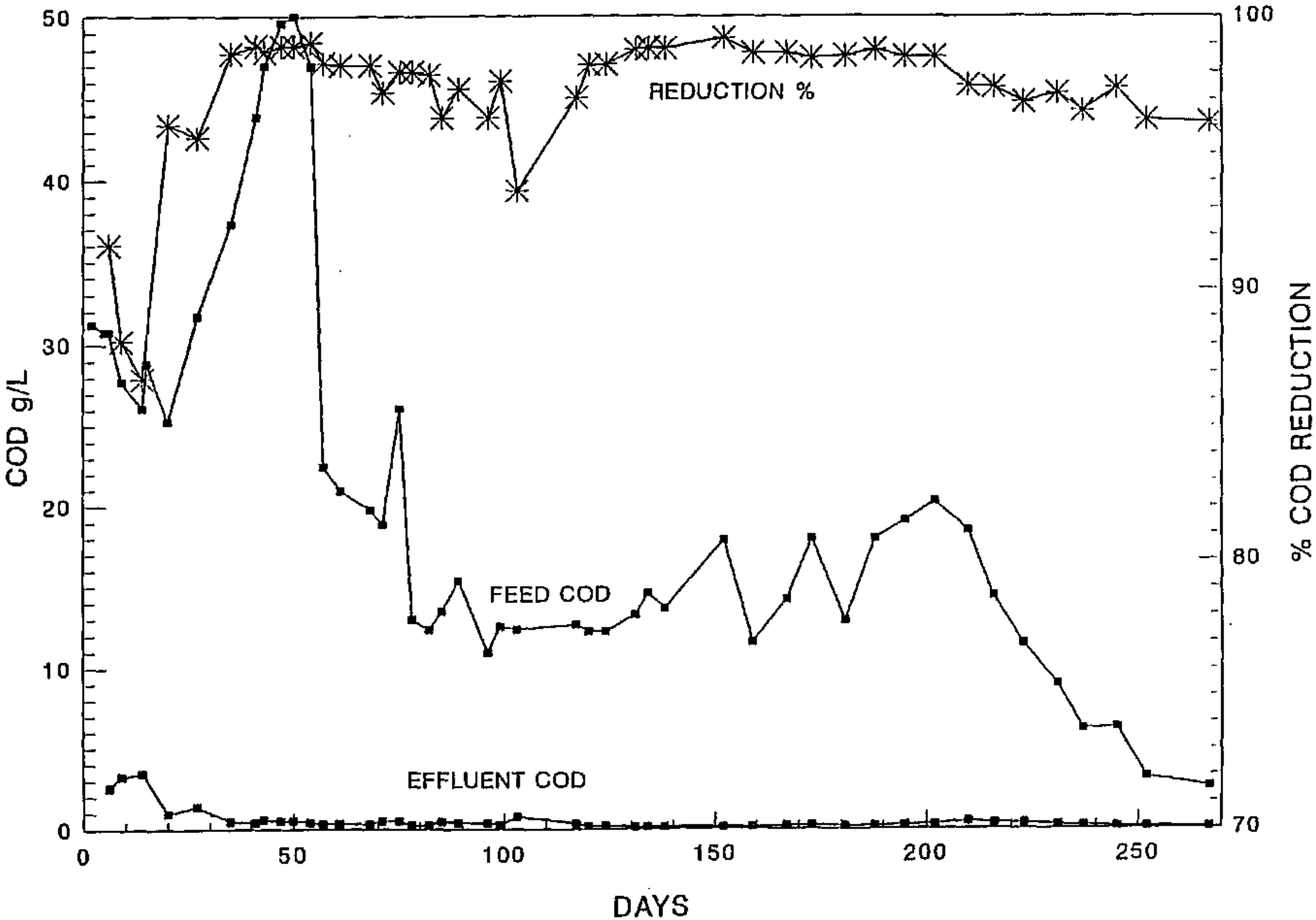


FIGURE 7: ADUF 2 - COD vs TIME

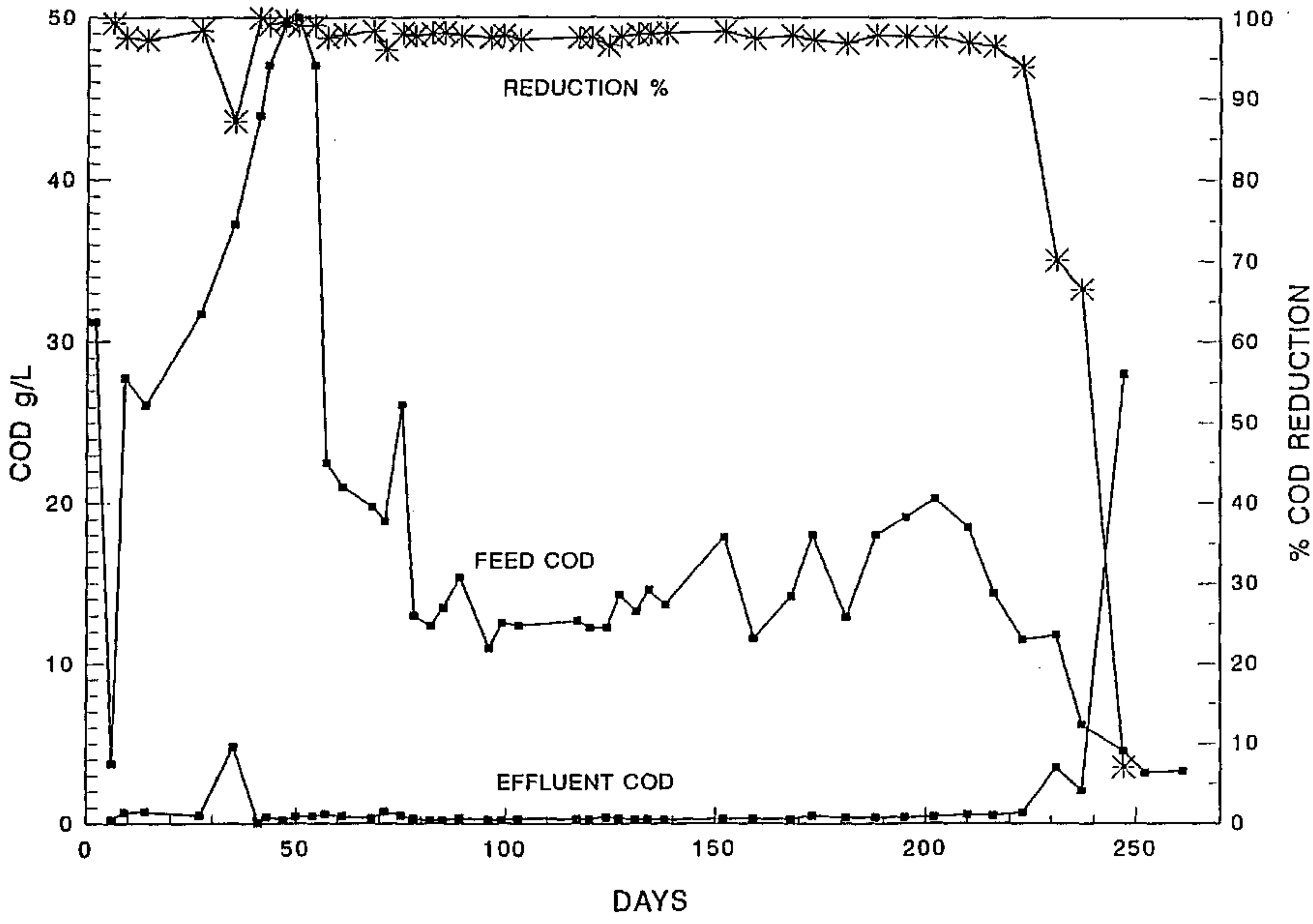


FIGURE 8: ADS - COD vs TIME

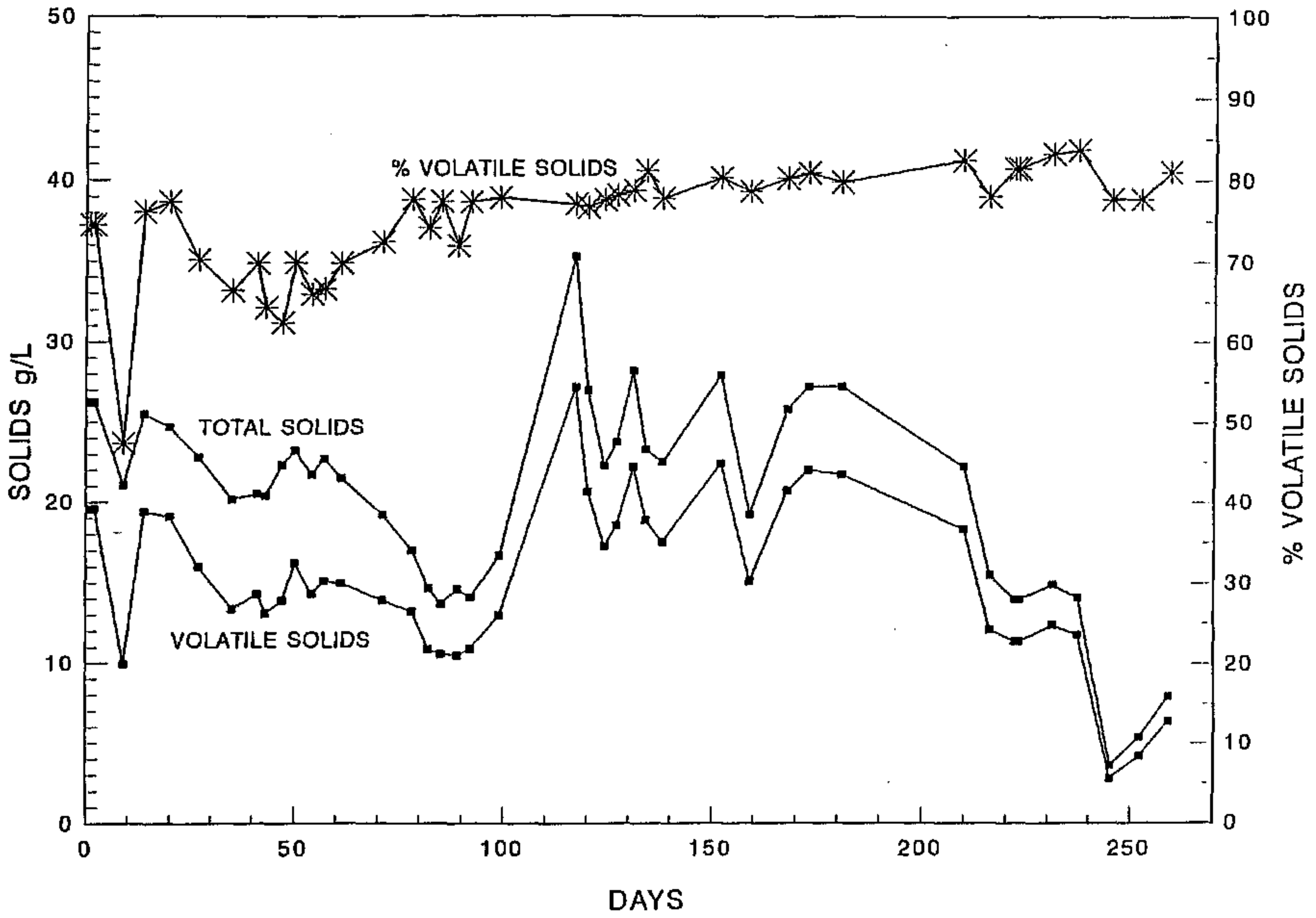


FIGURE 9: ADUF 1 - SOLIDS vs TIME

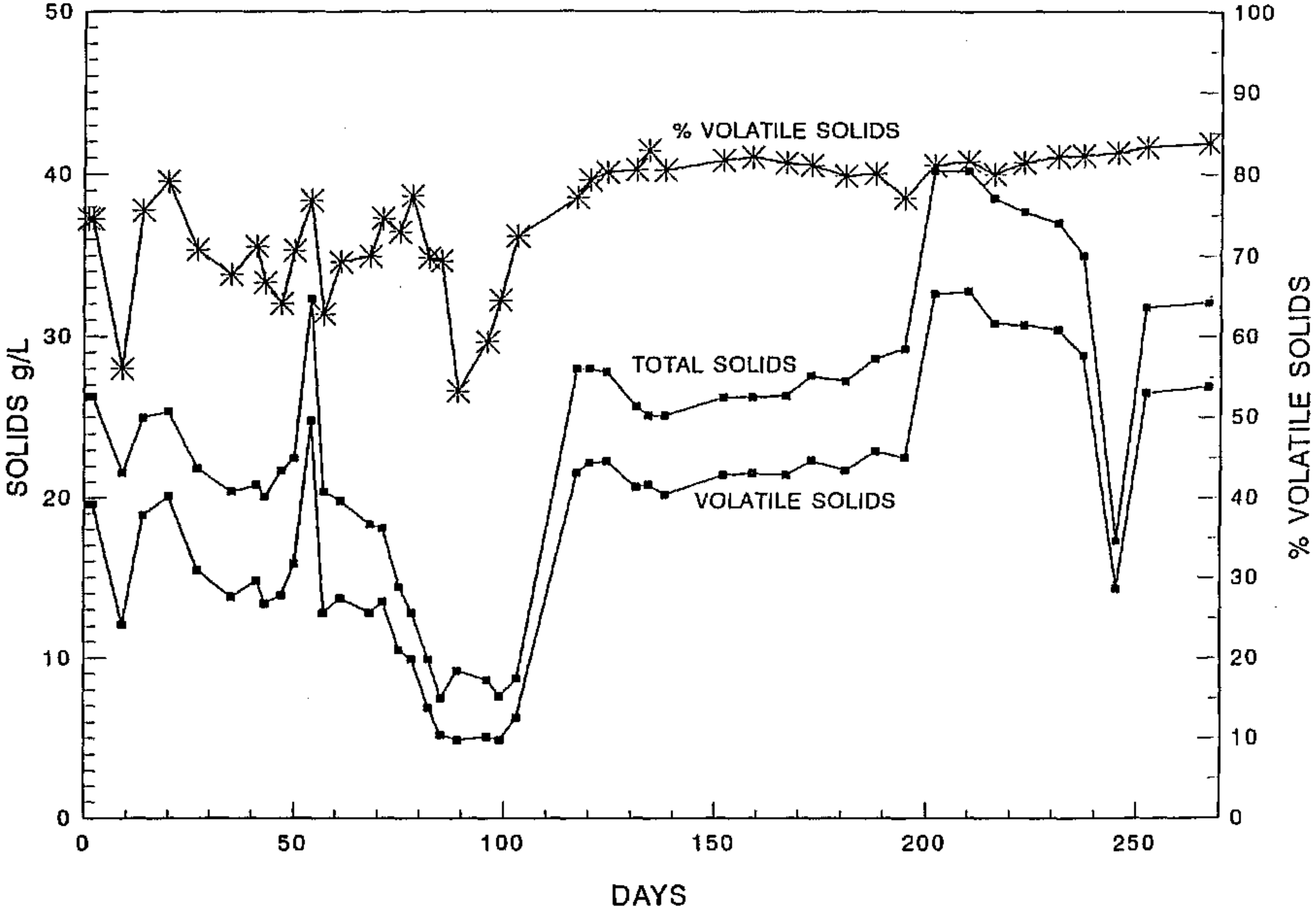


FIGURE 10: ADUF 2 - SOLIDS vs TIME

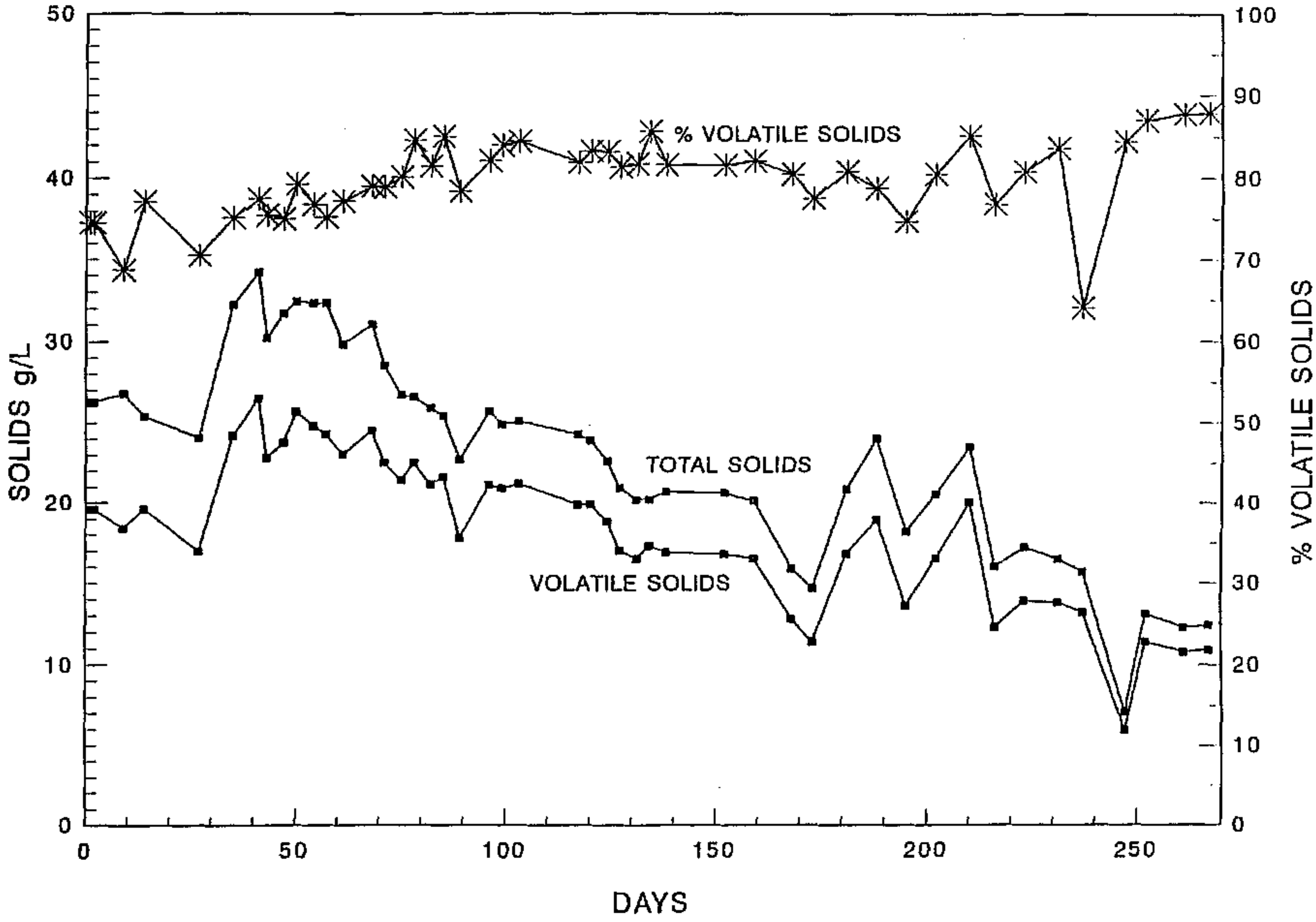


FIGURE 11: ADS - SOLIDS vs TIME

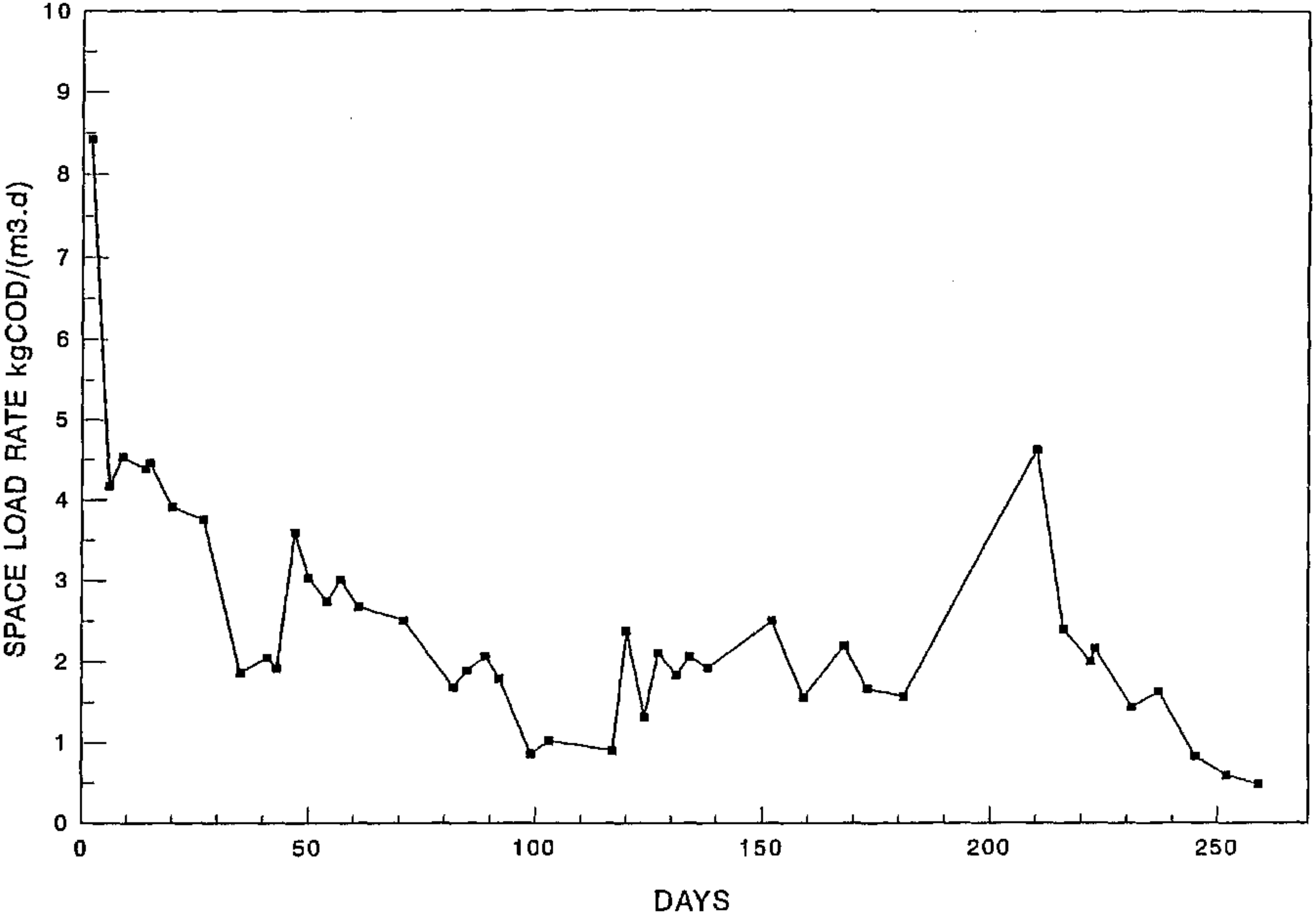


FIGURE 12: ADUF 1 - SPACE LOAD RATE vs TIME

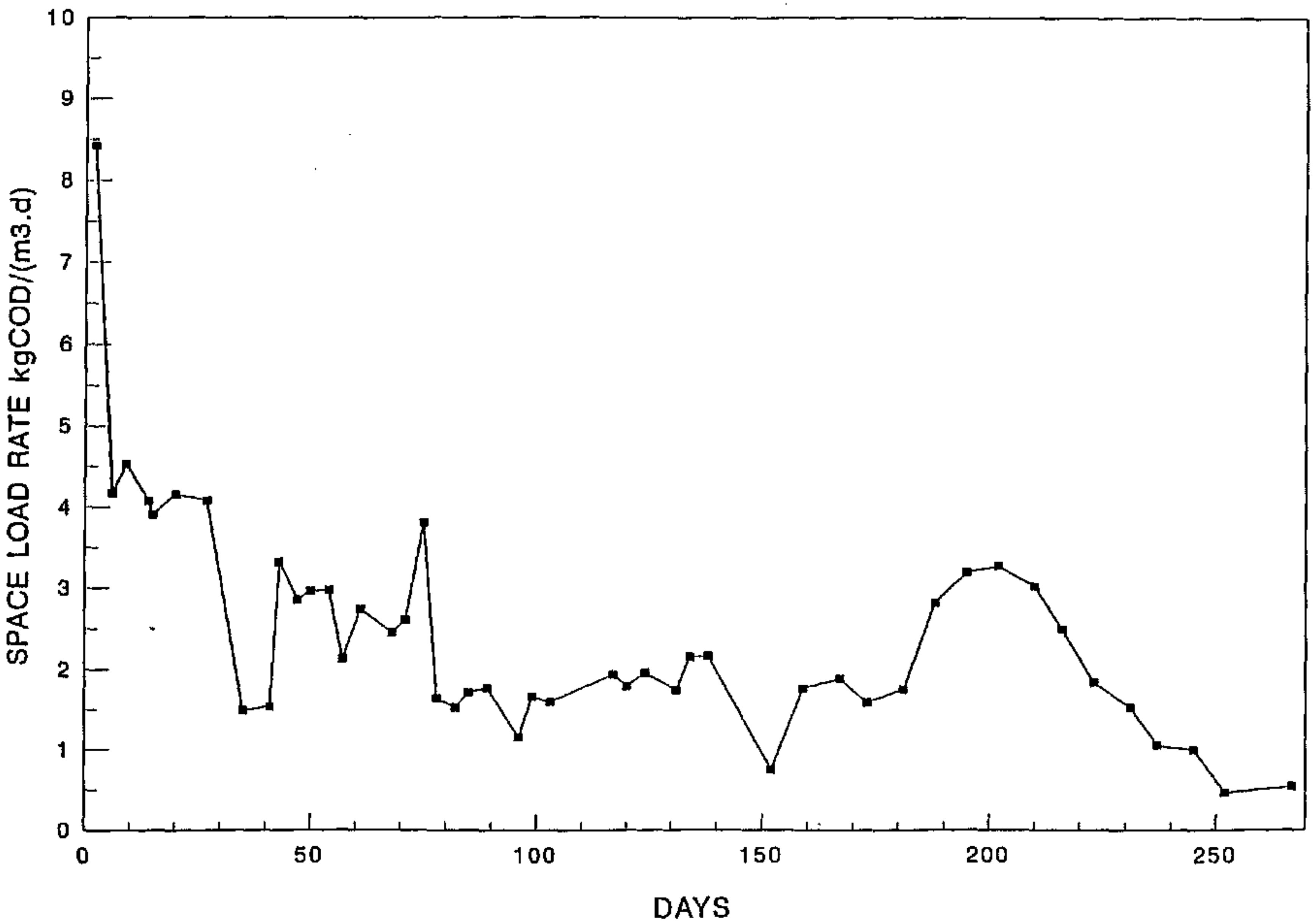


FIGURE 13: ADUF 2 - SPACE LOAD RATE vs TIME

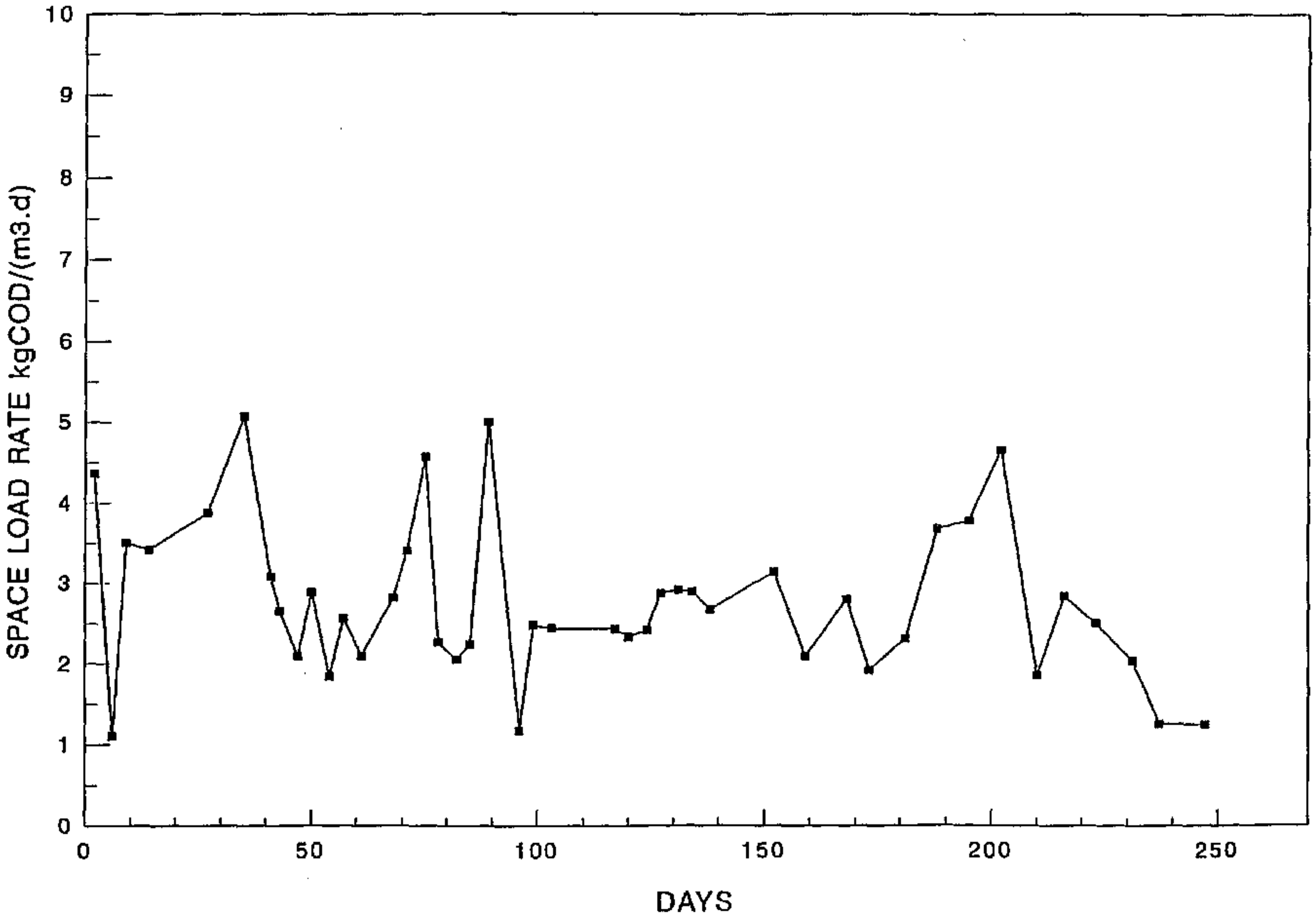


FIGURE 14: ADS - SPACE LOAD RATE vs TIME

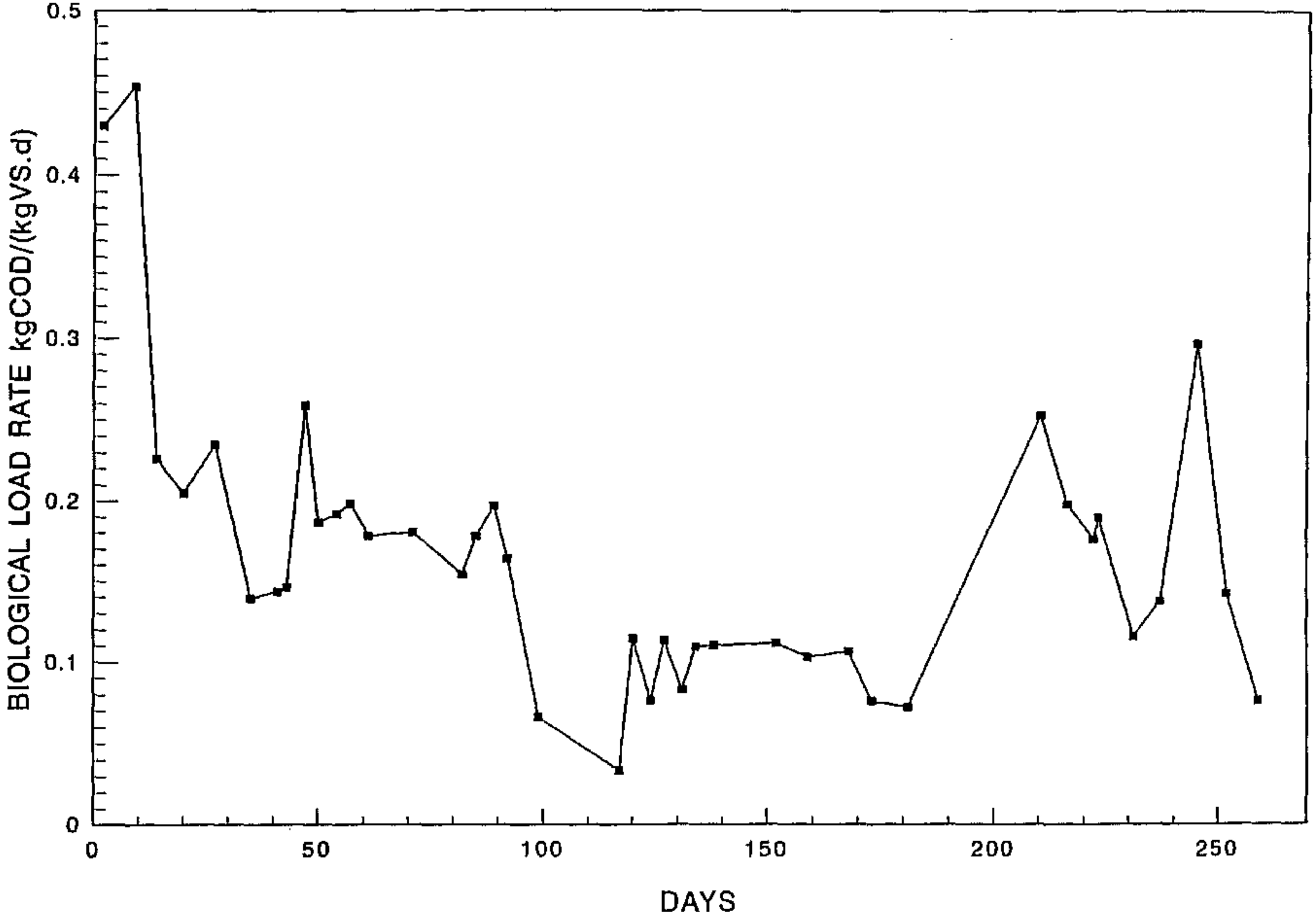


FIGURE 15: ADUF 1 - BIOLOGICAL LOAD RATE vs TIME

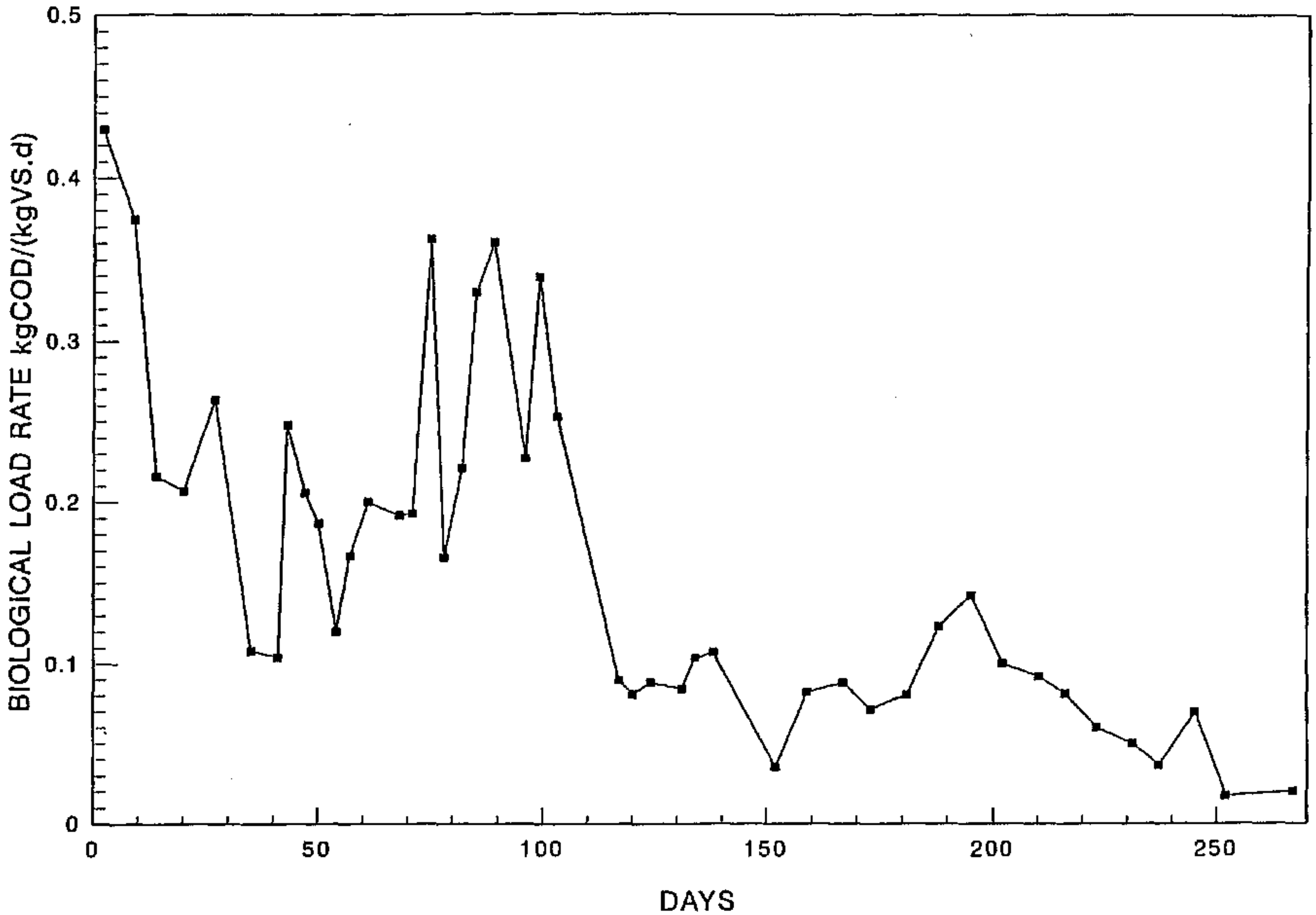


FIGURE 16: ADUF 2 - BIOLOGICAL LOAD RATE vs TIME

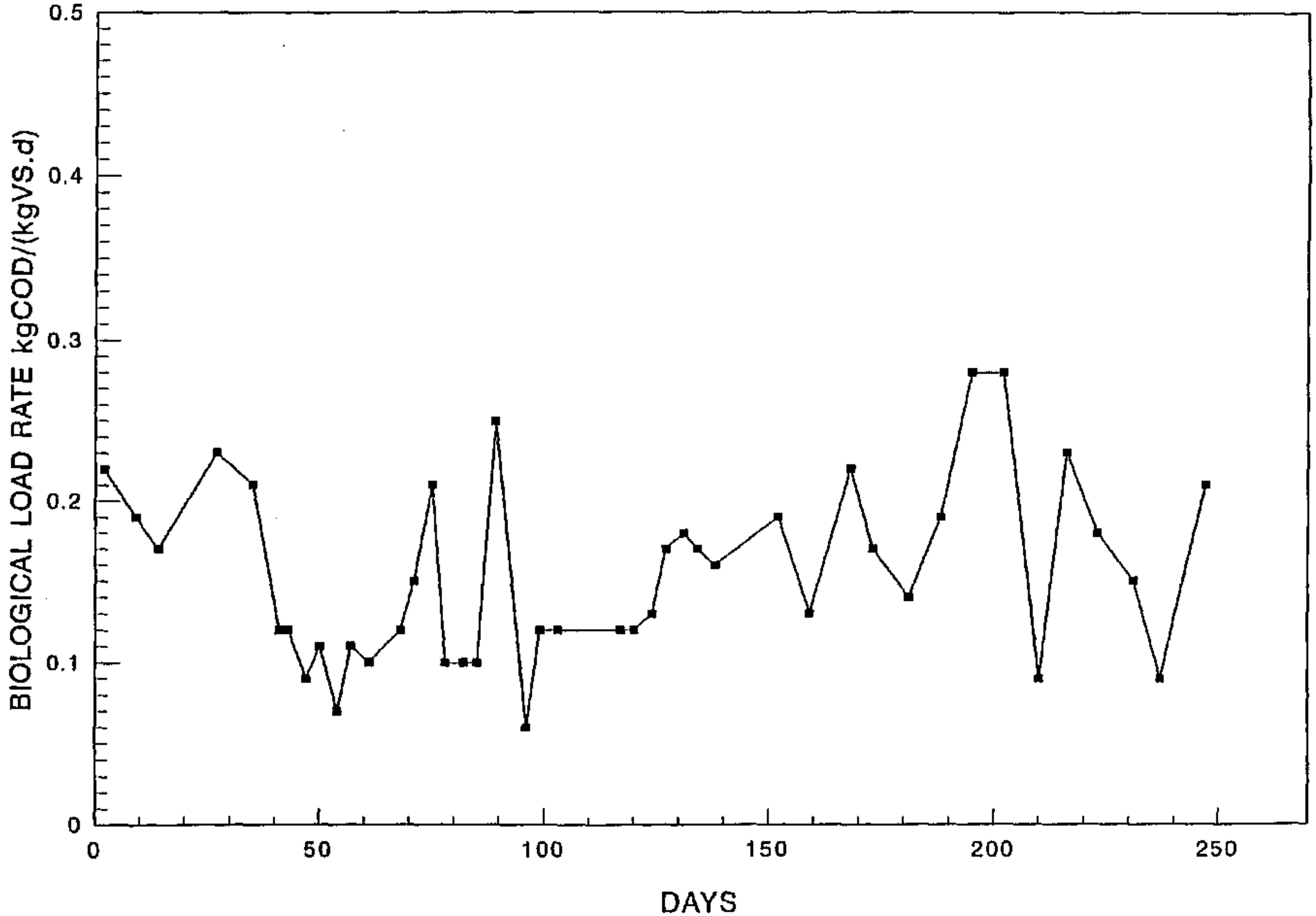


FIGURE 17: ADS - BIOLOGICAL LOAD RATE vs TIME

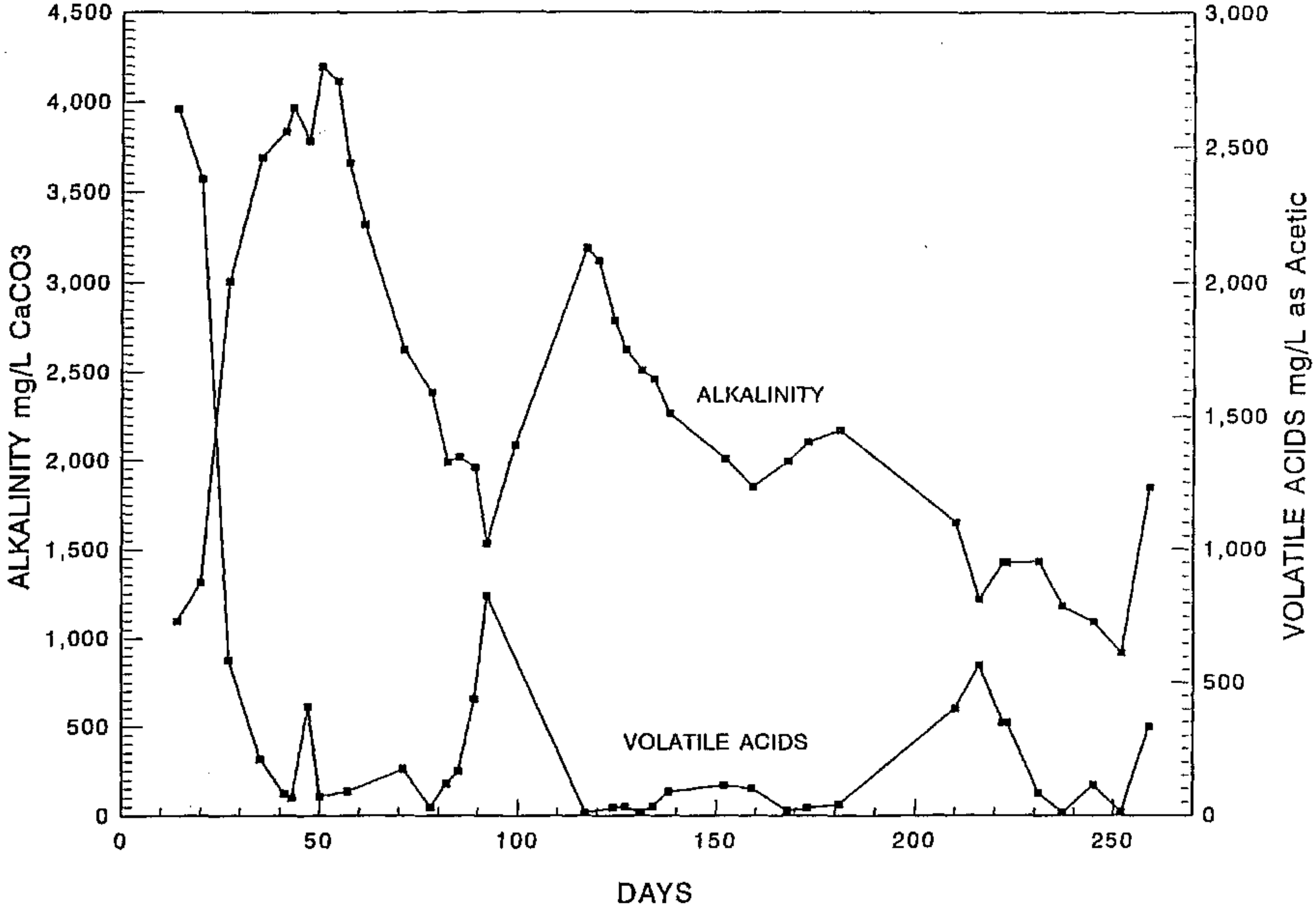


FIGURE 18: ADUF 1 - ALKALINITY AND VOLATILE ACIDS

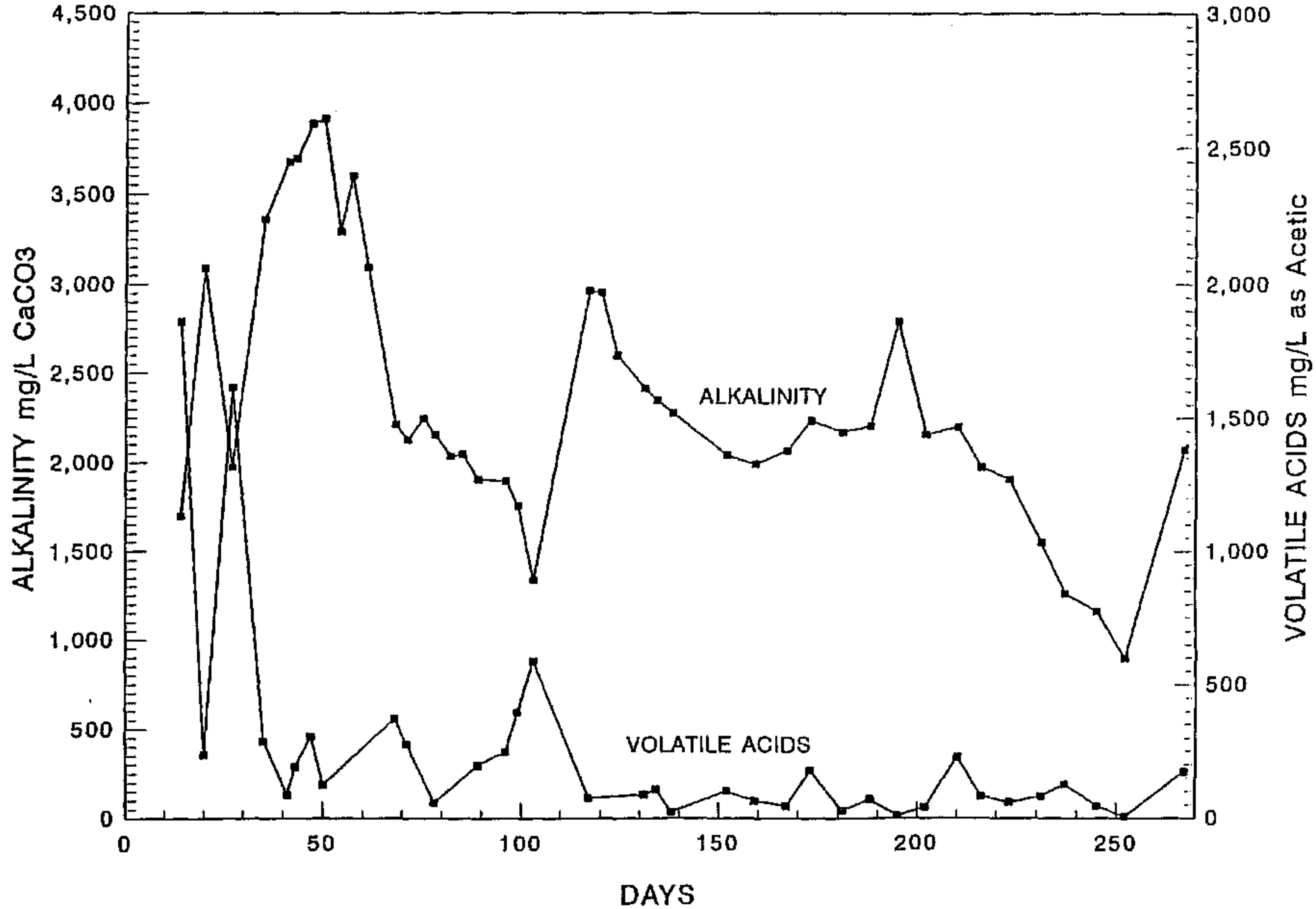


FIGURE 13: ADUF 2 - ALKALINITY AND VOLATILE ACIDS

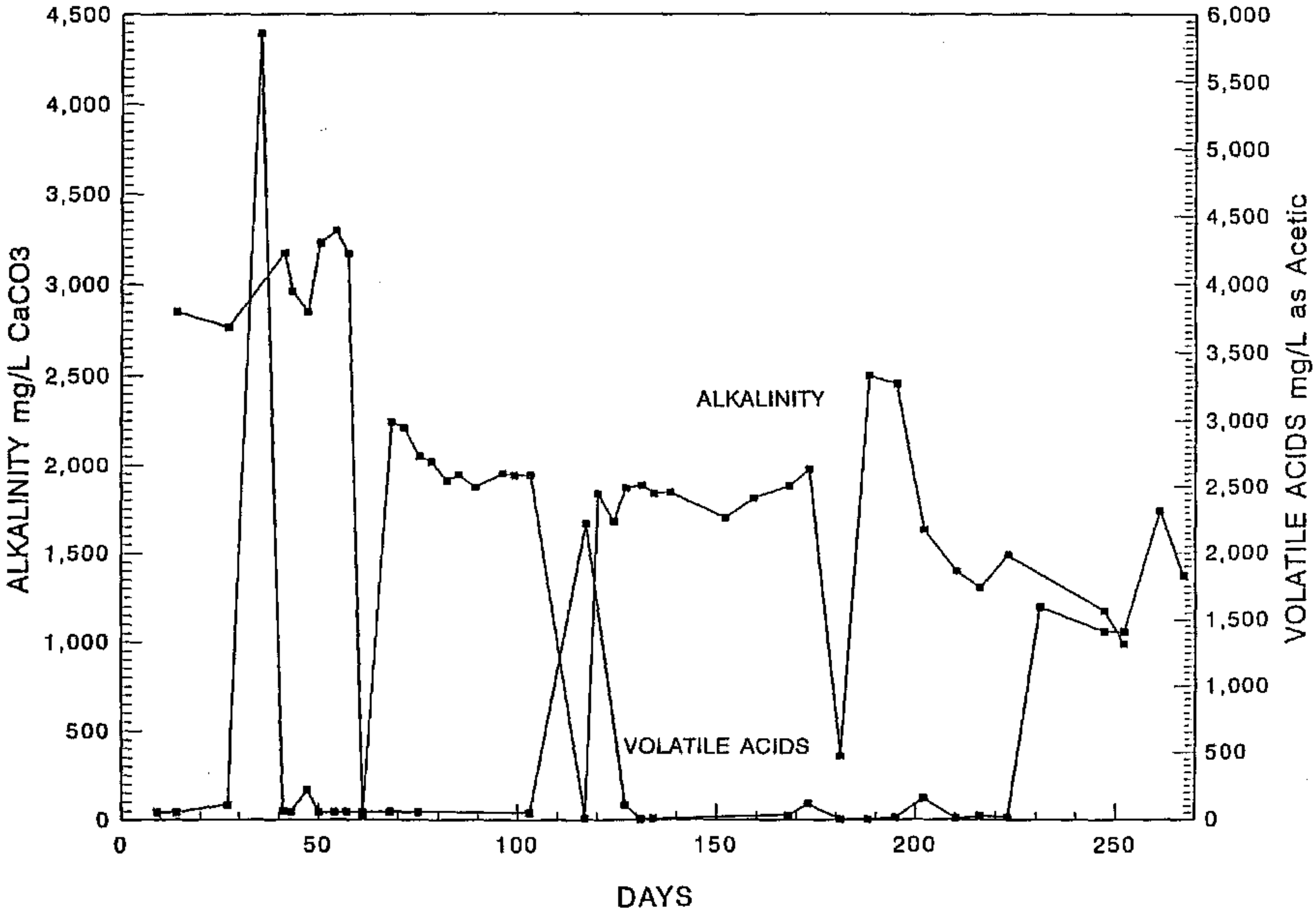


FIGURE 20: ADS - ALKALINITY AND VOLATILE ACIDS

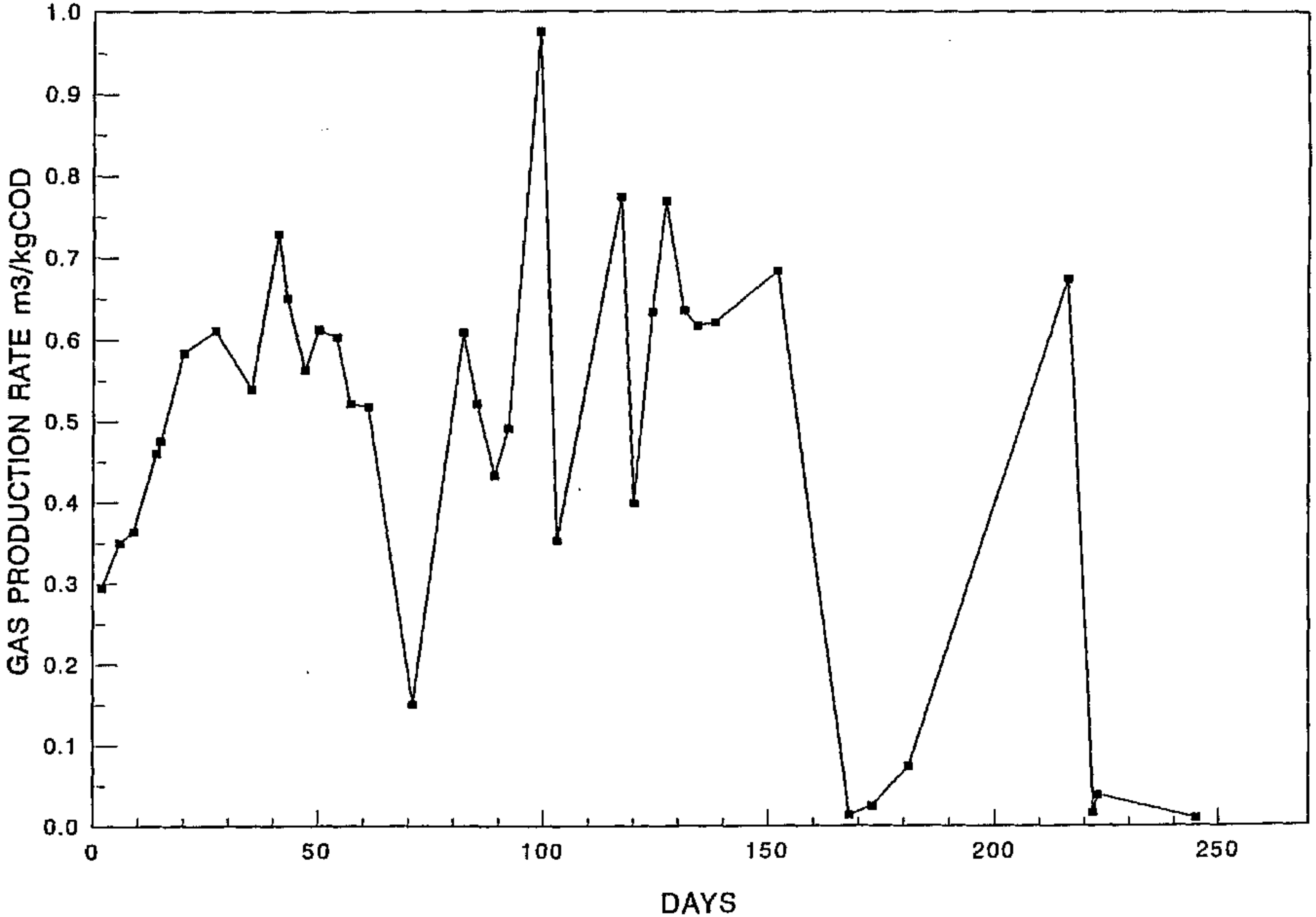


FIGURE 21: ADUF 1 - GAS PRODUCTION RATE vs TIME

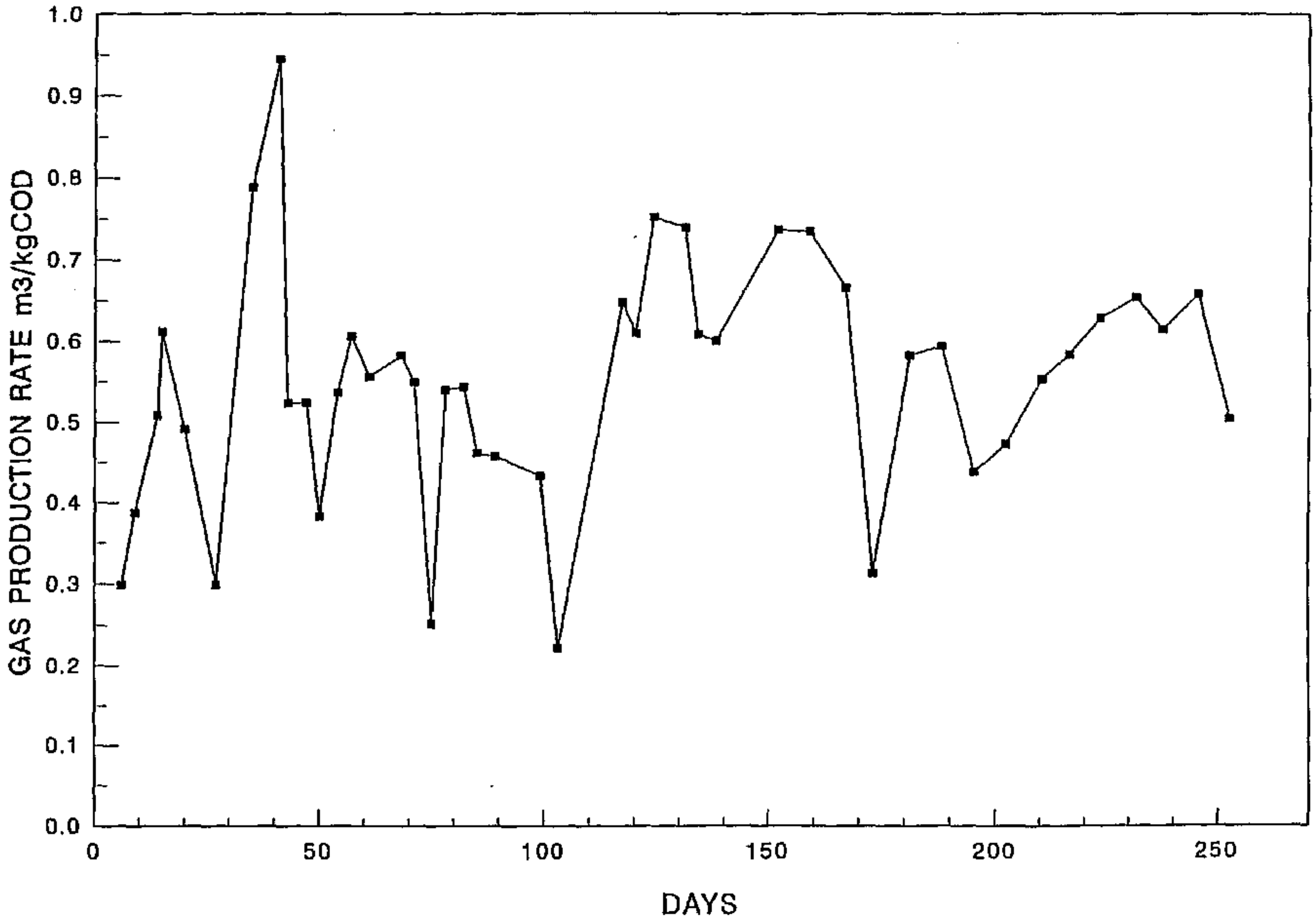


FIGURE 22: ADUF 2 - GAS PRODUCTION RATE vs TIME

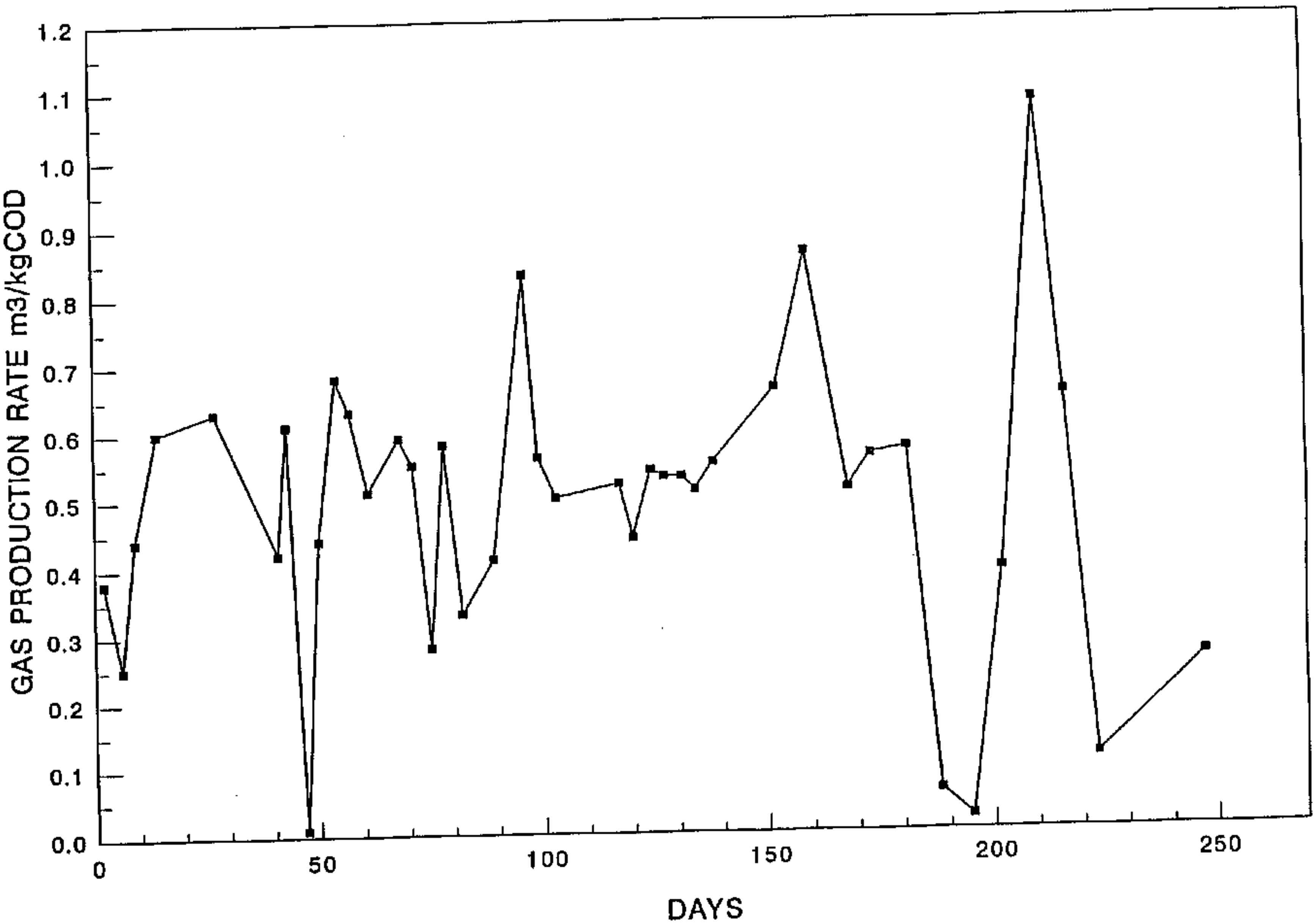


FIGURE 23: ADS - GAS PRODUCTION RATE vs TIME

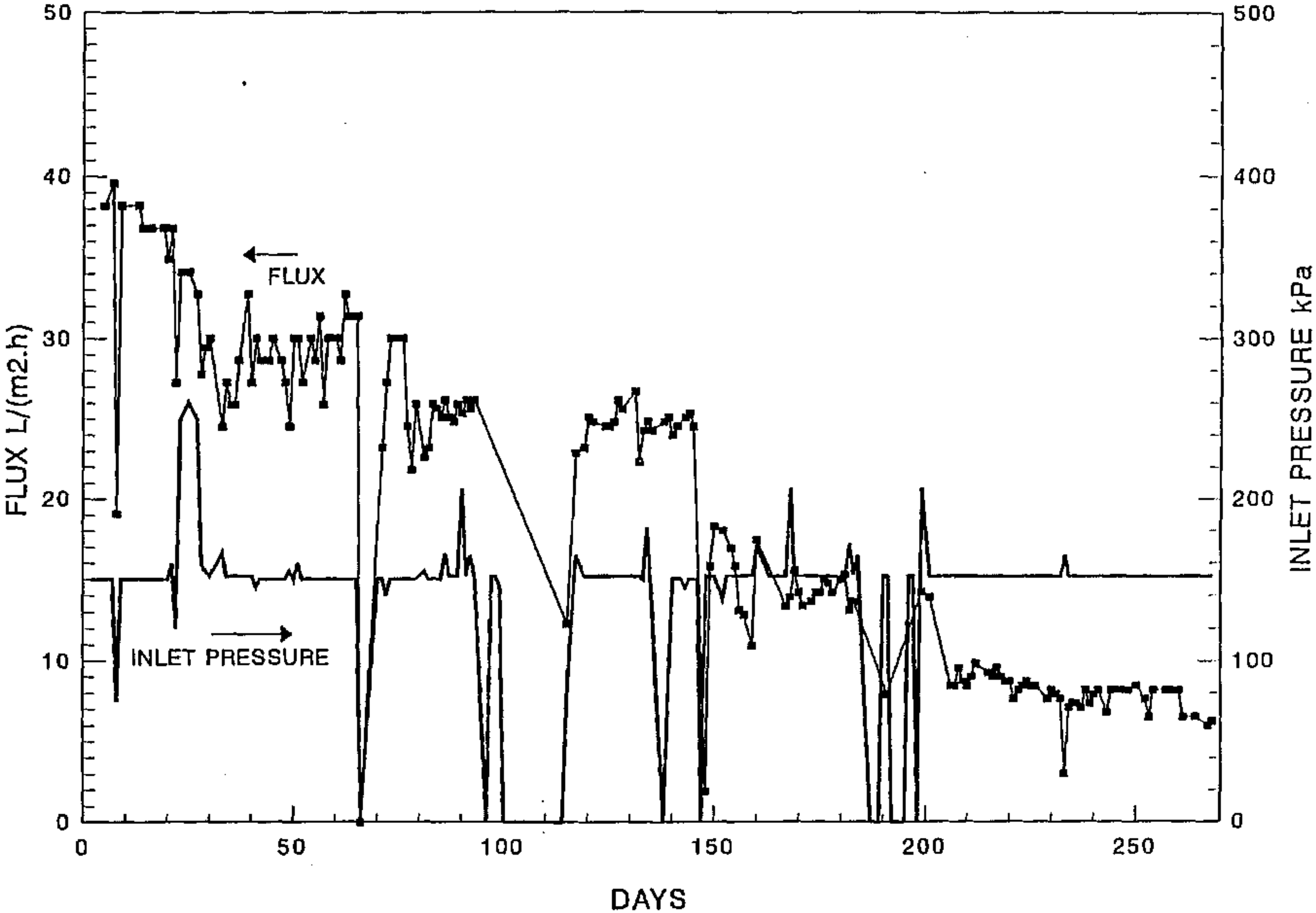


FIGURE 24: ADUF 1 - MEMBRANE FLUX & PRESSURE vs TIME

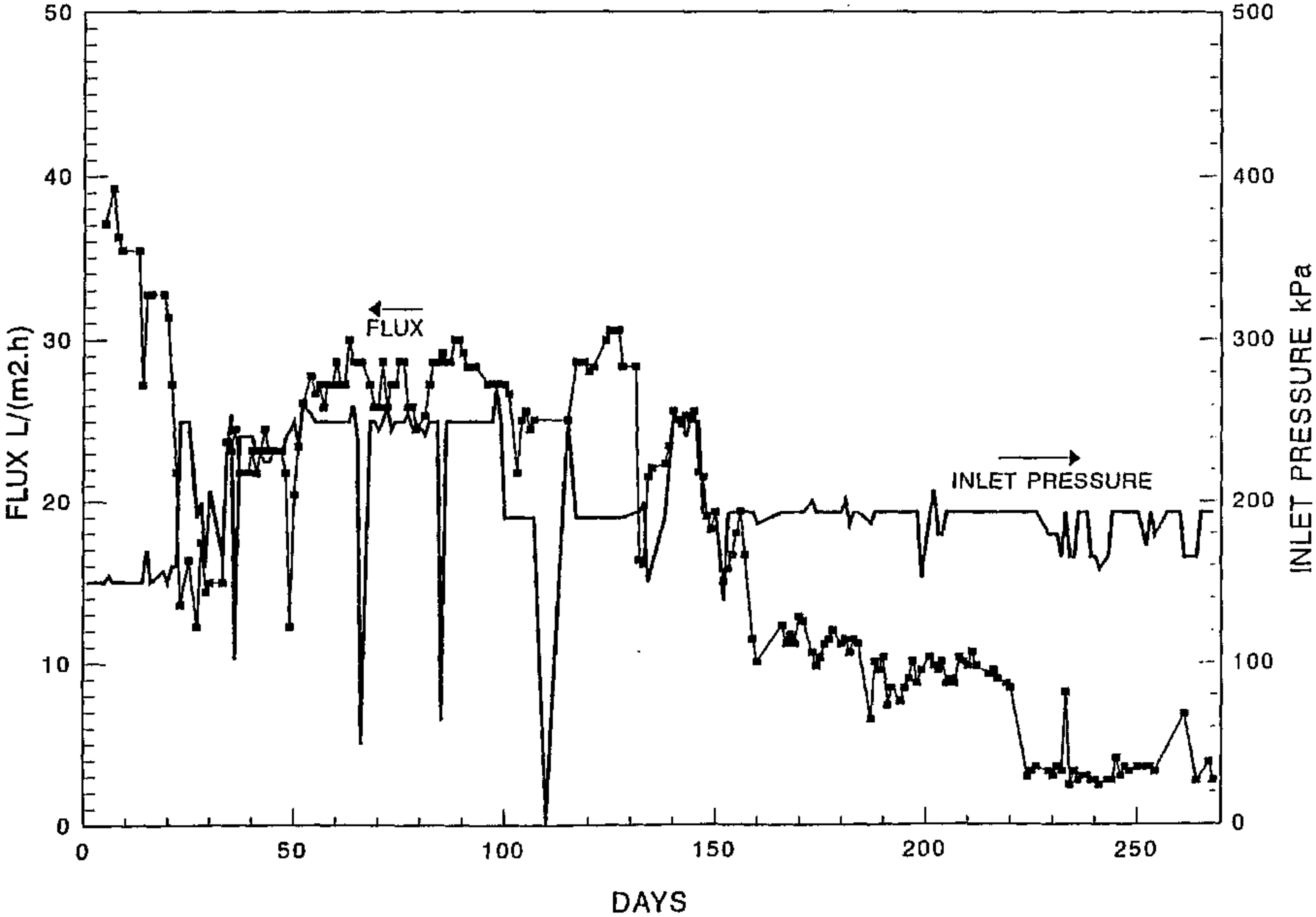


FIGURE 25: ADUF 2 - MEMBRANE FLUX & PRESSURE vs TIME

## 7. DISCUSSION

During this evaluation the ADUF units have not performed any better with regard to COD reduction or overall stability than the aerobic digester settler (ADS) unit. In terms of operational ease, the ADS unit has only experienced occasional blockages in the sludge feed pipe to the settler, while the ADUF units lost considerable amounts of sludge via foam production and leaks. The only advantages of the ADUF process that were evident from this evaluation appear to be its ability to produce a clear, low COD effluent consistently and retention of all suspended solids in the system.

The overall performance of these laboratory-scale units was poor. Although all three units maintained a COD reduction of more than 98% while operating under steady state conditions (not during periods of instability), the load rates that could be maintained were very poor. The ADUF units averaged a space load rate of approximately 2.5 kg $COD.m^{-3}.d^{-1}$, whereas larger pilot and full-scale ADUF plants have operated at rates of 11 to 15 kg $COD.m^{-3}.d^{-1}$ at hydraulic retention times of less than one day. The biological (or sludge) load rates were equally poor, averaging less than 0.15 kg $COD.kg^{-1}VS.d^{-1}$, whereas other larger units have attained 0.5 to 0.7 kg $COD.kg^{-1}VS.d^{-1}$.

The production of foam in the ADUF units is, however, a very serious drawback. It is impossible to increase the load rates beyond very modest levels without incurring large sludge losses and fouling of the gas systems, even if large foam traps are fitted to the gas outlets. The consistency of the sludge carried out in the foam is extremely fine and very "gluey", and bears no resemblance to the sludge in the digester. The reason for the formation of this very fine sludge is not clear. It may be related to the nature of the feed substrate or to the process itself. It appears to be more likely to be due to the feed substrate, as foaming problems have periodically occurred at the Paarl sewage works where spent wine is treated in anaerobic digesters with settling tanks. During the present evaluation, foam generation also occurred while the ADUF test units were operating on beer brewery waste, while no foam generation was observed on the ADS test unit. This would indicate that the foam was caused by the ADUF process itself, either by the rapid mixing action or by the pressurization of the sludge in the UF module, followed by depressurization when the sludge is returned into the digester. Alternatively, the sludge may be generating extracelluar polymers (such as those which bind fine sludge particles together to form larger sludge granules in UASB reactors) which are sheared off, go into solution and promote stable foam formation. It is probable that all these factors may play a part in the problem.

The design of the ADUF digester, with the feed to the UF module being taken off from the bottom cone, and the return flow entering near the surface, may have a bearing on the foam problem. Reversing the system, ie. feeding from bottom to top, may entrap the fine sludge and not eject it at the surface as foam. This modification was not tried, but it warrants further examination.

Membrane fouling in the ADUF units appears to be a problem that has to be managed by regular cleaning, even if the linear flow velocity is maintained at 1,6 to 2 $m.s^{-1}$. The flow rate problems experienced with the UF module on ADUF2 appears to be due to a restriction in the sludge flow path, possibly as a result of a manufacturing fault, as it requires a considerably higher pressure to achieve the same sludge throughput as ADUF1.

The rapid decline in flux on the UF modules is discouraging. Even operating at a very low inlet pressure of 150 kPa, the ADUF1 suffered a flux decline from an initial average value of 38 $\ell.m^{-2}.h^{-1}$ down to 8 $\ell.m^{-2}.h^{-1}$, or approximately at a rate of 3.4 $\ell.m^{-2}.d^{-1}$.. The flux loss of ADUF2 was slightly less at the higher inlet pressure of approximately 190 kPa. In this case the flux dropped from an initial average value of 35 $\ell.m^{-2}.h^{-1}$ down to 3 $\ell.m^{-2}.h^{-1}$, or approximately at a rate of 2.9 $\ell.m^{-2}.d^{-1}$. These high rates of flux loss are considerably more than expected and if this also occurs on full-scale plants it would seriously affect the economic viability of the ADUF process.

In general it was found that the 50 litre laboratory ADUF units are too small and too finicky to produce continuous meaningful results from which reliable design criteria can be generated. Scale effects play a very significant part in the functioning of the test units. Sludge pumping rates (and consequently mixing rates of the digester contents) to maintain adequate linear velocities in the ultrafiltration module system are far too high which appears to affect the digestion process and promote foam generation. In spite of the high mixing rate in the system, there appears to be no evidence of short circuiting of the undigested or partly digested feed substrate into the permeate from the UF unit. This would indicate that the breakdown of the feed substrate is quite rapid.

## 8. CONCLUSIONS

The tests carried out on the small (50 litre) ADUF laboratory units did not produce results which can conclusively prove the viability or otherwise of the ADUF process in treating two problem effluents, viz. spent wine waste and beer brewery waste. The units were adversely affected by scale effects and the test was hampered too frequently by disruptions and equipment malfunctions. The following conclusions can be drawn from this evaluation:

- The ADUF process did not perform better than the anaerobic digester equipped with an inclined settling tank with regard to most aspects, except that all suspended solids normally lost in the final effluent was retained in the digester.
- The generation of foam in the ADUF process severely limits the loading rate that the plant can handle. The space load rates as well as the biological load rates that could be maintained were very low when compared with those attained by larger plants.
- Short circuiting of raw or partially treated feed did not occur at the relatively low loading rates attained during this study, in spite of the high rates of digester mixing employed
- No build-up of intractable sludge residue was evident from the solids analyses.
- The rate of flux loss was far too high in both the ADUF systems. Cleaning procedures with warm water effected a temporary flux increase of approximately 10%. Over the test period the total flux declines of 3.4 $\ell.m^{-2}.d^{-1}$ and 2.9 $\ell.m^{-2}.d^{-1}$ for ADUF1 and ADUF2 was far too high for economic operation, especially if the low load rates are considered.

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# APPENDIX 1: OPERATION AND ANALYSES

TABLE I: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 1) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP ( C) | UF PRESS (kPa) | FLUX (L/m2/h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 26/03 | 16:00 | 0.00 | | | | | | | 31.2 | | 26.3 | 19.6 | 74.52 | | | | | | | |
| 2 | 27/03 | 16:00 | 24.00 | 13.5 | 124.00 | 35.9 | 150 | | | 31.2 | | 26.3 | 19.6 | 74.52 | | | | 8.42 | 0.430 | | 0.29 |
| 5 | 30/03 | 09:14 | 65.23 | 6.5 | 204.00 | 34.7 | 150 | | | | | | | | | | | | | | |
| 5 | 30/03 | 14:40 | 5.43 | | 2.95 | 34.7 | 150 | 38.18 | | | | | | | | | | | | | |
| 6 | 31/03 | 17:10 | 26.50 | 7.5 | 80.63 | 33.9 | 150 | | | 30.8 | 2.578 | | | | | | | 4.18 | | 91.6 | 0.35 |
| 7 | 01/04 | 15:45 | 22.58 | 7.0 | 78.95 | 34.5 | 150 | 39.55 | | | | | | | | | | | | | |
| 8 | 02/04 | 15:30 | 23.75 | 7.5 | 78.53 | 35.0 | 75 | 19.09 | 1.140 | | | | | | | | | | | | |
| 9 | 03/04 | 15:00 | 23.50 | 8.0 | 80.84 | 35.0 | 150 | 38.18 | 1.664 | 27.7 | 3.618 | 21.1 | 10 | 47.39 | | | | 4.53 | 0.453 | 87.0 | 0.36 |
| 13 | 07/04 | 13:43 | 94.72 | 30.5 | 384.63 | 35.2 | 150 | 38.18 | | | | | | | | | | | | | |
| 14 | 08/04 | 09:44 | 20.02 | 7.0 | 84.21 | 35.0 | 150 | 36.82 | | 26.1 | 5.020 | 25.5 | 19.4 | 76.08 | 2640 | 7.5 | 1100 | 4.38 | 0.226 | 80.8 | 0.46 |
| 15 | 09/04 | 09:00 | 23.27 | 7.5 | 102.95 | 35.0 | 150 | 36.82 | | 28.9 | | | | | | | | 4.47 | | | 0.48 |
| 16 | 10/04 | 14:02 | 29.03 | 10.0 | 126.11 | 35.0 | 150 | 36.82 | | | | | | | | | | | | | |
| 19 | 13/04 | 09:43 | 67.68 | 22.0 | 291.37 | 34.9 | 150 | 36.82 | | | | | | | | | | | | | |
| 20 | 14/04 | 10:34 | 24.85 | 8.0 | 118.11 | 35.0 | 150 | 34.91 | 1.615 | 25.3 | 5.400 | 24.7 | 19.1 | 77.33 | 2382 | 6.78 | 1320 | 3.91 | 0.205 | 78.7 | 0.58 |
| 21 | 15/04 | 09:47 | 23.22 | 5.0 | 123.16 | 35.0 | 160 | 36.82 | | | | | | | | | | | | | |
| 22 | 16/04 | 08:47 | 23.00 | 5.0 | 123.58 | 33.1 | 120 | 27.27 | | | | | | | | | | | | | |
| 23 | 17/04 | 06:56 | 22.15 | 2.0 | 91.58 | 35.0 | 250 | 34.09 | | | | | | | | | | | | | |
| 25 | 19/04 | 10:08 | 51.20 | 13.0 | 256.84 | 34.7 | 260 | 34.09 | | | | | | | | | | | | | |
| 27 | 21/04 | 08:43 | 46.58 | 11.5 | 222.74 | 32.9 | 250 | 32.73 | 1.522 | 31.7 | 1.500 | 22.8 | 16 | 70.18 | 582 | 7.33 | 3005 | 3.76 | 0.235 | 95.3 | 0.61 |
| 28 | 22/04 | 09:45 | 25.03 | 1.5 | 43.79 | 34.0 | 159 | 27.82 | 1.674 | | | | | | | | | | | | |
| 29 | 23/04 | 11:12 | 25.45 | 0.5 | 78.53 | 35.0 | 155 | 29.45 | | | | | | | | | | | | | |
| 30 | 24/04 | 14:06 | 26.90 | 5.5 | 121.89 | 35.0 | 152 | 30.00 | | | | | | | | | | | | | |
| 33 | 27/04 | 08:55 | 66.82 | 7.5 | 233.89 | 32.2 | 166 | 24.55 | | | | | | | | | | | | | |
| 34 | 28/04 | 08:53 | 23.97 | 1.0 | 41.68 | 33.4 | 152 | 27.27 | | | | | | | | | | | | | |
| 35 | 29/04 | 08:55 | 24.03 | 2.5 | 50.32 | 32.6 | 152 | 25.91 | | 37.3 | 0.400 | 20.2 | 13.4 | 66.34 | 210 | | 3690 | 1.86 | 0.139 | 98.9 | 0.54 |
| 36 | 30/04 | 08:15 | 23.33 | 3.0 | 73.26 | 32.7 | 152 | 25.91 | | | | | | | | | | | | | |
| 37 | 01/05 | 06:55 | 22.67 | 2.0 | 70.95 | 33.3 | 152 | 28.64 | | | | | | | | | | | | | |
| 39 | 03/05 | 12:36 | 53.68 | 6.5 | 177.26 | 34.8 | 152 | 32.73 | | | | | | | | | | | | | |
| 40 | 04/05 | 12:04 | 23.47 | 3.0 | 74.53 | 33.3 | 152 | 27.27 | | | | | | | | | | | | | |
| 41 | 05/05 | 08:37 | 20.55 | 2.0 | 64.00 | 34.7 | 145 | 30.00 | 1.569 | 43.9 | 0.607 | 20.5 | 14.3 | 69.76 | 84 | 7.5 | 3835 | 2.05 | 0.143 | 98.6 | 0.73 |
| 42 | 06/05 | 09:20 | 24.72 | 0.5 | 38.74 | 34.9 | 150 | 28.64 | | | | | | | | | | | | | |
| 43 | 07/05 | 08:53 | 23.55 | 2.0 | 61.05 | 34.6 | 150 | 28.64 | | 47.0 | 0.478 | 20.4 | 13.1 | 64.22 | 66 | 7.5 | 3970 | 1.92 | 0.146 | 99.0 | 0.65 |
| 44 | 08/05 | 14:12 | 29.32 | 5.5 | 125.68 | 35.0 | 150 | 28.64 | | | | | | | | | | | | | |
| 45 | 09/05 | 06:55 | 16.72 | 3.0 | 74.32 | 34.2 | 150 | 30.00 | | | | | | | | | | | | | |
| 47 | 11/05 | 08:40 | 49.75 | 7.5 | 209.26 | 32.3 | 150 | 28.64 | | 49.6 | 0.802 | 22.3 | 13.9 | 62.33 | 408 | 7.33 | 3785 | 3.59 | 0.258 | 98.4 | 0.56 |
| 48 | 12/05 | 09:16 | 24.60 | 4.1 | 107.16 | 34.9 | 150 | 27.27 | | | | | | | | | | | | | |
| 49 | 13/05 | 09:17 | 24.02 | 2.9 | 96.21 | 35.0 | 155 | 24.55 | 1.705 | | | | | | | | | | | | |
| 50 | 14/05 | 09:07 | 23.83 | 3.0 | 91.79 | 35.0 | 150 | 30.00 | | 50.0 | 0.540 | 23.2 | 16.2 | 69.83 | 72 | 7.43 | 4195 | 3.02 | 0.186 | 98.9 | 0.61 |
| 51 | 15/05 | 09:20 | 24.22 | 3.5 | 88.84 | 35.0 | 160 | 30.00 | | | | | | | | | | | | | |
| 52 | 16/05 | 06:55 | 21.58 | 2.0 | 75.16 | 34.9 | 150 | 27.27 | | | | | | | | | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | | [illegible] | 35.0 | 150 | 30.00 | | 47.0 | 0.430 | 21.7 | 14.3 | 65.90 | <60 | 7.68 | 4115 | 2.74 | 0.192 | 99.1 | 0.60 |

TABLE 1: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 1) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | UF PRESS (kPa) | FLUX (L/m2/h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/kgVS/d) | COD REDUC (%) | GAS PROD. (m3/kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55 | 19/05 | 09:20 | 25.00 | 3.5 | 81.47 | 35.0 | 150 | 28.64 | | | | | | | | | | | | | |
| 56 | 20/05 | 08:10 | 22.83 | 5.0 | 79.37 | 36.5 | 150 | 31.36 | | | | | | | | | | | | | |
| 57 | 21/05 | 09:25 | 25.25 | 7.0 | 82.11 | 35.1 | 150 | 25.91 | | 22.5 | 0.425 | 22.7 | 15.1 | 66.52 | 90 | 7.7 | 3660 | 2.99 | 0.198 | 98.1 | 0.52 |
| 58 | 22/05 | 09:25 | 24.00 | 5.0 | 77.05 | 35.0 | 150 | 30.00 | | | | | | | | | | | | | |
| 59 | 23/05 | 10:30 | 25.08 | 5.0 | 82.53 | 35.0 | 150 | 30.00 | | | | | | | | | | | | | |
| 60 | 24/05 | 10:00 | 23.50 | 5.5 | 75.37 | 35.0 | 150 | 30.00 | | | | | | | | | | | | | |
| 61 | 25/05 | 09:22 | 23.37 | 6.2 | 67.37 | 34.8 | 150 | 28.64 | 1.664 | 21.0 | 0.369 | 21.5 | 15 | 69.77 | <60 | 7.7 | 3320 | 2.67 | 0.178 | 98.2 | 0.52 |
| 62 | 26/05 | 14:15 | 28.88 | 7.8 | 93.68 | 35.0 | 150 | 32.73 | | | | | | | | | | | | | |
| 63 | 27/05 | 11:25 | 21.17 | 5.5 | 68.42 | 35.0 | 150 | 31.36 | | | | | | | | | | | | | |
| 64 | 28/05 | 10:35 | 23.17 | 5.5 | 73.47 | 34.3 | 150 | 31.36 | | | | | | | | | | | | | |
| 65 | 29/05 | 09:10 | 22.58 | 6.0 | 68.42 | 34.1 | 150 | 31.36 | | | | | | | | | | | | | |
| 66 | 30/05 | 07:10 | 22.00 | 6.5 | 40.42 | 28.1 | 0 | 0.00 | | | | | | | | | | | | | |
| 70 | 03/06 | 14:50 | 0.00 | 0.0 | 0.00 | 14.8 | 150 | - | | | | | | | | | | | | | |
| 71 | 04/06 | 10:45 | 19.92 | 5.5 | 15.58 | 35.0 | 150 | 23.18 | | 18.9 | 1.073 | 19.2 | 13.9 | 72.40 | 174 | 7.4 | 2625 | 2.51 | 0.180 | 94.3 | 0.15 |
| 72 | 05/06 | 08:10 | 21.42 | 5.0 | 13.26 | 35.0 | 140 | 27.27 | | | | | | | | | | | | | |
| 73 | 06/06 | 10:45 | 26.58 | 7.0 | 2.74 | 35.1 | 150 | 30.00 | | | | | | | | | | | | | |
| 74 | 07/06 | 10:05 | 23.33 | 6.0 | | 35.0 | 150 | 30.00 | | | | | | | | | | | | | |
| 75 | 08/06 | 10:40 | 24.58 | 7.5 | 35.79 | 35.1 | 150 | 30.00 | | | | | | | | | | | | | |
| 76 | 09/06 | 08:50 | 22.17 | 6.0 | 52.00 | 35.1 | 150 | 30.00 | | | | | | | | | | | | | |
| 77 | 10/06 | 08:10 | 23.33 | 7.0 | 54.32 | 35.1 | 150 | 24.55 | | | | | | | | | | | | | |
| 78 | 11/06 | 08:55 | 24.75 | 0.0 | 6.53 | 35.0 | 150 | 21.82 | | 13 | 0.233 | 17 | 13.2 | 77.65 | 30 | 7.3 | 2385 | | | 98.2 | |
| 79 | 12/06 | 07:00 | 22.08 | 6.5 | 50.11 | 35.0 | 150 | 25.91 | | | | | | | | | | | | | |
| 81 | 14/06 | 15:40 | 56.67 | 15.8 | 121.47 | 36.6 | 155 | 22.64 | | | | | | | | | | | | | |
| 82 | 15/06 | 08:40 | 17.00 | 4.8 | 36.21 | 35.0 | 150 | 23.18 | | 12.4 | 0.287 | 14.7 | 10.9 | 74.15 | 120 | 7.7 | 1990 | 1.68 | 0.154 | 97.7 | 0.61 |
| 83 | 16/06 | 10:00 | 25.33 | 8.4 | 62.53 | 35.7 | 150 | 25.91 | | | | | | | | | | | | | |
| 84 | 17/06 | 10:45 | 24.75 | 5.6 | 44.42 | 35.0 | 150 | 25.64 | | | | | | | | | | | | | |
| 85 | 18/06 | 08:45 | 22.00 | 6.4 | 45.05 | 35.0 | 150 | 25.09 | | 13.5 | 0.49 | 13.7 | 10.6 | 77.37 | 168 | 7.3 | 2020 | 1.89 | 0.178 | 96.4 | 0.52 |
| 86 | 19/06 | 07:55 | 23.17 | 7.0 | 47.37 | 35.0 | 166 | 26.18 | | | | | | | | | | | | | |
| 87 | 20/06 | 12:30 | 28.58 | 9.2 | 53.05 | 35.0 | 152 | 25.09 | | | | | | | | | | | | | |
| 88 | 21/06 | 13:30 | 25.00 | 6.8 | 54.53 | 35.0 | 152 | 24.82 | | | | | | | | | | | | | |
| 89 | 22/06 | 09:10 | 19.67 | 5.5 | 36.63 | 35.0 | 152 | 25.91 | | 15.4 | 0.951 | 14.6 | 10.5 | 71.92 | 438 | 7.2 | 1960 | 2.07 | 0.197 | 93.8 | 0.43 |
| 90 | 23/06 | 14:00 | 28.83 | 7.7 | 53.68 | 35.5 | 207 | 25.36 | | | | | | | | | | | | | |
| 91 | 24/06 | 08:50 | 18.83 | 5.4 | 31.37 | 35.0 | 152 | 26.18 | | | | | | | | | | | | | |
| 92 | 25/06 | 08:20 | 23.50 | 7.0 | 42.95 | 35.0 | 165 | 25.64 | | 12.5 | 1.349 | 14.1 | 10.9 | 77.30 | 828 | 7.1 | 1535 | 1.79 | 0.164 | 89.2 | 0.49 |
| 93 | 26/06 | 08:00 | 23.67 | 6.8 | 43.58 | 34.9 | 152 | 26.18 | | | | | | | | | | | | | |
| 96 | 29/06 | 11:40 | 75.67 | 0.0 | | 20.0 | 0 | | | 11 | | | | | | | | | | | |
| 97 | 30/06 | 17:15 | 29.58 | 0.1 | 6.95 | 16.6 | 152 | | | | | | | | | | | | | | |
| 98 | 01/07 | 10:45 | 17.50 | 2.8 | 14.53 | 32.7 | 152 | | | | | | | | | | | | | | |
| 99 | 02/07 | 08:30 | 21.75 | 3.1 | 38.11 | 35.1 | 145 | | | 12.6 | 0.255 | 16.7 | 13 | 77.84 | <60 | 7.4 | 2085 | 0.86 | 0.066 | 98.0 | 0.98 |
| 100 | 03/07 | 08:15 | 23.75 | 4.2 | 29.47 | 35.4 | 0 | | | | | | | | | | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 35.1 | 0 | | | | | | | | | | | | | | |

TABLE 1: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 1) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP ( C) | UF PRESS (kPa) | FLUX (L/m2/h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 103 | 06/07 | 11:40 | 52.75 | 9.1 | 39.79 | 0.0 | 0 | | | 12.4 | 0.195 | | | | | | | 1.03 | | 98.4 | 0.35 |
| 104 | 07/07 | 10:00 | 22.33 | 0.0 | | 0.0 | 0 | | | | | | | | | | | | | | |
| 105 | 08/07 | 09:00 | 23.00 | 0.0 | | 0.0 | 0 | | | | | | | | | | | | | | |
| 106 | 09/07 | 09:30 | 24.50 | 0.0 | | 0.0 | 0 | | | | | | | | | | | | | | |
| 107 | 10/07 | 08:15 | 22.75 | 0.0 | | 0.0 | 0 | | | | | | | | | | | | | | |
| 110 | 13/07 | 10:45 | 74.50 | 0.0 | | 0.0 | 0 | | | | | | | | | | | | | | |
| 111 | 14/07 | 14:15 | 27.50 | 0.0 | | 0.0 | 0 | | | | | | | | | | | | | | |
| 112 | 15/07 | 08:00 | 17.75 | 0.0 | | 0.0 | 0 | | | | | | | | | | | | | | |
| 113 | 16/07 | 13:55 | 29.92 | 0.0 | | 0.0 | 0 | | | | | | | | | | | | | | |
| 114 | 17/07 | 13:30 | 23.58 | 0.0 | | 18.7 | 0 | | | | | | | | | | | | | | |
| 115 | 18/07 | 11:30 | 22.00 | 4.0 | 24.21 | 34.2 | 76 | 12.27 | | | | | | | | | | | | | |
| 117 | 20/07 | 10:35 | 47.08 | 7.0 | 68.84 | 34.6 | 165 | 22.91 | | 12.7 | 0.263 | 35.3 | 27.2 | 77.05 | 12 | 7.3 | 3190 | 0.91 | 0.033 | 97.9 | 0.77 |
| 119 | 22/07 | 09:00 | 46.42 | 10.2 | 92.63 | 35.1 | 152 | 23.18 | | | | | | | | | | | | | |
| 120 | 23/07 | 07:40 | 22.67 | 9.1 | 44.63 | 34.2 | 152 | 25.09 | | 12.3 | 0.28 | 27 | 20.7 | 76.67 | <60 | 7.2 | 3120 | 2.37 | 0.115 | 97.7 | 0.40 |
| 121 | 24/07 | 09:30 | 25.83 | 6.0 | 47.37 | 35.8 | 152 | 24.82 | | | | | | | | | | | | | |
| 124 | 27/07 | 11:30 | 74.00 | 16.5 | 128.42 | 34.7 | 152 | 24.55 | | 12.3 | 0.23 | 22.3 | 17.3 | 77.58 | 30 | 7.3 | 2790 | 1.32 | 0.076 | 98.1 | 0.63 |
| 125 | 28/07 | 14:30 | 27.00 | 6.0 | 47.37 | 33.7 | 152 | 24.55 | | | | | | | | | | | | | |
| 126 | 29/07 | 11:00 | 20.50 | 8.9 | 43.16 | 33.7 | 152 | 24.82 | | | | | | | | | | | | | |
| 127 | 30/07 | 08:30 | 21.50 | 6.6 | 72.63 | 34.3 | 152 | 26.18 | | 14.3 | 0.667 | 23.8 | 18.6 | 78.15 | 36 | 7.2 | 2625 | 2.11 | 0.113 | 95.3 | 0.77 |
| 128 | 31/07 | 08:50 | 24.33 | 7.5 | 54.53 | 34.8 | 152 | 25.64 | | | | | | | | | | | | | |
| 131 | 03/08 | 10:30 | 73.67 | 20.0 | 179.16 | 39.4 | 152 | 26.73 | | 14.1 | 0.298 | 28.2 | 22.2 | 78.72 | 12 | 7.2 | 2510 | 1.84 | 0.083 | 97.9 | 0.64 |
| 132 | 04/08 | 10:30 | 24.00 | 6.5 | 66.74 | 37.1 | 152 | 22.36 | | | | | | | | | | | | | |
| 133 | 05/08 | 10:30 | 24.00 | 7.5 | 67.37 | 38.0 | 150 | 24.27 | | | | | | | | | | | | | |
| 134 | 06/08 | 10:55 | 24.42 | 7.2 | 64.84 | 37.3 | 182 | 24.82 | | 14.6 | | 23.3 | 18.9 | 81.12 | 36 | 7.3 | 2460 | 2.07 | 0.109 | | 0.62 |
| 135 | 07/08 | 15:00 | 28.08 | 6.5 | 66.95 | 40.6 | 140 | 24.27 | | | | | | | | | | | | | |
| 138 | 10/08 | 09:40 | 66.67 | 19.5 | 165.89 | 35.2 | 0 | 24.82 | | 13.7 | 0.437 | 22.5 | 17.5 | 77.78 | 90 | 7.1 | 2265 | 1.92 | 0.110 | 96.8 | 0.62 |
| 139 | 11/08 | 11:00 | 25.33 | 7.0 | 50.74 | 34.0 | | 25.09 | | | | | | | | | | | | | |
| 140 | 12/08 | 08:05 | 21.08. | 7.0 | 41.89 | 34.6 | 150 | 24.00 | | | | | | | | | | | | | |
| 141 | 13/08 | 15:00 | 30.92 | 8 | 68.42 | 35.2 | 150 | 24.55 | | | | | | | | | | | | | |
| 142 | 14/08 | 14:00 | 23.00 | 0 | 25.26 | 33.6 | 150 | | | | | | | | | | | | | | |
| 143 | 15/08 | 11:30 | 21.50 | 6.1 | 36.84 | 34.1 | 145 | 25.09 | | | | | | | | | | | | | |
| 144 | 16/08 | 10:50 | 23.33 | 5.9 | 52.21 | 33.6 | 150 | 25.36 | | | | | | | | | | | | | |
| 145 | 17/08 | 10:50 | 24.00 | 6.3 | 84.00 | 35.1 | 150 | 24.55 | | | | | | | | | | | | | |
| 146 | 18/08 | 10:50 | 24.00 | 6.7 | 87.37 | 35.3 | 150 | | | | | | | | | | | | | | |
| 147 | 19/08 | 08:25 | 21.58 | 0 | 24.21 | 34.9 | 0 | | | | | | | | | | | | | | |
| 148 | 20/08 | 08:35 | 24.17 | 7 | 52.84 | 34.6 | 152 | 1.91 | | | | | | | | | | | | | |
| 149 | 21/08 | 08:55 | 24.33 | 7.9 | 93.68 | 35.8 | 152 | 15.82 | | | | | | | | | | | | | |
| 150 | 22/08 | 06:55 | 22.00 | 5.9 | 61.47 | 35.2 | 152 | 18.27 | | | | | | | | | | | | | |
| 152 | 24/08 | 09:13 | 50.30 | 14.6 | 178.53 | 34.9 | 138 | 18.00 | | 17.9 | 0.749 | 27.9 | 22.4 | 80.29 | 114 | 7.1 | 2010 | 2.49 | 0.111 | 95.8 | 0.68 |
| 153 | 25/08 | 12:40 | 27.45 | 7.5 | 82.95 | 24.4 | 152 | | | | | | | | | | | | | | |

TABLE I: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 1) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | UF PRESS (kPa) | FLUX (L/m2/h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/kgVS/d) | COD REDUC (%) | GAS PROD. (m3/kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 155 | 27/08 | 12:30 | 27.00 | 7.5 | 60.42 | 34.1 | 152 | 15.82 | | | | | | | | | | | | | |
| 156 | 28/08 | 10:30 | 22.00 | 6.3 | 25.26 | 34.4 | 152 | 13.09 | | | | | | | | | | | | | |
| 157 | 29/08 | 07:09 | 20.65 | 5.2 | | 33.7 | 152 | 12.82 | | | | | | | | | | | | | |
| 159 | 31/08 | 11:07 | 51.97 | 14.5 | | 34.6 | 152 | 10.91 | | 11.6 | 0.45 | 19.2 | 15.1 | 78.65 | 102 | 7 | 1850 | 1.55 | 0.103 | 96.1 | |
| 160 | 01/09 | 11:30 | 24.38 | 6 | 26.32 | 34.6 | 170 | 17.45 | | | | | | | | | | | | | |
| 163 | 04/09 | 14:00 | 74.50 | 21 | 2.95 | 34.5 | 152 | | | | | | | | | | | | | | |
| 166 | 07/09 | 12:40 | 70.67 | 22 | | 35 | 152 | | | | | | | | | | | | | | |
| 167 | 08/09 | 11:30 | 22.83 | 5.5 | | 35.1 | 152 | 13.36 | | | | | | | | | | | | | |
| 168 | 09/09 | 10:45 | 23.25 | 7.5 | 1.47 | 35 | 207 | 13.91 | | 14.2 | 0.363 | 25.8 | 20.7 | 80.23 | 18 | 7.2 | 1995 | 2.20 | 0.106 | 97.4 | 0.01 |
| 169 | 10/09 | 12:20 | 25.58 | 11.5 | | 34.1 | 152 | 15.55 | | | | | | | | | | | | | |
| 170 | 11/09 | 11:50 | 23.50 | 2.9 | 18.11 | 34.8 | 152 | 14.18 | | | | | | | | | | | | | |
| 171 | 12/09 | 06:50 | 19.00 | 5.6 | 2.11 | 35.1 | 152 | 13.36 | | | | | | | | | | | | | |
| 173 | 14/09 | 10:50 | 52.00 | 10 | 4.42 | 35 | 152 | 13.64 | | 18 | 0.542 | 27.2 | 22 | 80.88 | 30 | 7.2 | 2105 | 1.66 | 0.076 | 97.0 | 0.02 |
| 174 | 15/09 | 08:10 | 21.33 | 5.5 | 0.21 | 35.1 | 152 | 14.18 | | | | | | | | | | | | | |
| 175 | 16/09 | 08:40 | 24.50 | 7.1 | | 35.4 | 152 | 14.18 | | | | | | | | | | | | | |
| 176 | 17/09 | 13:50 | 29.17 | 7.9 | 17.68 | 35.1 | 152 | 15.00 | | | | | | | | | | | | | |
| 177 | 18/09 | 14:50 | 25.00 | 8 | 2.32 | 35 | 152 | 14.73 | | | | | | | | | | | | | |
| 178 | 19/09 | 10:45 | 19.92 | 6.1 | 3.16 | 35.1 | 152 | 14.18 | | | | | | | | | | | | | |
| 180 | 21/09 | 16:00 | 53.25 | 15.5 | | 35.3 | 152 | 15.00 | | | | | | | | | | | | | |
| 181 | 22/09 | 07:50 | 15.83 | 4 | 3.79 | 34.2 | 152 | 15.27 | | 12.9 | 0.321 | 27.2 | 21.7 | 79.78 | 42 | 7.1 | 2170 | 1.56 | 0.072 | 97.5 | 0.07 |
| 182 | 23/09 | 08:35 | 24.75 | 8.5 | 5.89 | 32.8 | 172 | 13.09 | | | | | | | | | | | | | |
| 183 | 24/09 | 16:00 | 31.42 | 11.3 | 26.32 | 28.1 | 152 | 13.64 | | | | | | | | | | | | | |
| 184 | 25/09 | 08:48 | 16.80 | 0 | | 17.7 | 165 | | | | | | | | | | | | | | |
| 187 | 28/09 | 16:15 | 79.45 | 1.5 | 7.37 | 19.2 | 0 | | | | | | | | | | | | | | |
| 188 | 29/09 | 08:42 | 16.45 | 6.5 | 5.47 | 35.3 | 0 | | | | | | | | | | | | | | |
| 189 | 30/09 | 08:39 | 23.95 | 7.3 | 20.42 | 35.2 | 0 | | | | | | | | | | | | | | |
| 190 | 01/10 | 11:20 | 26.68 | 8.7 | 6.74 | 35.1 | 152 | | | | | | | | | | | | | | |
| 191 | 02/10 | 08:20 | 21.00 | 7 | 5.89 | 35 | 152 | 7.91 | | | | | | | | | | | | | |
| 192 | 03/10 | 07:03 | 22.72 | 8.3 | 49.89 | 35.2 | 0 | | | | | | | | | | | | | | |
| 194 | 05/10 | 11:20 | 52.28 | 0 | | 17.4 | 0 | | | | | | | | | | | | | | |
| 195 | 06/10 | 09:40 | 22.33 | 0.2 | | 17.4 | 0 | | | | | | | | | | | | | | |
| 196 | 07/10 | 08:45 | 23.08 | 14.6 | 0.21 | 35.1 | 152 | | | | | | | | | | | | | | |
| 197 | 08/10 | 13:30 | 28.75 | 21.7 | | 35.1 | 152 | | | | | | | | | | | | | | |
| 198 | 09/10 | 09:40 | 20.17 | 0 | | 20.2 | 0 | | | | | | | | | | | | | | |
| 199 | 10/10 | 09:50 | 24.17 | 8 | 1.05 | 34.8 | 207 | 14.18 | | | | | | | | | | | | | |
| 201 | 12/10 | 14:30 | 52.67 | 31.5 | 1.89 | 35 | 152 | 13.91 | | | | | | | | | | | | | |
| 202 | 13/10 | 11:00 | 20.50 | 2.5 | | 26.2 | | | | | | | | | | | | | | | |
| 203 | 14/10 | 08:10 | 21.17 | 16.3 | 0.63 | 35.3 | | | | | | | | | | | | | | | |
| 204 | 15/10 | 09:03 | 24.88 | 7.2 | | 34.3 | | | | | | | | | | | | | | | |
| 205 | 16/10 | 11:10 | 26.12 | 18 | | 35.3 | | | | | | | | | | | | | | | |

TABLE 1: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 1) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP ( C) | UF PRESS (kPa) | FLUX (L/m2/h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 207 | 18/10 | 12:48 | 30.08 | 16.3 | | 35.4 | 152 | 8.45 | | | | | | | | | | | | | |
| 208 | 19/10 | 13:40 | 24.87 | 14 | 0.42 | 34.8 | 152 | 9.55 | | | | | | | | | | | | | |
| 209 | 20/10 | 13:40 | 24.00 | 13.8 | 0.42 | 35.1 | 152 | 8.73 | | | | | | | | | | | | | |
| 210 | 21/10 | 08:53 | 19.22 | 10 | | 35.1 | 152 | 8.45 | | 18.5 | 1.19 | 22.2 | 18.3 | 82.43 | 402 | 6.9 | 1650 | 4.62 | 0.253 | 93.6 | |
| 211 | 22/10 | 09:50 | 24.95 | 12 | | 35.2 | 152 | 9.00 | | | | | | | | | | | | | |
| 212 | 23/10 | 14:15 | 28.42 | 14.3 | | 33.9 | 152 | 9.82 | | | | | | | | | | | | | |
| 215 | 26/10 | 13:54 | 71.65 | 36.4 | 14.11 | 35.2 | 152 | 9.27 | | | | | | | | | | | | | |
| 216 | 27/10 | 08:57 | 19.05 | 6.6 | 64.00 | 35.3 | 152 | 9.00 | | 14.4 | 1.461 | 15.5 | 12.1 | 78.06 | 564 | 6.9 | 1220 | 2.39 | 0.198 | 89.9 | 0.67 |
| 217 | 28/10 | 08:59 | 24.03 | 14.3 | 75.58 | 34.7 | 152 | 9.55 | | | | | | | | | | | | | |
| 218 | 29/10 | 10:41 | 25.70 | 6.1 | 58.53 | 34.8 | 152 | 9.00 | | | | | | | | | | | | | |
| 219 | 30/10 | 11:47 | 25.10 | 15.8 | | 35.4 | 152 | 8.73 | | | | | | | | | | | | | |
| 220 | 31/10 | 06:42 | 18.92 | 1.5 | 63.37 | 34.5 | 152 | 8.73 | | | | | | | | | | | | | |
| 221 | 01/11 | 10:56 | 28.23 | 10.5 | 65.26 | 35.1 | 152 | 7.64 | | | | | | | | | | | | | |
| 222 | 02/11 | 11:40 | 24.73 | 9 | 1.68 | 34.9 | 152 | 8.18 | | 11.5 | 1.223 | 14 | 11.4 | 81.43 | 348 | 6.9 | 1425 | 2.01 | 0.176 | 89.4 | 0.02 |
| 223 | 03/11 | 10:55 | 23.25 | 9.1 | 4.00 | 35.2 | 152 | 8.45 | | 11.5 | 1.223 | 14 | 11.4 | 81.43 | 348 | 6.9 | 1425 | 2.16 | 0.190 | 89.4 | 0.04 |
| 224 | 04/11 | 08:40 | 21.75 | 8.1 | 0.63 | 35.3 | 152 | 8.73 | | | | | | | | | | | | | |
| 225 | 05/11 | 10:50 | 26.17 | 9.8 | | 35 | 152 | 8.45 | | | | | | | | | | | | | |
| 226 | 06/11 | 11:00 | 24.17 | 8.9 | 0.63 | 35.6 | 152 | 8.45 | | | | | | | | | | | | | |
| 229 | 09/11 | 11:05 | 72.08 | 27 | | 35.2 | 152 | 7.64 | | | | | | | | | | | | | |
| 230 | 10/11 | 08:10 | 21.08 | 8 | | 35 | 152 | 8.18 | | | | | | | | | | | | | |
| 231 | 11/11 | 09:35 | 25.42 | 8.46 | | 35.1 | 152 | 7.91 | | 9 | 0.558 | 14.9 | 12.4 | 83.22 | 84 | 7 | 1430 | 1.44 | 0.116 | 93.8 | |
| 232 | 12/11 | 08:00 | 22.42 | 8 | | 35 | 152 | 7.64 | | | | | | | | | | | | | |
| 233 | 13/11 | 08:05 | 24.08 | 8 | | 35 | 165 | 3.00 | | | | | | | | | | | | | |
| 234 | 14/11 | 08:05 | 24.00 | 10 | | 35.5 | 152 | 7.09 | | | | | | | | | | | | | |
| 235 | 15/11 | 08:05 | 24.00 | 9 | | 35.1 | 152 | 7.36 | | | | | | | | | | | | | |
| 236 | 16/11 | 08:10 | 24.08 | 6 | | 35.6 | 152 | 7.36 | | | | | | | | | | | | | |
| 237 | 17/11 | 08:05 | 23.92 | 9 | | 34.8 | 152 | 7.09 | | 9 | 0.298 | 14.1 | 11.8 | 83.69 | 12 | 7 | 1180 | 1.63 | 0.138 | 96.7 | |
| 238 | 18/11 | 08:35 | 24.50 | 9 | | 36 | 152 | 8.18 | | | | | | | | | | | | | |
| 239 | 19/11 | 08:30 | 23.92 | 9 | | 35.1 | 152 | 7.36 | | | | | | | | | | | | | |
| 240 | 20/11 | 08:30 | 24.00 | 9 | | 35.1 | 152 | 7.91 | | | | | | | | | | | | | |
| 241 | 21/11 | 08:45 | 24.25 | 7 | 0.21 | 35.3 | 152 | 8.18 | | | | | | | | | | | | | |
| 243 | 23/11 | 08:30 | 47.75 | 19 | 0.21 | 35.5 | 152 | 6.82 | | | | | | | | | | | | | |
| 244 | 24/11 | 08:30 | 24.00 | 9 | 0.21 | 35 | 152 | 8.18 | | | | | | | | | | | | | |
| 245 | 25/11 | 10:00 | 25.50 | 7 | 0.42 | 34.9 | 152 | 8.18 | | 6.3 | 0.22 | 3.6 | 2.8 | 77.78 | 114 | 6.9 | 1090 | 0.83 | 0.296 | 96.5 | 0.01 |
| 246 | 26/11 | 08:25 | 22.42 | 9 | | 35.5 | 152 | 8.18 | | | | | | | | | | | | | |
| 247 | 27/11 | 08:30 | 24.08 | 10 | | 35.9 | 152 | 8.18 | | | | | | | | | | | | | |
| 248 | 28/11 | 13:00 | 28.50 | 11 | | 35.4 | 152 | 8.18 | | | | | | | | | | | | | |
| 250 | 30/11 | 09:30 | 44.50 | 17 | | 35.2 | 152 | 8.45 | | | | | | | | | | | | | |
| 252 | 02/12 | 07:50 | 46.33 | 18 | | 35.5 | 152 | 7.64 | | 3.2 | 0.127 | 5.4 | 4.2 | 77.78 | 12 | 7.4 | 920 | 0.60 | 0.142 | 96.0 | |
| 253 | 03/12 | 08:40 | 24.83 | 10 | | 35.1 | 152 | 6.55 | | | | | | | | | | | | | |

TABLE I: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 1) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | UF PRESS (kPa) | FLUX (L/m2/h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/kgVS/d) | COD REDUC (%) | GAS PROD. (m3/kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 257 | 07/12 | 11:35 | 68.33 | 21.5 | | 35.1 | 152 | 8.18 | | | | | | | | | | | | | |
| 259 | 09/12 | 09:50 | 46.25 | 18 | | 36.6 | 152 | 8.18 | | 2.6 | 0.805 | 7.9 | 6.4 | 81.01 | 330 | 7.3 | 1845 | 0.49 | 0.076 | 69.0 | |
| 260 | 10/12 | 11:25 | 25.58 | 9 | | 35.8 | 152 | 8.18 | | | | | | | | | | | | | |
| 261 | 11/12 | 12:05 | 24.67 | 10 | | 35.1 | 152 | 6.55 | | | | | | | | | | | | | |
| 264 | 14/12 | 09:30 | 69.42 | 33 | | 34.8 | 152 | 6.55 | | | | | | | | | | | | | |
| 265 | 15/12 | 08:46 | 23.27 | 12 | | 35.5 | 152 | | | | | | | | | | | | | | |
| 267 | 17/12 | 09:35 | 48.82 | 24 | | 34.9 | 152 | 6.00 | | | | | | | | | | | | | |
| 268 | 18/12 | 14:30 | 28.92 | 8 | | 35.2 | 152 | 6.27 | | | | | | | | | | | | | |

TABLE 2: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 2) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | UF PRESS (kPa) | FLUX (L/m2.h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 26/03/92 | 16:00 | 0.00 | 0.00 | 0.0 | 27.0 | 150 | | | | | 26.30 | 19.60 | 74.52 | | | | | | | |
| 2 | 27/03/92 | 16:00 | 24.00 | 13.50 | | | 150 | | | 31.200 | | 26.30 | 19.60 | 74.52 | | | | 8.42 | 0.430 | | |
| 5 | 30/03/92 | 09:14 | 65.23 | 6.50 | 86.0 | | 150 | | | | | | | | | | | | | | |
| 5 | 30/03/92 | 14:40 | 5.43 | | 3.6 | | 150 | 37.09 | | 30.750 | | | | | | | | | | | |
| 6 | 31/03/92 | 17:10 | 26.50 | 7.50 | 69.0 | | 154 | | | 30.750 | 2.578 | | | | | | | 4.18 | | 91.6 | 0.30 |
| 7 | 01/04/92 | 15:45 | 22.58 | 7.50 | 91.4 | | 150 | 39.27 | | | | | | | | | | | | | |
| 8 | 02/04/92 | 15:30 | 23.75 | 7.00 | 87.8 | | 150 | 36.27 | 1.692 | | | | | | | | | | | | |
| 9 | 03/04/92 | 15:00 | 23.50 | 8.00 | 86.0 | | 150 | 35.45 | 1.657 | 27.745 | 3.293 | 21.60 | 12.10 | 56.02 | | | | 4.53 | 0.375 | 88.1 | 0.39 |
| 13 | 07/04/92 | 14:14 | 95.23 | 30.50 | 397.4 | 35.0 | 150 | 35.45 | | | | | | | | | | | | | |
| 14 | 08/04/92 | 10:11 | 19.95 | 6.50 | 86.4 | 33.2 | 150 | 27.27 | | 26.120 | 3.460 | 25.00 | 18.90 | 75.60 | 1860 | 7.70 | 1700 | 4.08 | 0.216 | 86.8 | 0.51 |
| 15 | 09/04/92 | 09:11 | 23.00 | 6.50 | 114.8 | 35.0 | 170 | 32.73 | | 28.860 | | | | | | | | 3.91 | | | 0.61 |
| 16 | 10/04/92 | 14:15 | 29.07 | 8.50 | 145.0 | 35.0 | 150 | 32.73 | | | | | | | | | | | | | |
| 19 | 13/04/92 | 09:57 | 67.70 | 20.50 | 281.4 | 33.9 | 157 | 32.73 | | | | | | | | | | | | | |
| 20 | 14/04/92 | 10:45 | 24.80 | 8.50 | 105.8 | 34.9 | 150 | 31.36 | 1.643 | 25.300 | 1.000 | 25.40 | 20.10 | 79.13 | 240 | 7.46 | 3090 | 4.16 | 0.207 | 96.0 | 0.49 |
| 21 | 15/04/92 | 10:08 | 23.38 | 7.50 | 126.0 | 34.7 | 160 | 27.27 | | | | | | | | | | | | | |
| 22 | 16/04 | 09:13 | 23.08 | 7.50 | 113.0 | 34.2 | 160 | 21.82 | | | | | | | | | | | | | |
| 23 | 17/04 | 07:05 | 21.87 | 2.00 | 38.6 | 34.7 | 250 | 13.64 | | | | | | | | | | | | | |
| 25 | 19/04 | 10:15 | 51.17 | 10.50 | 192.0 | 32.5 | 250 | 16.36 | | | | | | | | | | | | | |
| 27 | 21/04 | 08:50 | 46.58 | 12.50 | 118.6 | 30.2 | 190 | 12.27 | 1.019 | 31.700 | 1.400 | 21.90 | 15.50 | 70.78 | 1614 | 7.03 | 1975 | 4.08 | 0.263 | 95.6 | 0.30 |
| 28 | 22/04 | 10:00 | 25.17 | 2.50 | 40.2 | 31.8 | 200 | 17.45 | 1.594 | | | | | | | | | | | | |
| 29 | 23/04 | 11:20 | 25.33 | 0.00 | 81.6 | 33.1 | 159 | 14.45 | | | | | | | | | | | | | |
| 30 | 24/04 | 14:14 | 26.90 | 5.00 | 119.2 | 35.0 | 207 | 15.00 | | | | | | | | | | | | | |
| 33 | 27/04 | 09:15 | 67.02 | 9.00 | 167.4 | 31.4 | 166 | 15.00 | | | | | | | | | | | | | |
| 34 | 28/04 | 09:10 | 23.92 | 1.50 | 56.6 | 33.7 | 235 | 23.73 | | | | | | | | | | | | | |
| 35 | 29/04 | 09:10 | 24.00 | 2.00 | 58.8 | 33.0 | 255 | 23.18 | 1.617 | 37.300 | 0.500 | 20.40 | 13.80 | 67.65 | 288 | 7.40 | 3360 | 1.49 | 0.108 | 98.7 | 0.79 |
| 36 | 30/04 | 08:20 | 23.17 | 3.00 | 70.0 | 30.5 | 103 | 24.55 | | | | | | | | | | | | | |
| 37 | 01/05 | 07:00 | 22.67 | 2.00 | 78.4 | 33.7 | 241 | 21.82 | | | | | | | | | | | | | |
| 39 | 03/05 | 12:46 | 53.77 | 6.00 | 166.4 | 34.1 | 241 | 21.82 | | | | | | | | | | | | | |
| 40 | 04/05 | 12:10 | 23.40 | 2.50 | 72.4 | 33.6 | 241 | 23.18 | | | | | | | | | | | | | |
| 41 | 05/05 | 08:42 | 20.53 | 1.50 | 62.2 | 34.7 | 230 | 21.82 | 1.682 | 43.900 | 0.466 | 20.80 | 14.80 | 71.15 | 90 | 7.40 | 3675 | 1.54 | 0.104 | 98.9 | 0.94 |
| 42 | 06/05 | 09:35 | 24.88 | 1.50 | 82.2 | 34.4 | 230 | 23.18 | | | | | | | | | | | | | |
| 43 | 07/05 | 09:21 | 23.77 | 3.50 | 86.2 | 34.6 | 225 | 24.55 | | 47.000 | 0.599 | 20.10 | 13.40 | 66.67 | 192 | 7.50 | 3695 | 3.32 | 0.248 | 98.7 | 0.52 |
| 44 | 08/05 | 14:23 | 29.03 | 3.00 | 100.0 | 35.0 | 225 | 23.18 | | | | | | | | | | | | | |
| 45 | 09/05 | 07:01 | 16.63 | 1.50 | 56.2 | 34.2 | 230 | 23.18 | | | | | | | | | | | | | |
| 47 | 11/05 | 08:58 | 49.95 | 6.00 | 156.0 | 32.5 | 230 | 23.18 | | 49.600 | 0.532 | 21.70 | 13.90 | 61.06 | 306 | 7.34 | 3885 | 2.86 | 0.206 | 98.9 | 0.52 |
| 48 | 12/05 | 09:22 | 24.40 | 2.50 | 73.6 | 34.2 | 240 | 21.82 | | | | | | | | | | | | | |
| 49 | 13/05 | 09:05 | 23.72 | 2.00 | 60.8 | 33.9 | 120/230 | 12.27 | 1.227 | | | | | | | | | | | | |
| 50 | 14/05 | 09:20 | 24.25 | 3.00 | 57.4 | 35.0 | 250 | 20.45 | | 50.000 | 0.540 | 22.50 | 15.90 | 70.67 | 126 | 7.35 | 3915 | 2.97 | 0.187 | 98.9 | 0.38 |
| 51 | 15/05 | 09:08 | 23.80 | 3.00 | 71.2 | 35.0 | 235 | 23.45 | | | | | | | | | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 33.6 | 260 | 26.18 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0.54 |

TABLE 2: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 2) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP ( C) | UF PRESS (kPa) | FLUX (L/m2.h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55 | 19/05 | 09:29 | 25.07 | 3.50 | 80.4 | 34.7 | 250 | 26.73 | | | | | | | | | | | | | |
| 56 | 20/05 | 08:15 | 22.77 | 5.00 | 69.0 | 35.0 | 250 | 27.27 | | | | | | | | | | | | | |
| 57 | 21/05 | 09:35 | 25.33 | 5.00 | 68.2 | 35.0 | 250 | 25.91 | | 22.500 | 0.378 | 20.40 | 12.80 | 62.75 | <60 | 7.70 | 3600 | 2.13 | 0.167 | 98.3 | 0.61 |
| 58 | 22/05 | 09:35 | 24.00 | 6.50 | 74.8 | 34.9 | 250 | 27.27 | | | | | | | | | | | | | |
| 59 | 23/05 | 10:20 | 24.75 | 6.00 | 85.2 | 35.0 | 250 | 27.27 | | | | | | | | | | | | | |
| 60 | 24/05 | 10:10 | 23.83 | 6.00 | 78.2 | 34.9 | 250 | 28.64 | | | | | | | | | | | | | |
| 61 | 25/05 | 09:10 | 23.00 | 6.25 | 73.0 | 34.1 | 250 | 27.27 | | 21.000 | 0.369 | 19.80 | 13.70 | 69.19 | <60 | 7.70 | 3095 | 2.74 | 0.200 | 98.2 | 0.56 |
| 62 | 26/05 | 14:25 | 29.25 | 7.75 | 86.0 | 34.4 | 250 | 27.27 | | | | | | | | | | | | | |
| 63 | 27/05 | 11:35 | 21.17 | 5.50 | 59.0 | 34.2 | 250 | 30.00 | | | | | | | | | | | | | |
| 64 | 28/05 | 10:30 | 22.92 | 5.00 | 68.0 | 31.8 | 260 | 28.64 | | | | | | | | | | | | | |
| 65 | 29/05 | 09:20 | 22.83 | 6.00 | 68.6 | 31.1 | 240 | 28.64 | | | | | | | | | | | | | |
| 66 | 30/05 | 07:15 | 21.92 | 6.40 | 69.0 | 30.9 | 50 | 28.64 | | | | | | | | | | | | | |
| 68 | 01/06 | 08:05 | 48.83 | 12.60 | 145.2 | 31.6 | 250 | 27.27 | | 19.8 | 0.349 | 18.3 | 12.8 | 69.95 | 372 | 7.3 | 2215 | 2.45 | 0.192 | 98.2 | 0.58 |
| 69 | 02/06 | 09:05 | 25.00 | 8.00 | 79.8 | 33.3 | 250 | 25.91 | | | | | | | | | | | | | |
| 70 | 03/06 | 08:40 | 23.58 | 7.00 | 77.2 | 33.7 | 245 | 25.91 | | | | | | | | | | | | | |
| 71 | 04/06 | 10:45 | 26.08 | 7.50 | 78.0 | 32.0 | 250 | 28.64 | | 18.9 | 0.52 | 18.1 | 13.5 | 74.59 | 276 | 7.2 | 2125 | 2.61 | 0.193 | 97.2 | 0.55 |
| 72 | 05/06 | 08:17 | 21.53 | 5.50 | 53.8 | | 260 | 25.91 | | | | | | | | | | | | | |
| 73 | 06/06 | 10:55 | 26.63 | 8.00 | 62.0 | 31.2 | 245 | 27.27 | | | | | | | | | | | | | |
| 74 | 07/06 | 10:10 | 23.25 | 6.50 | 57.6 | 32.5 | 250 | 27.27 | | | | | | | | | | | | | |
| 75 | 08/06 | 10:50 | 24.67 | 7.50 | 49.2 | 32.6 | 250 | 28.64 | | 26.1 | 0.522 | 14.4 | 10.5 | 72.92 | <60 | 7.1 | 2245 | 3.81 | 0.363 | 98.0 | 0.25 |
| 76 | 09/06 | 08:59 | 22.15 | 6.00 | 47.4 | 34.8 | 250 | 28.64 | | | | | | | | | | | | | |
| 77 | 10/06 | 08:20 | 23.35 | 4.70 | 35.6 | 35.0 | 255 | 25.91 | | | | | | | | | | | | | |
| 78 | 11/06 | 09:05 | 24.75 | 6.50 | 45.6 | 35.0 | 245 | 25.91 | | 13 | 0.261 | 12.8 | 9.9 | 77.34 | 60 | 7.2 | 2155 | 1.64 | 0.166 | 98.0 | 0.54 |
| 79 | 12/06 | 07:10 | 22.08 | 6.00 | 39.6 | 35.0 | 250 | 24.55 | | | | | | | | | | | | | |
| 81 | 14/06 | 16:00 | 56.83 | 13.70 | 15.6 | 35.0 | 242 | 25.36 | | | | | | | | | | | | | |
| 82 | 15/06 | 08:46 | 16.77 | 4.30 | 29.0 | 35.0 | 250 | 27.27 | | 12.4 | 0.263 | 9.9 | 6.9 | 69.70 | <30 | 7.6 | 2035 | 1.53 | 0.221 | 97.9 | 0.54 |
| 83 | 16/06 | 10:15 | 25.48 | 7.50 | 49.6 | 35.0 | 250 | 28.64 | | | | | | | | | | | | | |
| 84 | 17/06 | 11:00 | 24.75 | 5.00 | 34.6 | 35.0 | 250 | 28.64 | | | | | | | | | | | | | |
| 85 | 18/06 | 08:55 | 21.92 | 5.80 | 36.2 | 34.9 | 65 | 29.18 | | 13.5 | 0.498 | 7.5 | 5.2 | 69.33 | <30 | 7.3 | 2045 | 1.71 | 0.330 | 96.3 | 0.46 |
| 86 | 19/06 | 08:05 | 23.17 | 5.80 | 36.4 | 35.0 | 250 | 28.64 | | | | | | | | | | | | | |
| 87 | 20/06 | 12:45 | 28.67 | 8.80 | 48.8 | 35.0 | 250 | 28.64 | | | | | | | | | | | | | |
| 88 | 21/06 | 13:45 | 25.00 | 5.40 | 47.4 | 35.0 | 250 | 30.00 | | | | | | | | | | | | | |
| 89 | 22/06 | 09:25 | 19.67 | 4.70 | 33.2 | 35.0 | 250 | 30.00 | | 15.4 | 0.405 | 9.2 | 4.9 | 53.26 | 198 | 7.2 | 1905 | 1.77 | 0.361 | 97.4 | 0.46 |
| 90 | 23/06 | 14:30 | 29.08 | 7.80 | 53.0 | 35.0 | 250 | 29.18 | | | | | | | | | | | | | |
| 91 | 24/06 | 09:05 | 18.58 | 5.00 | 34.4 | 35.0 | 250 | 28.36 | | | | | | | | | | | | | |
| 92 | 25/06 | 08:30 | 23.42 | 6.10 | 39.4 | 35.0 | 250 | 28.36 | | | | | | | | | | | | | |
| 93 | 26/06 | 08:10 | 23.67 | 6.10 | 10.6 | 35.0 | 250 | 28.36 | | | | | | | | | | | | | |
| 96 | 29/06 | 11:47 | 75.62 | 16.60 | 0.0 | 35.0 | 250 | 27.27 | | 11 | 0.406 | 8.6 | 5.1 | 59.30 | 252 | 7.1 | 1895 | 1.16 | 0.227 | 96.3 | |
| 97 | 30/06 | 14:10 | 26.38 | 8.10 | 37.8 | 35.0 | 250 | 27.27 | | | | | | | | | | | | | |
| 98 | 01/07 | 10:55 | 20.75 | 0.20 | 15.6 | 35.0 | 270 | | | | | | | | | | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 27.27 | | 12.6 | 0.295 | 7.6 | 4.9 | 64.47 | 396 | 7.2 | 1755 | 1.66 | 0.339 | 97.7 | 0.43 |

TABLE 2: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 2) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP ( C) | UF PRESS (kPa) | FLUX (L/m2.h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 03/07 | 08:25 | 23.67 | 5.70 | 33.2 | 32.3 | 190 | 27.27 | | | | | | | | | | | | | |
| 101 | 04/07 | 07:05 | 22.67 | 5.50 | 21.0 | 35.0 | 190 | 26.73 | | | | | | | | | | | | | |
| 103 | 06/07 | 11:45 | 52.67 | 14.10 | 38.8 | 35.0 | 190 | 21.82 | | 12.4 | 0.791 | 8.7 | 6.3 | 72.41 | 588 | 7.1 | 1340 | 1.59 | 0.253 | 93.6 | 0.22 |
| 104 | 07/07 | 10:10 | 22.42 | 6.50 | 15.4 | 35.0 | 190 | 25.09 | | | | | | | | | | | | | |
| 105 | 08/07 | 09:01 | 22.85 | 7.00 | 15.8 | 35.0 | 190 | 25.64 | | | | | | | | | | | | | |
| 106 | 09/07 | 09:35 | 24.57 | 6.90 | 16.4 | 35.0 | 190 | 24.55 | | | | | | | | | | | | | |
| 107 | 10/07 | 08:17 | 22.70 | 7.10 | 13.4 | 35.0 | 190 | 25.09 | | | | | | | | | | | | | |
| 110 | 13/07 | 10:46 | 74.48 | 14.40 | 29.0 | 27.1 | 0 | | | | | | | | | | | | | | |
| 111 | 14/07 | 14:16 | 27.50 | | | | | | | | | | | | | | | | | | |
| 112 | 15/07 | 08:02 | 17.77 | | | | | | | | | | | | | | | | | | |
| 113 | 16/07 | 13:57 | 29.92 | | | | | | | | | | | | | | | | | | |
| 114 | 17/07 | 13:47 | 23.83 | | | 18.3 | | | | | | | | | | | | | | | |
| 115 | 18/07 | 11:35 | 21.80 | 7.30 | 0.2 | 34.9 | 250 | 25.09 | | | | | | | | | | | | | |
| 117 | 20/07 | 10:45 | 47.17 | 15.00 | 123.4 | 35.0 | 190 | 28.64 | | 12.7 | 0.375 | 28 | 21.6 | 77.14 | 78 | 7.3 | 2960 | 1.94 | 0.090 | 97.0 | 0.65 |
| 119 | 22/07 | 09:05 | 46.33 | 15.20 | 118.4 | 34.8 | 190 | 28.64 | | | | | | | | | | | | | |
| 120 | 23/07 | 07:50 | 22.75 | 6.90 | 51.8 | 35.0 | 190 | 28.09 | | 12.3 | 0.217 | 28 | 22.2 | 79.29 | <60 | 7.2 | 2955 | 1.79 | 0.081 | 98.2 | 0.61 |
| 121 | 24/07 | 09:40 | 25.83 | 8.60 | 25.6 | 35.0 | 190 | 28.36 | | | | | | | | | | | | | |
| 124 | 27/07 | 11:15 | 73.58 | 24.40 | 225.8 | 35.0 | 190 | 30.00 | | 12.3 | 0.214 | 27.8 | 22.3 | 80.22 | <30 | 7.2 | 2600 | 1.96 | 0.088 | 98.3 | 0.75 |
| 125 | 28/07 | 14:40 | 27.42 | 8.60 | 64.2 | 35.0 | 190 | 30.55 | | | | | | | | | | | | | |
| 126 | 29/07 | 11:10 | 20.50 | 6.10 | 55.2 | 35.0 | 190 | 30.55 | | | | | | | | | | | | | |
| 127 | 30/07 | 08:40 | 21.50 | 6.90 | 59.6 | 35.0 | 190 | 30.55 | | | | | | | | | | | | | |
| 128 | 31/07 | 08:55 | 24.25 | 7.50 | 66.6 | 35.0 | 190 | 28.36 | | | | | | | | | | | | | |
| 131 | 03/08/92 | 10:40 | 73.75 | 20.10 | 197.6 | 35.0 | 193 | 28.36 | | 13.3 | 0.161 | 25.7 | 20.7 | 80.54 | 90 | 7.1 | 2415 | 1.74 | 0.084 | 98.8 | 0.74 |
| 132 | 04/08/92 | 10:40 | 24.00 | 7.00 | 65.6 | 35.0 | 193 | 16.36 | | | | | | | | | | | | | |
| 133 | 05/08/92 | 10:40 | 24.00 | 8.00 | 65.0 | 34.9 | 200 | 16.09 | | | | | | | | | | | | | |
| 134 | 06/08/92 | 11:05 | 24.42 | 7.50 | 66.6 | 35.1 | 150 | 21.55 | | 14.6 | 0.168 | 25.1 | 20.8 | 82.87 | 108 | 7.2 | 2350 | 2.15 | 0.103 | 98.8 | 0.61 |
| 135 | 07/08/92 | 15:00 | 27.92 | 7.50 | 78.8 | 35.0 | | 22.09 | | | | | | | | | | | | | |
| 138 | 10/08/92 | 09:50 | 66.83 | 22.00 | 180.8 | 34.9 | 190 | 22.36 | | 13.7 | 0.159 | 25.1 | 20.2 | 80.48 | 24 | 7.1 | 2280 | 2.16 | 0.107 | 98.8 | 0.60 |
| 139 | 11/08/92 | 11:10 | 25.33 | 8.00 | 70.4 | 35.0 | | 23.45 | | | | | | | | | | | | | |
| 140 | 12/08/92 | 08:10 | 21.00 | 7.10 | 52.4 | 35.0 | 250 | 25.64 | | | | | | | | | | | | | |
| 141 | 13/08/92 | 15:10 | 31.00 | 9.20 | 83.6 | 35.0 | 250 | 25.09 | | | | | | | | | | | | | |
| 142 | 14/08/92 | 14:10 | 23.00 | 7.50 | 77.0 | 35.0 | 250 | 24.82 | | | | | | | | | | | | | |
| 143 | 15/08/92 | 11:40 | 21.50 | 7.10 | 75.0 | 35.0 | 240 | 25.36 | | | | | | | | | | | | | |
| 144 | 16/08/92 | 10:40 | 23.00 | 7.40 | 81.2 | 35.0 | 250 | 25.09 | | | | | | | | | | | | | |
| 145 | 17/08/92 | 10:40 | 24.00 | 8.00 | 85.6 | 35.0 | 250 | 25.64 | | | | | | | | | | | | | |
| 146 | 18/08/92 | 10:40 | 24.00 | 7.90 | 84.0 | 35.0 | 250 | 21.82 | | | | | | | | | | | | | |
| 147 | 19/08/92 | 08:35 | 21.92 | 6.10 | 65.2 | 35.0 | 193 | 21.55 | | | | | | | | | | | | | |
| 148 | 20/08/92 | 08:39 | 24.07 | 7.90 | 74.0 | 35.0 | 193 | 19.09 | | | | | | | | | | | | | |
| 149 | 21/08/92 | 09:01 | 24.37 | 5.50 | 74.4 | 35.0 | 193 | 18.27 | | | | | | | | | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 79.0 | 35.0 | 193 | 19.36 | | | | | | | | | | | | | |

TABLE 2: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 2) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | UF PRESS (kPa) | FLUX (L/m2.h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALINs CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/kgVS/d) | COD REDUC (%) | GAS PROD. (m3/kgCOD/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 152 | 24/08/92 | 09:20 | 50.28 | 4.40 | 58.0 | 35.2 | 138 | 15.00 | | 17.9 | 0.14 | 26.2 | 21.4 | 81.68 | 102 | 7.1 | 2040 | 0.75 | 0.035 | 99.2 | 0.74 |
| 153 | 25/08/92 | 12:50 | 27.50 | 0.00 | 8.8 | 35.1 | 192 | 15.82 | | | | | | | | | | | | | |
| 154 | 26/08/92 | 09:20 | 20.50 | 7.50 | 76.6 | 35.0 | 193 | 16.64 | | | | | | | | | | | | | |
| 155 | 27/08/92 | 12:40 | 27.33 | 9.90 | 101.4 | 35.0 | 193 | 18.00 | | | | | | | | | | | | | |
| 156 | 28/08/92 | 10:40 | 22.00 | 7.40 | 69.6 | 35.0 | 193 | 19.36 | | | | | | | | | | | | | |
| 157 | 29/08/92 | 07:17 | 20.62 | 7.60 | 60.8 | 35.0 | 193 | 16.64 | | | | | | | | | | | | | |
| 159 | 31/08/92 | 11:11 | 51.90 | 16.40 | 139.8 | 35.0 | 193 | 11.45 | 1.739 | 11.6 | 0.153 | 26.2 | 21.5 | 82.06 | 66 | 7 | 1990 | 1.76 | 0.082 | 98.7 | 0.73 |
| 160 | 01/09/92 | 11:06 | 23.92 | 7.20 | 58.4 | 35.0 | 186 | 10.09 | 1.729 | | | | | | | | | | | | |
| 163 | 04/09/92 | 14:00 | 74.90 | 22.60 | 177.0 | 35.0 | | | | | | | | | | | | | | | |
| 166 | 07/09/92 | 12:55 | 70.92 | 23.00 | 214.2 | 35.0 | 193 | 12.27 | | | | | | | | | | | | | |
| 167 | 08/09/92 | 11:00 | 22.08 | 6.10 | 57.6 | 35.0 | 193 | 11.18 | | 14.2 | 0.187 | 26.3 | 21.4 | 81.37 | 48 | 7.2 | 2065 | 1.88 | 0.088 | 98.7 | 0.66 |
| 168 | 09/09/92 | 11:00 | 24.00 | 7.10 | 53.6 | 35.1 | 193 | 11.73 | | | | | | | | | | | | | |
| 169 | 10/09/92 | 12:10 | 25.17 | 6.50 | 66.8 | 35.0 | 193 | 11.18 | | | | | | | | | | | | | |
| 170 | 11/09/92 | 11:40 | 23.50 | 6.80 | 63.8 | 35.0 | 193 | 12.82 | | | | | | | | | | | | | |
| 171 | 12/09/92 | 14:00 | 26.33 | 6.50 | 57.8 | 35.0 | 193 | 12.55 | | | | | | | | | | | | | |
| 173 | 14/09/92 | 10:40 | 44.67 | 8.20 | 46.2 | 35.1 | 200 | 10.64 | | 18 | 0.269 | 27.5 | 22.3 | 81.09 | 180 | 7.1 | 2235 | 1.59 | 0.071 | 98.5 | 0.31 |
| 174 | 15/09/92 | 08:20 | 21.67 | 6.90 | | 35.0 | 193 | 9.82 | | | | | | | | | | | | | |
| 175 | 16/09/92 | 08:45 | 24.42 | 7.20 | 0.2 | 35.0 | 193 | 10.36 | | | | | | | | | | | | | |
| 176 | 17/09/92 | 13:40 | 28.92 | 9.00 | 84.6 | 35.0 | 193 | 11.18 | | | | | | | | | | | | | |
| 177 | 18/09/92 | 14:40 | 25.00 | 7.50 | 73.2 | 35.0 | 193 | 11.45 | | | | | | | | | | | | | |
| 178 | 19/09/92 | 10:50 | 20.17 | 5.90 | 55.8 | 35.1 | 193 | 12.00 | | | | | | | | | | | | | |
| 180 | 21/09/92 | 16:00 | 53.17 | 15.60 | 133.8 | 35.0 | 193 | 11.18 | | | | | | | | | | | | | |
| 181 | 22/09/92 | 07:58 | 15.97 | 4.50 | 33.8 | 34.9 | 200 | 11.45 | | 12.9 | 0.185 | 27.2 | 21.7 | 79.78 | 30 | 7.1 | 2170 | 1.75 | 0.080 | 98.6 | 0.58 |
| 182 | 23/09/92 | 08:35 | 24.62 | 7.80 | 76.6 | 35.0 | 186 | 10.64 | | | | | | | | | | | | | |
| 183 | 24/09/92 | 16:00 | 31.42 | 10.70 | 101.2 | 35.0 | 193 | 11.45 | | | | | | | | | | | | | |
| 184 | 25/09/92 | 08:50 | 16.83 | 5.60 | 53.8 | 35.0 | 193 | 11.18 | | | | | | | | | | | | | |
| 187 | 28/09/92 | 12:30 | 75.67 | 24.20 | 270.8 | 35.1 | 186 | 6.55 | | | | | | | | | | | | | |
| 188 | 29/09/92 | 08:45 | 20.25 | 6.60 | 70.6 | 35.0 | 193 | 10.09 | | 18 | 0.216 | 28.6 | 22.9 | 80.07 | 72 | 7.2 | 2205 | 2.82 | 0.123 | 98.8 | 0.59 |
| 189 | 30/09/92 | 09:02 | 24.28 | 8.20 | 88.4 | 35.1 | 193 | 9.55 | | | | | | | | | | | | | |
| 190 | 01/10/92 | 11:25 | 26.38 | 6.00 | 92.8 | 35.0 | 193 | 10.36 | | | | | | | | | | | | | |
| 191 | 02/10/92 | 08:30 | 21.08 | 6.50 | 69.4 | 34.9 | 193 | 7.36 | | | | | | | | | | | | | |
| 192 | 03/10/92 | 07:10 | 22.67 | 7.50 | 88.6 | 35.0 | 193 | 8.45 | | | | | | | | | | | | | |
| 194 | 05/10/92 | 11:50 | 52.67 | 18.20 | 211.0 | 35.0 | 193 | 7.64 | | | | | | | | | | | | | |
| 195 | 06/10/92 | 09:20 | 21.50 | 7.50 | 62.8 | 35.0 | 193 | 8.45 | | 19.1 | 0.278 | 29.2 | 22.5 | 77.05 | 12 | 7.7 | 2790 | 3.20 | 0.142 | 98.5 | 0.44 |
| 196 | 07/10/92 | 08:50 | 23.50 | 8.30 | 1.0 | 32.9 | 193 | 9.00 | | | | | | | | | | | | | |
| 197 | 08/10/92 | 13:40 | 28.83 | 9.50 | 85.6 | 35.8 | 193 | 10.09 | | | | | | | | | | | | | |
| 198 | 09/10/92 | 14:10 | 24.50 | 9.00 | 79.2 | 35.2 | 193 | 8.73 | | | | | | | | | | | | | |
| 199 | 10/10/92 | 09:40 | 19.50 | 6.30 | 65.2 | 35.1 | 152 | 9.55 | | | | | | | | | | | | | |
| 201 | 12/10/92 | 14:00 | 52.33 | 17.70 | 174.4 | 35.3 | 193 | 10.36 | | | | | | | | | | | | | |
| 202 | 13/10/92 | 10:52 | 20.87 | 7.00 | 67.2 | 34.8 | 207 | 9.82 | | 20.3 | 0.295 | 40.2 | 32.6 | 81.09 | 42 | 7.3 | 2155 | 3.27 | 0.100 | 98.5 | 0.47 |
| [illegible] | [illegible] | [illegible] | [illegible] | 7.00 | [illegible] | 35.1 | 179 | 9.55 | | | | | | | | | | | | | |

TABLE 2: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 2) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP ( C) | UF PRESS (kPa) | FLUX (L/m2.h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 204 | 15/10/92 | 09:07 | 24.78 | 9.00 | 87.6 | 34.7 | 179 | 10.09 | | | | | | | | | | | | | |
| 205 | 16/10/92 | 11:20 | 26.22 | 5.50 | 90.0 | 35.3 | 193 | 8.73 | | | | | | | | | | | | | |
| 206 | 17/10/92 | 06:48 | 19.47 | 7.10 | 91.4 | 35.7 | 193 | 9.00 | | | | | | | | | | | | | |
| 207 | 18/10/92 | 12:57 | 30.15 | 10.40 | 145.2 | 35.0 | 193 | 8.73 | | | | | | | | | | | | | |
| 208 | 19/10/92 | 13:50 | 24.88 | 8.00 | 99.8 | 34.8 | 193 | 10.36 | | | | | | | | | | | | | |
| 209 | 20/10/92 | 14:50 | 25.00 | 7.70 | 81.0 | 34.9 | 193 | 10.09 | | | | | | | | | | | | | |
| 210 | 21/10/92 | 08:55 | 18.08 | 6.15 | 63.0 | 34.6 | 193 | 9.82 | | 18.5 | 0.46 | 40.2 | 32.8 | 81.59 | 228 | 7.1 | 2200 | 3.02 | 0.092 | 97.5 | 0.55 |
| 211 | 22/10/92 | 09:40 | 24.75 | 8.00 | 80.8 | 35.0 | 193 | 10.64 | | | | | | | | | | | | | |
| 212 | 23/10/92 | 14:20 | 28.67 | 9.80 | 93.2 | 35.5 | 193 | 9.82 | | | | | | | | | | | | | |
| 215 | 26/10/92 | 14:00 | 71.67 | 24.00 | 220.4 | 35.1 | 193 | 9.27 | | | | | | | | | | | | | |
| 216 | 27/10/92 | 09:07 | 19.12 | 6.90 | 58.0 | 35.2 | 193 | 9.55 | | 14.4 | 0.368 | 38.5 | 30.8 | 80.00 | 84 | 7.1 | 1975 | 2.49 | 0.081 | 97.4 | 0.58 |
| 217 | 28/10/92 | 08:50 | 23.72 | 7.60 | 72.0 | 35.2 | 193 | 9.00 | | | | | | | | | | | | | |
| 218 | 29/10/92 | 10:50 | 26.00 | 0.00 | 30.4 | | 193 | | | | | | | | | | | | | | |
| 219 | 30/10/92 | 11:37 | 24.78 | 8.80 | 85.4 | 35.1 | 193 | 8.73 | | | | | | | | | | | | | |
| 220 | 31/10/92 | 06:44 | 19.12 | 6.20 | 42.4 | 35.3 | 193 | 8.45 | | | | | | | | | | | | | |
| 221 | 01/11/92 | 11:00 | 28.27 | 10.00 | 88.2 | 35.5 | 193 | | | | | | | | | | | | | | |
| 222 | 02/11/92 | 11:33 | 24.55 | 8.00 | 74.0 | 35.0 | 193 | | | | | | | | | | | | | | |
| 223 | 03/11/92 | 10:50 | 23.28 | 7.80 | 56.4 | 35.1 | 193 | | | 11.5 | 0.356 | 37.7 | 30.7 | 81.43 | 60 | 7.1 | 1905 | 1.85 | 0.060 | 96.9 | 0.63 |
| 224 | 04/11/92 | 08:33 | 21.72 | 7.20 | 50.2 | 34.9 | 193 | 3.00 | | | | | | | | | | | | | |
| 225 | 05/11/92 | 10:50 | 26.28 | 9.00 | 61.8 | 35.0 | 193 | 3.27 | | | | | | | | | | | | | |
| 226 | 06/11/92 | 10:52 | 24.03 | 8.00 | 52.6 | 34.9 | 193 | 3.55 | | | | | | | | | | | | | |
| 229 | 09/11/92 | 11:15 | 72.38 | 24.00 | 133.8 | 35.1 | 179 | 3.27 | | | | | | | | | | | | | |
| 230 | 10/11/92 | 08:15 | 21.00 | 7.00 | 86.2 | 35.1 | 179 | 3.00 | | | | | | | | | | | | | |
| 231 | 11/11/92 | 09:45 | 25.50 | 9.00 | 53.0 | 35.0 | 179 | 3.55 | | 9 | 0.25 | 37 | 30.4 | 82.16 | 84 | 7 | 1550 | 1.52 | 0.050 | 97.2 | 0.65 |
| 232 | 12/11/92 | 08:10 | 22.42 | 8.00 | 44.4 | 34.9 | 165 | 3.27 | | | | | | | | | | | | | |
| 233 | 13/11/92 | 08:05 | 23.92 | 9.00 | 46.4 | 36.0 | 193 | 8.18 | | | | | | | | | | | | | |
| 234 | 14/11/92 | 08:06 | 24.02 | 7.00 | 47.6 | 35.0 | 165 | 2.45 | | | | | | | | | | | | | |
| 235 | 15/11/92 | 08:10 | 24.07 | 8.00 | 42.4 | 35.0 | 165 | 3.27 | | | | | | | | | | | | | |
| 236 | 16/11/92 | 08:15 | 24.08 | 8.00 | 39.2 | 35.1 | 193 | 2.73 | | | | | | | | | | | | | |
| 237 | 17/11/92 | 08:10 | 23.92 | 8.50 | 32.4 | 35.3 | 193 | 3.00 | | 6.2 | 0.212 | 35 | 28.8 | 82.29 | 126 | 7.1 | 1260 | 1.06 | 0.037 | 96.6 | 0.61 |
| 238 | 18/11/92 | 08:15 | 24.08 | 8.00 | 33.0 | 35.0 | 193 | 3.00 | | | | | | | | | | | | | |
| 239 | 19/11/92 | 08:20 | 24.08 | 8.50 | 31.4 | 34.8 | 165 | 2.73 | | | | | | | | | | | | | |
| 240 | 20/11/92 | 08:35 | 24.25 | 8.00 | 29.4 | 34.6 | 165 | 2.73 | | | | | | | | | | | | | |
| 241 | 21/11/92 | 08:30 | 23.92 | 7.00 | 40.0 | 35.1 | 158 | 2.45 | | | | | | | | | | | | | |
| 243 | 23/11/92 | 08:20 | 47.83 | 16.00 | 86.0 | 35.0 | 165 | 2.73 | | | | | | | | | | | | | |
| 244 | 24/11/92 | 08:35 | 24.25 | 8.00 | 41.4 | 36.1 | 193 | 2.73 | | | | | | | | | | | | | |
| 245 | 25/11/92 | 08:55 | 24.33 | 8.00 | 33.2 | 35.1 | 193 | 4.09 | | 6.3 | 0.163 | 17.3 | 14.3 | 82.66 | 48 | 7.3 | 1160 | 0.99 | 0.070 | 97.4 | 0.66 |
| 246 | 26/11/92 | 08:30 | 23.58 | 7.00 | 18.8 | 35.2 | 193 | 3.00 | | | | | | | | | | | | | |
| 247 | 27/11/92 | 08:45 | 24.25 | 9.00 | 19.2 | 35.0 | 193 | 3.55 | | | | | | | | | | | | | |
| 248 | 28/11/92 | 12:50 | 28.08 | 9.00 | 21.8 | 35.8 | 193 | 3.27 | | | | | | | | | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 28.4 | 35.0 | 193 | 3.55 | | | | | | | | | | | | | |

TABLE 2: ANAEROBIC DIGESTION / ULTRAFILTRATION (ADUF 2) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME (h/m) | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP ( C) | UF PRESS (kPa) | FLUX (L/m2.h) | LIN VEL (m/s) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 252 | 02/12/92 | 07:50 | 46.33 | 14.00 | 22.6 | 35.1 | 172 | 3.55 | | 3.2 | 0.12 | 31.8 | 26.5 | 83.33 | 6 | 7.5 | 895 | 0.46 | 0.018 | 96.3 | 0.50 |
| 253 | 03/12/92 | 08:25 | 24.58 | 9.00 | 14.8 | 35.1 | 193 | 3.55 | | | | | | | | | | | | | |
| 254 | 04/12/92 | 15:30 | 31.08 | 10.00 | 18.8 | 35.1 | 179 | 3.27 | | | | | | | | | | | | | |
| 257 | 07/12/92 | 11:35 | 68.08 | 23.00 | 31.0 | 35.0 | 193 | | | | | | | | | | | | | | |
| 259 | 09/12/92 | 09:50 | 46.25 | 8.20 | 18.0 | 35.0 | 193 | | | | | | | | | | | | | | |
| 260 | 10/12/92 | 11:25 | 25.58 | 8.80 | 13.0 | 35.5 | 193 | | | | | | | | | | | | | | |
| 261 | 11/12/92 | 09:00 | 21.58 | 8.00 | 21.8 | 35.4 | 165 | 6.82 | | | | | | | | | | | | | |
| 264 | 14/12/92 | 09:05 | 72.08 | 27.00 | | 35.1 | 165 | 2.73 | | | | | | | | | | | | | |
| 265 | 15/12/92 | 08:50 | 23.75 | 9.00 | | 35.2 | 193 | | | | | | | | | | | | | | |
| 267 | 17/12/92 | 09:30 | 48.67 | 21.00 | | 35.1 | 193 | 3.82 | | 2.6 | 0.1 | 32.1 | 26.9 | 83.80 | 174 | 7.3 | 2070 | 0.54 | 0.020 | 96.2 | |
| 268 | 18/12/92 | 14:35 | 29.08 | 13.00 | | 35.0 | 193 | 2.73 | | | | | | | | | | | | | |

TABLE 3: ANAEROBIC DIGESTER WITH SETTLING TANK (AD-S) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/kgVS/d) | COD REDUC (%) | GAS PROD. (m3/kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 26/03 | 0.00 | | | 26.0 | 31.2 | | 26.3 | 19.6 | 74.52 | | | | | | | |
| 2 | 27/03 | 24.00 | 3.5 | 41.9 | 35.0 | 31.2 | | 26.3 | 19.6 | 74.52 | | | | 4.37 | 0.22 | | 0.38 |
| 5 | 30/03 | 70.67 | | 20.2 | 35.0 | | | | | | | | | | | | |
| 6 | 31/03 | 26.50 | 1.0 | 7.7 | 34.9 | 3.8 | 0.218 | | | | | | | 1.11 | | 99.3 | 0.25 |
| 7 | 01/04 | 22.58 | 4.0 | 42.5 | 34.8 | | | | | | | | | | | | |
| 8 | 02/04 | 23.75 | 2.4 | 30.4 | 33.5 | | | | | | | | | | | | |
| 9 | 03/04 | 23.50 | 3.1 | 37.7 | 33.1 | 27.8 | 0.683 | 26.8 | 18.4 | 68.66 | 60 | | | 3.51 | 0.19 | 97.5 | 0.44 |
| 13 | 07/04 | 95.52 | 12.7 | 200.7 | 35.0 | | | | | | | | | | | | |
| 14 | 08/04 | 20.55 | 2.8 | 43.6 | 35.1 | 26.1 | 0.740 | 25.4 | 19.6 | 77.17 | 60 | | 2850 | 3.42 | 0.17 | 97.2 | 0.60 |
| 15 | 09/04 | 22.27 | 4.0 | 47.5 | 34.9 | | | | | | | | | | | | |
| 16 | 10/04 | 29.17 | 3.5 | 61.5 | 35.1 | | | | | | | | | | | | |
| 19 | 13/04 | 67.58 | 10.0 | 134.0 | 35.0 | | | | | | | | | | | | |
| 20 | 14/04 | 24.83 | 2.5 | 52.7 | 34.9 | | | | | | | | | | | | |
| 21 | 15/04 | 23.93 | 2.5 | 62.9 | 34.9 | | | | | | | 6.99 | | | | | |
| 22 | 16/04 | 22.65 | 3.5 | 60.9 | 35.0 | | | | | | | | | | | | |
| 23 | 17/04 | 21.75 | 2.5 | 59.2 | 35.0 | | | | | | | | | | | | |
| 25 | 19/04 | 50.62 | 7.0 | 159.4 | 35.0 | | | | | | | | | | | | |
| 27 | 21/04 | 47.07 | 6.0 | 120.5 | 34.9 | 31.7 | 0.500 | 24.1 | 17.0 | 70.54 | 114 | 6.86 | 2765 | 3.88 | 0.23 | 98.4 | 0.63 |
| 28 | 22/04 | 25.23 | 4.5 | 67.5 | 35.0 | | | | | | | | | | | | |
| 29 | 23/04 | 24.92 | | 32.7 | 35.0 | | | | | | | 7.03 | | | | | |
| 30 | 24/04 | 27.33 | 3.5 | 84.6 | 35.0 | | | | | | | | | | | | |
| 33 | 27/04 | 66.67 | 9.5 | 189.9 | 34.9 | | | | | | | | | | | | |
| 34 | 28/04 | 24.33 | 3.1 | 15.2 | 35.0 | | | | | | | | | | | | |
| 35 | 29/04 | 24.00 | 3.4 | | 35.0 | 37.3 | 4.800 | 32.2 | 24.2 | 75.16 | 5856 | 5.05 | | 5.07 | 0.21 | 87.1 | |
| 36 | 30/04 | 21.00 | 1.0 | 9.0 | 34.9 | | | | | | | 6.93 | | | | | |
| 37 | 01/05 | 24.67 | 1.0 | 32.5 | 34.9 | | | | | | | 6.99 | | | | | |
| 39 | 03/05 | 5.85 | 4.0 | 66.3 | 34.9 | | | | | | | 6.97 | | | | | |
| 40 | 04/05 | 23.32 | 1.0 | | 35.0 | | | | | | | 6.92 | | | | | |
| 41 | 05/05 | 20.55 | 1.5 | 27.5 | 35.0 | 43.9 | 0.049 | 34.2 | 26.5 | 77.49 | 66 | 6.91 | 3170 | 3.08 | 0.12 | 99.9 | 0.42 |
| 42 | 06/05 | 24.95 | 0.5 | 30.2 | 35.0 | | | | | | | 6.88 | | | | | |
| 43 | 07/05 | 25.50 | 1.5 | 42.7 | 34.9 | 47.0 | 0.437 | 30.2 | 22.8 | 75.50 | 60 | 6.94 | 2960 | 2.65 | 0.12 | 99.1 | 0.61 |
| 44 | 08/05 | 27.37 | 2.5 | 27.1 | 35.0 | | | | | | | 7.08 | | | | | |
| 45 | 09/05 | 16.55 | 0.5 | 9.6 | 33.7 | | | | | | | 6.95 | | | | | |
| 47 | 11/05 | 50.07 | 2.2 | 1.0 | 20.6 | 49.6 | 0.214 | 31.7 | 23.8 | 75.08 | 222 | 6.69 | 2850 | 2.09 | 0.09 | 99.6 | 0.01 |
| 48 | 12/05 | 24.27 | 1.3 | 44.4 | 35.0 | | | | | | | 6.90 | | | | | |
| 49 | 13/05 | 23.05 | 1.0 | 36.5 | 34.9 | | | | | | | 6.95 | | | | | |
| 50 | 14/05 | 24.95 | 1.5 | 32.9 | 35.1 | 50.0 | 0.476 | 32.4 | 25.7 | 79.32 | 60 | 6.90 | 3225 | 2.89 | 0.11 | 99.0 | 0.44 |
| 51 | 15/05 | 24.00 | 1.5 | 33.8 | 35.0 | | | | | | | 6.89 | | | | | |
| 52 | 16/05 | 21.92 | 1.0 | 30.0 | 34.9 | | | | | | | 6.94 | | | | | |
| 54 | 18/05 | 49.12 | 2.0 | 63.8 | 35.0 | 47.0 | 0.482 | 32.3 | 24.8 | 76.78 | 60 | 6.88 | 3295 | 1.84 | 0.07 | 99.0 | 0.66 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | | | | 6.92 | | | | | |

TABLE 3: ANAEROBIC DIGESTER WITH SETTLING TANK (AD-S) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/kgVS/d) | COD REDUC (%) | GAS PROD. (m3/kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 56 | 20/05 | 22.72 | 1.5 | 31.5 | 35.0 | | | | | | | 6.96 | | | | | |
| 57 | 21/05 | 25.28 | 3.0 | 42.3 | 35.0 | 22.5 | 0.562 | 32.3 | 24.3 | 75.23 | 60 | 6.90 | 3165 | 2.56 | 0.11 | 97.5 | 0.63 |
| 58 | 22/05 | 23.58 | 4.5 | 40.4 | 35.0 | | | | | | | 6.96 | | | | | |
| 59 | 23/05 | 24.92 | 3.5 | 43.6 | 35.0 | | | | | | | 6.94 | | | | | |
| 60 | 24/05 | 24.17 | 3.5 | 40.9 | 35.0 | | | | | | | 6.94 | | | | | |
| 61 | 25/05 | 22.75 | 3.5 | 38.3 | 35.0 | 21.0 | 0.442 | 29.8 | 23.0 | 77.18 | 60 | 6.94 | 26.8 | 2.1 | 0.1 | 97.9 | 0.51 |
| 62 | 26/05 | 29.00 | 4.5 | 49.0 | 35.0 | | | | | | | 6.96 | | | | | |
| 63 | 27/05 | 21.17 | 3.0 | 32.5 | 34.9 | | | | | | | 6.96 | | | | | |
| 64 | 28/05 | 23.42 | 3.0 | 36.3 | 35.0 | | | | | | | 6.97 | | | | | |
| 65 | 29/05 | 22.83 | 3.0 | 39.4 | 34.8 | | | | | | | 6.95 | | | | | |
| 66 | 30/05 | 21.58 | 3.5 | 39.0 | 34.8 | | | | | | | 6.96 | | | | | |
| 68 | 01/06 | 49.17 | 7.3 | 84.6 | 35.0 | 19.8 | 0.340 | 31.0 | 24.5 | 79.03 | 60 | 6.96 | 2245 | 2.82 | 0.12 | 98.3 | 0.59 |
| 69 | 02/06 | 25.00 | 4.0 | 45.2 | 34.9 | | | | | | | 6.97 | | | | | |
| 70 | 03/06 | 23.25 | 2.5 | 39.2 | 34.8 | | | | | | | 6.90 | | | | | |
| 71 | 04/06 | 26.58 | 5.0 | 52.3 | 35.1 | 18.9 | 0.764 | 28.5 | 22.5 | 78.95 | | 6.90 | 2210 | 3.41 | 0.15 | 96.0 | 0.55 |
| 72 | 05/06 | 21.33 | 3.5 | 33.3 | 34.8 | | | | | | | 6.90 | | | | | |
| 73 | 06/06 | 26.67 | 4.5 | 37.5 | 35.0 | | | | | | | 6.91 | | | | | |
| 74 | 07/06 | 23.25 | 4.5 | 26.3 | 35.0 | | | | | | | 6.92 | | | | | |
| 75 | 08/06 | 24.67 | 4.5 | 33.1 | 35.0 | 26.1 | 0.522 | 26.7 | 21.4 | 80.15 | 60 | 7.00 | 2050 | 4.57 | 0.21 | 98.0 | 0.28 |
| 76 | 09/06 | 22.17 | 4.0 | 25.8 | 35.1 | | | | | | | 7.00 | | | | | |
| 77 | 10/06 | 23.33 | 4.5 | 32.1 | 34.9 | | | | | | | 6.89 | | | | | |
| 78 | 11/06 | 24.75 | 4.5 | 33.8 | 35.0 | 13.0 | 0.297 | 26.6 | 22.5 | 84.59 | | | 2015 | 2.27 | 0.1 | 97.7 | 0.58 |
| 79 | 12/06 | 22.08 | 4.0 | 25.4 | 34.9 | | | | | | | | | | | | |
| 81 | 14/06 | 56.08 | 10.5 | 54.8 | 35.1 | | | | | | | 6.76 | | | | | |
| 82 | 15/06 | 17.42 | 3.0 | 12.3 | 34.9 | 12.4 | 0.247 | 25.9 | 21.1 | 81.47 | | 6.67 | 1910 | 2.05 | 0.1 | 98.0 | 0.33 |
| 83 | 16/06 | 25.67 | 6.0 | 0.2 | 35.0 | | | | | | | 6.72 | | | | | |
| 84 | 17/06 | 24.67 | 3.4 | 12.5 | 35.0 | | | | | | | 6.58 | | | | | |
| 85 | 18/06 | 22.00 | 3.8 | | 34.9 | 13.5 | 0.257 | 25.4 | 21.6 | 85.04 | | 6.59 | 1945 | 2.24 | 0.1 | 98.1 | |
| 86 | 19/06 | 23.08 | 1.3 | 1.3 | 34.4 | | | | | | | | | | | | |
| 87 | 20/06 | 28.75 | 10.4 | 65.7 | 35.0 | | | | | | | | | | | | |
| 88 | 21/06 | 25.00 | 5.9 | 47.7 | 34.9 | | | | | | | | | | | | |
| 89 | 22/06 | 18.92 | 6.4 | 40.2 | 34.9 | 15.4 | 0.356 | 22.7 | 17.8 | 78.41 | | | 1675 | 5 | 0.25 | 97.7 | 0.41 |
| 90 | 23/06 | 29.33 | 5.3 | 40.2 | 35.0 | | | | | | | 6.55 | | | | | |
| 91 | 24/06 | 19.00 | 4.2 | 22.5 | 34.9 | | | | | | | 6.56 | | | | | |
| 92 | 25/06 | 22.92 | 4.5 | 28.3 | 35.0 | | | | | | | 6.65 | | | | | |
| 93 | 26/06 | 24.17 | 5.1 | 28.8 | 34.9 | | | | | | | 6.67 | | | | | |
| 96 | 29/06 | 75.50 | 8.4 | 76.5 | 34.9 | 11.0 | 0.279 | 25.7 | 21.1 | 82.10 | | 6.64 | 1950 | 1.17 | 0.06 | 97.5 | 0.83 |
| 97 | 30/06 | 26.17 | 5.5 | 36.3 | 35.0 | | | | | | | 6.66 | | | | | |
| 98 | 01/07 | 21.08 | 3.6 | 30.2 | 35.0 | | | | | | | 6.65 | | | | | |
| 99 | 02/07 | 21.92 | 4.5 | 31.5 | 35.0 | 12.6 | 0.283 | 24.9 | 20.9 | 83.94 | | 6.66 | 1940 | 2.48 | 0.12 | 97.8 | 0.56 |
| 100 | 03/07 | 23.58 | 0.4 | 1.0 | 31.3 | | | | | | | 6.59 | | | | | |

TABLE 3: ANAEROBIC DIGESTER WITH SETTLING TANK (AD-S) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 04/07 | 22.67 | | 1.3 | 34.9 | | | | | | | 6.61 | | | | | |
| 103 | 06/07 | 52.58 | 10.8 | 67.1 | 35.0 | 12.4 | 0.349 | 25.1 | 21.2 | 84.46 | 54 | 6.63 | 1940 | 2.44 | 0.12 | 97.2 | 0.50 |
| 104 | 07/07 | 22.50 | 4.5 | 27.1 | 34.9 | | | | | | | 6.67 | | | | | |
| 105 | 08/07 | 22.83 | 4.7 | 25.4 | 34.9 | | | | | | | 6.65 | | | | | |
| 106 | 09/07 | 24.50 | 4.5 | 31.7 | 34.9 | | | | | | | | | | | | |
| 107 | 10/07 | 22.83 | 4.3 | 38.8 | 34.9 | | | | | | | | | | | | |
| 110 | 13/07 | 74.32 | 10.7 | 66.9 | 24.2 | | | | | | | | | | | | |
| 111 | 14/07 | 27.47 | | 2.5 | 19.0 | | | | | | | | | | | | |
| 112 | 15/07 | 17.77 | 0.5 | 2.9 | 34.6 | | | | | | | | | | | | |
| 113 | 16/07 | 29.95 | 6.0 | 30.4 | 35.0 | | | | | | | | | | | | |
| 114 | 17/07 | 24.00 | 5.5 | 24.8 | 34.9 | | | | | | | | | | | | |
| 115 | 18/07 | 21.75 | 4.0 | 33.8 | 34.9 | | | | | | | | | | | | |
| 117 | 20/07 | 47.17 | 9.4 | 61.9 | 34.9 | 12.7 | 0.319 | 24.3 | 19.9 | 81.89 | 2220 | | 10 | 2.43 | 0.12 | 97.5 | 0.52 |
| 119 | 22/07 | 46.25 | 10.5 | 56.1 | 34.9 | | | | | | | | | | | | |
| 120 | 23/07 | 22.83 | 4.5 | 24.6 | 35.0 | 12.3 | 0.312 | 23.9 | 19.9 | 83.26 | | | 1835 | 2.33 | 0.12 | 97.5 | 0.44 |
| 121 | 24/07 | 25.83 | 5.0 | 32.7 | 35.0 | | | | | | | | | | | | |
| 124 | 27/07 | 73.17 | 15.0 | 99.0 | 35.0 | 12.3 | 0.436 | 22.6 | 18.8 | 83.19 | | | 1680 | 2.42 | 0.13 | 96.5 | 0.54 |
| 125 | 28/07 | 27.75 | 5.6 | 12.7 | 34.2 | | | | | | | | | | | | |
| 126 | 29/07 | 20.58 | 4.0 | 31.3 | 35.0 | | | | | | | | | | | | |
| 127 | 30/07 | 21.50 | 4.5 | 34.0 | 34.9 | 14.3 | 0.345 | 20.9 | 17.0 | 81.34 | 114 | | 1870 | 2.87 | 0.17 | 97.6 | 0.53 |
| 128 | 31/07 | 24.17 | 5.1 | 39.4 | 34.9 | | | | | | | | | | | | |
| 131 | 03/08 | 78.83 | 16.9 | 118.4 | 35.0 | 13.3 | 0.278 | 20.2 | 16.5 | 81.68 | 6 | | 1885 | 2.92 | 0.18 | 97.9 | 0.53 |
| 132 | 04/08 | 24.00 | 0.2 | 3.8 | 35.1 | | | | | | | 6.71 | | | | | |
| 133 | 05/08 | 23.95 | 4.8 | 45.9 | 35.1 | | | | | | | 6.64 | | | | | |
| 134 | 06/08 | 24.25 | 5.0 | 37.3 | 35.0 | 14.6 | 0.296 | 20.2 | 17.3 | 85.64 | 12 | 6.54 | 1840 | 2.89 | 0.17 | 98.0 | 0.51 |
| 135 | 07/08 | 27.97 | 6.0 | 46.9 | 35.0 | | | | | | | 6.55 | | | | | |
| 138 | 10/08 | 66.50 | 13.5 | 101.7 | 34.9 | 13.7 | 0.254 | 20.7 | 16.9 | 81.64 | | 6.57 | 1845 | 2.67 | 0.16 | 98.1 | 0.55 |
| 139 | 11/08 | 25.83 | 5.3 | 40.4 | 34.9 | | | | | | | 6.59 | | | | | |
| 140 | 12/08 | 25.83 | 5.3 | 40.4 | 34.9 | | | | | | | 6.59 | | | | | |
| 141 | 13/08 | 31.08 | 5.6 | 45.0 | 35.0 | | | | | | | 6.57 | | | | | |
| 142 | 14/08 | 23.00 | 3.6 | 47.7 | 34.9 | | | | | | | 6.61 | | | | | |
| 143 | 15/08 | 21.42 | 4.5 | 49.6 | 35.2 | | | | | | | 6.60 | | | | | |
| 144 | 16/08 | 22.75 | 4.7 | 62.5 | 34.9 | | | | | | | 6.59 | | | | | |
| 145 | 17/08 | 24.00 | 4.7 | 45.2 | 34.9 | | | | | | | 6.58 | | | | | |
| 146 | 18/08 | 24.50 | 5.2 | 52.9 | 35.0 | | | | | | | 6.55 | | | | | |
| 147 | 19/08 | 21.75 | 4.5 | 46.1 | 34.9 | | | | | | | 6.57 | | | | | |
| 148 | 20/08 | 23.97 | 4.8 | 52.5 | 35.0 | | | | | | | 6.60 | | | | | |
| 149 | 21/08 | 24.43 | 5.0 | 54.4 | 35.0 | | | | | | | 6.61 | | | | | |
| 150 | 22/08 | 2.07 | 3.4 | 47.9 | 35.0 | | | | | | | 6.57 | | | | | |
| 152 | 24/08 | 50.28 | 9.2 | 108.2 | 35.0 | 17.9 | 0.305 | 20.6 | 16.8 | 81.55 | | 6.59 | 1700 | 3.14 | 0.19 | 98.3 | 0.66 |

TABLE 3: ANAEROBIC DIGESTER WITH SETTLING TANK (AD-S) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 154 | 26/08 | 20.67 | 3.4 | 41.5 | 34.9 | | | | | | | | | | | | |
| 155 | 27/08 | 27.17 | 5.2 | 52.3 | 35.0 | | | | | | | | | | | | |
| 157 | 29/08 | 20.15 | 3.5 | 35.4 | 35.0 | | | | | | | | | | | | |
| 159 | 31/08 | 52.27 | 9.8 | 97.3 | 35.0 | 11.6 | 0,297 | 20.1 | 16.5 | 82.09 | | | 1810 | 2.09 | 0.13 | 97.4 | 0.86 |
| 160 | 01/09 | 23.75 | 4.5 | 35.0 | 35.0 | | | | | | | | | | | | |
| 163 | 04/09 | 75.00 | 23.2 | 129.8 | 34.8 | | | | | | | | | | | | |
| 166 | 07/09 | 70.42 | 14.0 | 170.5 | 35.0 | | | | | | | | | | | | |
| 167 | 08/09 | 22.75 | 5.5 | 31.9 | 35.0 | | | | | | | | | | | | |
| 168 | 09/09 | 23.33 | 4.8 | 35.0 | 35.0 | 14.2 | 0.311 | 15.9 | 12.8 | 80.50 | 36 | | 1880 | 2.8 | 0.22 | 97.8 | 0.51 |
| 169 | 10/09 | 25.50 | 4.0 | 46.1 | 35.0 | | | | | | | | | | | | |
| 170 | 11/09 | 23.50 | 4.5 | 46.5 | 35.2 | | | | | | | 6.75 | | | | | |
| 171 | 12/09 | 19.67 | 4.3 | 42.3 | 35.0 | | | | | | | 6.67 | | | | | |
| 173 | 14/09 | 51.33 | 5.7 | 57.1 | 35.0 | 18.0 | 0.511 | 14.7 | 11.4 | 77.55 | 120 | 6.78 | 1975 | 1.92 | 0.17 | 97.2 | 0.56 |
| 174 | 15/09 | 22.00 | 4.6 | 50.2 | 35.1 | | | | | | | 6.88 | | | | | |
| 175 | 16/09 | 24.33 | 3.2 | 51.7 | 35.0 | | | | | | | 6.89 | | | | | |
| 176 | 17/09 | 28.67 | 2.3 | 52.5 | 35.0 | | | | | | | 6.89 | | | | | |
| 177 | 18/09 | 25.00 | 7.6 | 55.0 | 35.0 | | | | | | | 6.90 | | | | | |
| 178 | 19/09 | 20.50 | 2.1 | 26.9 | 35.0 | | | | | | | 6.88 | | | | | |
| 180 | 21/09 | 53.00 | 11.5 | 78.6 | 35.0 | | | | | | | 6.84 | | | | | |
| 181 | 22/09 | 16.05 | 3.0 | 22.1 | 35.0 | 12.9 | 0.410 | 20.8 | 16.8 | 80,77 | 6 | 6.82 | 360 | 2.31 | 0.14 | 96.8 | 0.57 |
| 182 | 23/09 | 24.53 | 4.6 | 20.4 | 35.1 | | | | | | | 6.84 | | | | | |
| 183 | 24/09 | 31.42 | 5.9 | 0.2 | 35.1 | | | | | | | 6.85 | | | | | |
| 184 | 25/09 | 17.08 | 3.6 | 0.4 | 35.1 | | | | | | | 6.88 | | | | | |
| 187 | 28/09 | 75.33 | 14.2 | 5.8 | 35.0 | | | | | | | 6.88 | | | | | |
| 188 | 29/09 | 20.20 | 4.3 | 4.8 | 35.0 | 18.0 | 0,393 | 24.0 | 18.9 | 78.75 | 6 | 6.89 | 2500 | 3.68 | 0.19 | 97.8 | 0.06 |
| 189 | 30/09 | 24.55 | 3.4 | 13.3 | 35.0 | | | | | | | 6.90 | | | | | |
| 190 | 01/10 | 26.33 | 4.5 | 1.0 | 35.3 | | | | | | | 6.89 | | | | | |
| 191 | 02/10 | 21.17 | 4.5 | | 35.1 | | | | | | | 6.91 | | | | | |
| 192 | 03/10 | 22.58 | 3.8 | 0.8 | 35.0 | | | | | | | 6.97 | | | | | |
| 194 | 05/10 | 52.42 | 10.5 | 0.2 | 35.0 | | | | | | | 6.92 | | | | | |
| 195 | 06/10 | 21.83 | 4.5 | 1.9 | 35.0 | 19.1 | 0.432 | 18.2 | 13.6 | 74.73 | 18 | 6.91 | 2455 | 3.78 | 0.28 | 97.7 | 0.02 |
| 196 | 07/10 | 23.50 | 5.1 | 3.3 | 35.0 | | | | | | | 6.90 | | | | | |
| 197 | 08/10 | 28.33 | 5.8 | 0.2 | 35.0 | | | | | | | 6.92 | | | | | |
| 198 | 09/10 | 24.67 | 4.5 | 35.0 | 35.1 | | | | | | | 6.92 | | | | | |
| 199 | 10/10 | 19.67 | 3.9 | 31.9 | 35.0 | | | | | | | 6.94 | | | | | |
| 201 | 12/10 | 52.58 | 9.9 | 91.9 | 35.0 | | | | | | | 6.93 | | | | | |
| 202 | 13/10 | 20.55 | 4.9 | 38.6 | 35.0 | 20.3 | 0.459 | 20.5 | 16.5 | 80.49 | 162 | 6.95 | 1630 | 4.65 | 0.28 | 97.7 | 0.39 |
| 203 | 14/10 | 21.70 | 4.8 | 50.4 | 35.0 | | | | | | | 6.93 | | | | | |
| 204 | 15/10 | 24.75 | 5.5 | 45.0 | 35.0 | | | | | | | 6.92 | | | | | |
| 205 | 16/10 | 26.25 | 5.0 | 47.9 | 35.0 | | | | | | | 6.92 | | | | | |
| 206 | 17/10 | 19.45 | 3.0 | 33.3 | 35.0 | | | | | | | | | | | | |

TABLE 3: ANAEROBIC DIGESTER WITH SETTLING TANK (AD-S) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/kgVS/d) | COD REDUC (%) | GAS PROD. (m3/kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 207 | 18/10 | 30.20 | 6.1 | 48.4 | 35.0 | | | | | | | | | | | | |
| 208 | 19/10 | 24.85 | 5.6 | 49.2 | 35.0 | | | | | | | | | | | | |
| 209 | 20/10 | 23.75 | 5.6 | 37.1 | 35.0 | | | | | | | | | | | | |
| 210 | 21/10 | 19.25 | 2.0 | 39.8 | 34.9 | 18.5 | 0.571 | 23.5 | 20.0 | 85.11 | 12 | | 1400 | 1.85 | 0.09 | 96.9 | 1.08 |
| 211 | 22/10 | 24.58 | 6.5 | 45.0 | 35.0 | | | | | | | | | | | | |
| 212 | 23/10 | 28.92 | 5.9 | 53.6 | 35.0 | | | | | | | | | | | | |
| 215 | 26/10 | 71.67 | 14.5 | 28.5 | 35.0 | | | | | | | | | | | | |
| 216 | 27/10 | 19.08 | 3.9 | 36.7 | 35.0 | 14.4 | 0.507 | 16.0 | 12.3 | 76.88 | 30 | | 1305 | 2.83 | 0.23 | 96.5 | 0.65 |
| 217 | 28/10 | 23.47 | 0.2 | 2.1 | 35.0 | | | | | | | | | | | | |
| 218 | 29/10 | 26.45 | 4.0 | 0.6 | 35.0 | | | | | | | | | | | | |
| 219 | 30/10 | 24.00 | 5.5 | 0.4 | 35.0 | | | | | | | | | | | | |
| 220 | 31/10 | 19.67 | 4.0 | | 35.0 | | | | | | | | | | | | |
| 221 | 01/11 | 28.25 | 6.0 | | 36.1 | | | | | | | | | | | | |
| 222 | 02/11 | 24.25 | 6.0 | | 41.9 | | | | | | | | | | | | |
| 223 | 03/11 | 23.43 | 5.3 | 6.7 | 41.3 | 11.5 | 0.696 | 17.2 | 13.9 | 80.81 | 18 | | 1485 | 2.5 | 0.18 | 93.9 | 0.11 |
| 224 | 04/11 | 21.65 | 5.3 | | 53.3 | | | | | | | 6.89 | | | | | |
| 225 | 05/11 | 26.42 | 5.3 | | 43.2 | | | | | | | 6.91 | | | | | |
| 226 | 06/11 | 24.00 | 5.0 | | 41.9 | | | | | | | | | | | | |
| 229 | 09/11 | 72.50 | 15.0 | | 47.3 | | | | | | | 6.49 | | | | | |
| 230 | 10/11 | 21.17 | 4.5 | | 35.0 | | | | | | | | | | | | |
| 231 | 11/11 | 25.17 | 4.5 | | 35.1 | 11.8 | 3.525 | 16.5 | 13.8 | 83.64 | 1596 | | | 2.03 | 0.15 | 70.1 | |
| 232 | 12/11 | 22.58 | 4.0 | | 45.9 | | | | | | | | | | | | |
| 233 | 13/11 | 24.00 | 6.0 | | 40.3 | | | | | | | 4.96 | | | | | |
| 234 | 14/11 | 24.00 | 5.0 | | 48.3 | | | | | | | | | | | | |
| 235 | 15/11 | 24.25 | 4.0 | | 49.1 | | | | | | | 4.59 | | | | | |
| 236 | 16/11 | 23.92 | 6.0 | | 40.2 | | | | | | | 4.71 | | | | | |
| 237 | 17/11 | 23.83 | 5.0 | | 41.9 | 6.2 | 2.080 | 15.7 | 13.2 | 64.08 | | 4.65 | | 1.25 | 0.09 | 66.5 | |
| 238 | 18/11 | 24.17 | 5.0 | | 45.6 | | | | | | | | | | | | |
| 239 | 19/11 | 23.83 | 5.0 | | 43.2 | | | | | | | | | | | | |
| 240 | 20/11 | 24.42 | 5.0 | 0.2 | 41.8 | | | | | | | | | | | | |
| 241 | 21/11 | 23.58 | 4.0 | | 34.4 | | | | | | | | | | | | |
| 243 | 23/11 | 48.42 | 10.0 | | 35.2 | | | | | | | | | | | | |
| 244 | 24/11 | 23.58 | 5.0 | 1.0 | 46.4 | | | | | | | | | | | | |
| 245 | 25/11 | 24.75 | 4.0 | 1.7 | 35.4 | | | | | | | | | | | | |
| 246 | 26/11 | 23.58 | 4.0 | 9.0 | 46.7 | | | | | | | | | | | | |
| 247 | 27/11 | 24.34 | 8.3 | | 6.3 | 4.5 | 28.000 | 7.1 | 6.0 | 84.51 | 1410 | 4.70 | 1175 | 1.24 | 0.21 | 7.1 | 0.26 |
| 248 | 28/11 | 28.17 | 6.0 | | | | | | | | | | | | | | |
| 250 | 30/11 | 44.42 | 9.5 | | | | | | | | | | | | | | |
| 252 | 02/12 | 48.00 | | | | 3.2 | | 13.1 | 11.4 | 87.02 | 1410 | 4.80 | 990 | | | | |
| 253 | 03/12 | 22.33 | 1.0 | | | | | | | | | | | | | | |

TABLE 3: ANAEROBIC DIGESTER WITH SETTLING TANK (AD-S) - OPERATION AND ANALYSES - 1992

| DAY NO. | DATE 1992 | TIME DIFF (h) | FEED VOL (L) | GAS VOL (L) | TEMP (C) | FEED COD (g/L) | EFFL COD (g/L) | TOTAL SOLID (g/L) | VOLAT SOLID (g/L) | VOLAT SOLID (%) | VOLAT ACIDS (mg/L) | pH | ALKALIN as CaCO3 (mg/L) | SPACE LOAD (kgCOD/m3/d) | BIOLOG LOAD (kgCOD/ kgVS/d) | COD REDUC (%) | GAS PROD. (m3/ kgCOD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 257 | 07/12 | 68.00 | | | | | | | | | | | | | | | |
| 259 | 09/12 | 46.25 | 9.8 | | | | | | | | | | | | | | |
| 260 | 10/12 | 25.58 | 6.2 | | | | | | | | | | | | | | |
| 261 | 11/12 | 24.83 | | | | 3.3 | | 12.3 | 10.8 | 87.80 | 2316 | 5.00 | | | | | |
| 264 | 14/12 | 69.00 | 1.0 | | | | | | | | | | | | | | |
| 267 | 17/12 | 48.83 | 13.0 | | | | | 12.4 | 10.9 | 87.90 | 1830 | 5.40 | <50 | | | | |
| 268 | 18/12 | 29.08 | 7.0 | | | | | | | | | | | | | | |

# APPENDIX 2 : OPERATION NOTES ON ADUF AND ADS TESTS

# OPERATION NOTES ON ADUF AND ADS TESTS

ADUF 1 (These notes are from 26/05/92 to 17/12/92)

| DAY | DATE | NOTE |
|---|---|---|
| 62 | 26/5 | Remove and clean all dirty piping |
| 63 | 27/5 | Found gas seal broken, piping coated with sludge. Clean piping and re-establish the gas seal. |
| 66 | 30/5 | Recirculation Mono-pump stopped, sludge leaking from the insulated heater pipe. Switch off ADUF 1 totally at 07:30. Found the heater element had melted. |
| 67 | 1-2/6 | Plant off. Replace piping and heating element. Add a clear PVC sludge trap to the gas outlet, directly on top of the digester. |
| 70 | 3/6 | Restart the plant at 14:50. |
| 72 | 5/6 | Foam/sludge present in the sludge trap. Remove and clean. |
| 74 | 7/6 | Gas system is leaking. No increase in gas reading since 31/5 at 19h15. |
| 75 | 8/6 | Repair gas leak. Gasket removed and sealed with silicone rubber on both sides. |
| 77 | 10/6 | Feed pump stopped for repairs. |
| 78 | 11/6 | Feed pump restarted at 08:55. |
| 79 | 12/6 | A general power failure had caused the Monopump to stop. Did not restart again and caused severe overheating which led to melting of the insulation. Restart manually at 16:00 after repairs. |
| 82 | 15/6 | Gas/sludge trap full. Clean and continue. |
| | 16/6 | Gas/sludge trap full. Clean and continue. |
| 86 | 19/6 | Gas/sludge trap full. Clean and continue. |
| 90 | 23/6 | Adjust belt tension on the Monopump. |
| 91 | 24/6 | Remove and clean gas/sludge trap. Repair leaks in trap. |

| | | |
|---|---|---|
| 93 | 26/6 | Sludge leaking from Monopump gland. Tighten seal. ADUF 1 off to change feeding cycle at 09:00. |
| 95 | 28/6 | Stellenbosch power off from 08:00 till 17:00. |
| 97 | 30/6 | Restart ADUF 1 at 17:15. The unit is now on INTERMITTENT OPERATION. Mixing by gas recirculation for 01:55, Feed for 25 minutes, UF on for 5 minutes. This 2 hour cycle repeats. |
| 99 | 2/7 | Increase feed pump rate setting from 120 to 125 units. |
| 100 | 3/7 | Gas recirculation pump stopped. Fit new gas recirculation pump at 12h20. Increase feed timer from 25 to 30 minutes. |
| 101 | 4/7 | Gas/sludge trap full. Clean and continue. |
| 103 | 6/7 | Sludge entered the gas recirculation pump and shorted out the entire plant. Plant off for repairs. |
| 114 | 17/7 | Removed gas recirculation pump, sealed off inlet. Drained all old sludge and refilled with fresh sludge from the Paarl WW digester. Reset the feed pump to 250 units. Restart plant, still on intermittent operation but without gas recirculation. |
| 117 | 20/7 | Sludge leaking from the Monopump seal. Tighten seal. |
| 124 | 27/7 | Gas seal broken. Reestablish seal. |
| 125 | 28/7 | Increase feed cycle from 30 minutes to 60 minutes per 2 hour cycle, with the UF Monopump operating for 5 minutes.<br>Cycle as follows: Feed 60 min, Rest 55 min, UF 5 min. |
| 126 | 29/9 | Increase UF from 5 to 10 minutes per 2 hour cycle.<br>Cycle as follows: Feed 60 min, Rest 50 min, UF 10 min. |
| 131 | 3/8 | High temperature - 39.4°C. Monopump seal leaking. Tighten. |
| 133 | 5/8 | Pressure gauge failed. Replace with a gauge reading in PSI. |
| 134 | 6/8 | No permeate collected (float valve jammed?). |
| 138 | 10/8 | Clean pressure gauge and fittings/piping. Replace the relay which controls the heating elements. |
| 139 | 11/8 | Pressure gauge faulty. |
| 146 | 18/8 | Plant switched off to replace the packing on the Monopump. |

| | | |
|---|---|---|
| 147 | 19/8 | Plant restarted. |
| 152 | 24/8 | Gas/sludge trap full. Clean and continue. |
| 159 | 31/8 | Increase UF pump operation time from 10 to 30 minutes. New cycle is now as 2 hours 30 minutes: Feed 60 min, Rest 60 min. UF 30 min. |
| 160 | 1/9 | Increase feed pump setting from 250 to 330 units. UF pump rate is 6.00 litres/minute. |
| 166 | 7/9 | No gas production registered, gas system faulty. |
| 167 | 8/9 | No gas. Gas/sludge trap full. Clean and continue. |
| 168 | 9/9 | Gas meter not working. |
| 173 | 14-16/9 | Gas meter not working. |
| 181 | 22/9 | Gas seal does not indicate any pressure difference. Meter or gas system leaking? Increase feed rate by 20% (from 330 to 396 units). |
| 182 | 23/9 | Repair one of the solenoid valves (Sol 1) of the gas meter. |
| 183 | 24/9 | Pipe blown off the Monopump and ALL the sludge in digester was lost! Switch off the plant at 09:50. |
| 184 | 25/9 | Refill the plant with fresh sludge from Paarl WW digester. Restart system at 08:45. |
| 187 | 28/9 | All sludge lost again! Refill and start up at 16:15. |
| 188 | 29/9 | All sludge lost for third time! Refill and start up at 14:00. |
| 189 | 30/9 | Another blockage caused the sludge to be lost again. Clean out digester, membrane unit pipes etc. Fill system with water and start at 14:37. |
| 191 | 2/10 | Drain water from plant and refill with fresh sludge from Paarl WW digester. |
| 192 | 3/10 | Lost all sludge again. switch system off. |
| 195 | 6/10 | Fill with water and start up at 09:40. |
| 196 | 7/10 | Leak in the membrane module housing. |
| 201 | 12/10 | Stop plant and seal leak in the module housing. |

202 13/10 Drain plant, refill with fresh sludge from Paarl WW digester. Restart at 11:30.

205 16/10 Gas/sludge trap full. Clean and continue. No gas readings registered, meter U/S?

208 19/10 Still no gas measured by meter (since 16/10).

222 2/11 Change feed substrate to a mixture of spent wine waste to beer brewery waste in a 3:1 ratio.

225 5/11 Replace tubing in the peristaltic feed pump.

226 6/11 Feed mixture, spent wine: beer waste = 2:1

231 11/11 Feed mixture, spent wine: beer waste = 1:1

236 16/11 Feed mixture, spent wine: beer waste = 1:2

240 20/11 Feed mixture, spent wine: beer waste = 1:3

244 24/11 Power failure at 14:30.

245 25/11 Plant operating on beer brewery waste only from now on.

265 15/12 Numerous leaks in plant - repair where possible.

268 18/12 Stop plant and clean.

ADUF 2 (These notes cover the period from 26/5 to 17/12)

| DAY | DATE | NOTE |
|---|---|---|
| 62 | 26/5 | UF Monopump gland leaking. Tighten gland. Foam out of gas outlet. clean all piping and add some antifoam agent to digester. |
| 65 | 29/5 | Gas seal broken, pipes all full of sludge. Rectify and clean. |
| 69 | 2/6 | Gas seal broken, gas/water trap and pipes filled with sludge, clean all. |
| 70 | 3/6 | Gas seal broken, gas/water trap and pipes filled with sludge, clean all. Sludge flow rate measured as 7.7 litres/minute. |
| 73 | 6/6 | Temperature down. Sludge leaking from the Monopump seal. Tighten gland. |
| 75 | 8/6 | Gas seal broken, pipes all full of sludge. Rectify and clean. |
| 76 | 9/6 | Stop plant at 09:30 to install a gas/sludge trap made from clear PVC directly above the gas outlet on top of the digester. Remove heater element from around the digester and wind it around the galvanized sludge pipe. Refit pipe to Monopump and restart at 14:00. |
| 79 | 12/6 | A general power failure at 09:30 caused the Monopump to stop and it could not restart automatically when the power was restored. Overheating of the heating elements caused severe damage to the insulation. System restarted at 16:00. |
| 81 | 14/6 | Top gas/sludge trap full of sludge and blocked, causing the gas seal to blow out. Clean all traps and pipes. |
| 85 | 18/6 | Top gas/sludge trap full of sludge. Clean all traps and pipes. Low pressure reading on the UF. |
| 95 | 28/6 | Power off in Stellenbosch from 08:00 to 17:00. Modify the system so that the Monopump can restart automatically after a power failure. |
| 111 | 14/7 | Plant off-line for repairs. |
| 114 | 17/7 | Restart plant. |
| 117 | 20/7 | Sludge leaking from Monopump gland. Tighten gland. |
| 128 | 31/7 | Sludge leaking from Monopump gland. Tighten gland. |
| 133 | 5/8 | Replace UF pressure gauge, calibrated in PSI. |
| 139 | 11/8 | Pressure gauge U/S, clean gauge and refit. |
| 148 | 20/8 | Stop plant at 08:39, replace gland packing in Monopump. Remove a plastic cap that was stuck inside the pump. Restart at 12:30. |

153 25/8 Blockage in feed line. Clear and continue.

159 31/8 UF sludge flow rate 6.2 litres/minute.

160 1/9 UF sludge flow rate 6.16 litres/minute.

181 22/9 Increase feed rate by 20% (65 to 78 units on feed pump adjustment).

222 2/11 Change to a feed substrate mixture of spent wine waste to beer brewery waste in a ratio of 3:1.

226 6/11 Feed mixture, spent wine : beer waste 2:1.

231 11/11 Feed mixture, spent wine : beer waste 1:1.

236 16/11 Feed mixture, spent wine : beer waste 1:2.

240 20/11 Feed mixture, spent wine : beer waste 1:3.

244 24/11 Power failure 14:30.

245 25/11 Feed pure beer brewery waste from now onwards.

261 11/12 Increase feed pump setting to 94 units.

265 15-17/12 No gas reading.

268 18/12 Stop plant and clean.

ANAEROBIC DIGESTION - SETTLING (AD-S) (These notes cover the period from 26/5 to 17/12)

| DAY | DATE | NOTE |
|---|---|---|
| 62 | 27/5 | Very poor settling - effluent contains sludge. |
| 64 | 28/5 | Poor settling - effluent contains sludge. |
| 65 | 29/5 | Pipe between digester and settling tank blocked, level in settling tank low. Clean pipe. |
| 72 | 5/6 | Low level in settling tank, poor settling of sludge results in sludge in effluent. |
| 73 | 6/6 | Low level in settling tank, poor settling of sludge results in sludge in effluent. Clean out all pipes and fittings. |
| 74 | 7/6 | No visible settling of sludge. Sludge present in the effluent. |
| 75 | 8/6 | No visible settling of sludge. Sludge present in the effluent. |
| 76 | 9/6 | Some settling of sludge, but still far from satisfactory condition. |
| 81 | 14/6 | Decrease setting on feed pump from 220 to 200 units. Low pH 6.76 in digester. |
| 82 | 15/6 | Poor settling. |
| 84 | 17/6 | Poor settling. Gas leak causes low gas reading. |
| 85 | 18/6 | Poor settling. No gas registered. Feed pump switched off at 16:00. |
| 86 | 19/6 | Feed pump on at 07:30. No gas registered. Low level in settling tank. |
| 88 | 21/6 | No settling. Sludge in effluent. |
| 89 | 22/6 | No settling. Sludge in effluent. |
| 93 | 26/6 | Power off in Stellenbosch from 08:00 to 17:00. Plant off. |
| 100 | 3/7 | Low level in settling tank. Very low gas production. Feed pump did not restart from 08:35. |
| 101 | 4/7 | Restart feed pump. Low level in settling tank. Poor gas production, only 6 units (1.2 litres) on meter. |
| 106 | 9/7 | Pipe between digester and settling tank blocked, causing low level in settler and filling up of the digester. Very little final effluent (70 m$\ell$) produced. Clean system. |
| 110 | 13/7 | Power failure over the weekend stopped plant. |

| | | |
|---|---|---|
| 111 | 14/7 | Switch power on at 14:15. Stopped feed pump at 16:09. |
| 112 | 15/7 | Start feed pump at 08:00. |
| 124 | 27/7 | Sludge return pump leaking. Replace the silicone tubing. Approximately 3 litres of sludge has been lost from the system. Sludge present in the effluent. |
| 125 | 28/7 | Added 3.5 litres sludge to the digester. Settling tank empty due to system malfunction. |
| 142 | 14/8 | Feed pump on at 08:30. low level in settling tank. |
| 144 | 16/8 | Low level in settling tank. Sludge lost owing to blockage in pipe fitting. |
| 166 | 7/9 | Digester under pressure, sludge spurting out. Pies blocked again. Switch off sludge return pump and refill digester with fresh sludge from the Paarl WW digester. Gas seal broken. Settling tank empty. |
| 173 | 14/9 | Gas seal broken, re-establish. |
| 177 | 18/9 | Blockage in pipe to settling tank, causing low level in settling tank. |
| 183 | 24/9 | Low level in settling tank. Silicone pipe in peristaltic sludge return pump failed. Lost a lot of sludge. Refill digester with fresh sludge from Paarl WW digester. |
| 184 | 25/9 | Very low gas production, only 2 units registered. |
| 190 | 1/10 | No gas registered. |
| 192 | 3/10 | No gas registered. |
| 194 | 5/10 | Settling tank completely empty, owing to blockage in pipe. Bottom outlet of digester also blocked. Clean and re-establish gas seal. |
| 203 | 14/10 | Low level in settling tank. |
| 208 | 19/10 | Blockage in pipe to settling tank, causing low level in settler. |
| 212 | 23/10 | Replace silicone pipe in sludge return pump. |
| 217 | 28/10 | Feed pump switched off. |
| 222 | 2/11 | From today feeding a mixture of diluted spent wine and beer brewery waste, mixed in a ratio of spent wine : beer waste of 3:1. |
| 224 | 4/11 | High temperature reading (43.3°C). Checked digester temperature with a thermometer (35°C). It appears as if the temperature control unit is malfunctioning. High temperature readings from 4/11 till 9/11 of 40°C +. |
| 226 | 6/11 | Feed mixture, spent wine : beer waste 2:1. |

230 10/11 Temperature registering normally 35°C.

231 11/11 Feed mixture, spent wine : beer waste 1:1. Temperature normal.

232 12/11 High temperature reading of 45.9°C

233 13/11 High temperature reading of 40.3°C

234 14/11 High temperature reading of 48.3°C

235 15/11 High temperature reading of 49.1°C

236 16/11 High temperature reading of 40.2°C. Feed mixture, spent wine : beer waste 1:2.

237 17/11 High temperature reading of 41.9°C. Low pH of 4.69. It appears as if the digester is completely dead.

238 18/11 Temperature indicator at 45.6°C, but temperature of the digester sludge on a thermometer is 34.0°C.

240 20/11 No gas registered. Feed mixture, spent wine : beer waste 1:3.

241 21/11 No gas registered.

244 24/11 Power failure from 14:30 till 19:30. Plant off.

246 26/11 High temperature reading of 46.7°C

247 27/11 Temperature indicator now completely useless. Ignore readings.

250 30/11 Turn off feed and sludge return pumps for digester to recover.

252 2/12 Restart pumps and fill feed tank with fresh beer brewery waste.

254 4/12 Feed pump off (accidentally?). Reset feed pump from 200 to 220 units to increase feed rate.

261 11/12 Increase feed rate by resetting feed pump from 220 to 240 units.

265 15/12 Blockage in feed line. Clean and check.

268 18/12 Stop plant and clean. Note: There were no temperature readings since 27/11.