RESEARCH INTO THE EVALUATION AND OPTIMISATION OF FULL SCALE CHEMICAL PHOSPHATE REMOVAL IN BIOLOGICAL SEWAGE TREATMENT PROCESSES

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TOWN COUNCIL OF BOKSBURG

AND

SCOTT AND DE WAAL INCORPORATED

REPORT SUBMITTED TO THE

WATER RESEARCH COMMISSION

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by

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EXECUTIVE SUMMARY

Currently about half of the sewage treated in the sensitive catchments in South Africa is purified by means of the biological filter process. The popularity of this process can be attributed to its low maintenance requirements, low energy usage, stability and reliability, as well as its compliance with the General Standard for effluents. A serious limitation of the process, however, is its inability to remove phosphate biologically to any significant degree.

Methods for upgrading of the biological filter process for the removal of phosphate have been developed and tested in South Africa. However, criteria for the optimal design and operation of such processes were lacking. In particular, there was a need for the development of a chemical dosing strategy to mini- mize chemical consumption, but assure the attainment of the effluent phosphate standard for at least 95 per cent of the time. The advantages of a process which is operated optimally are minimization of: (i) chemical usage, (ii) sludge production, (iii) effluent salination, (iv) treatment costs.

A considerable degree of uncertainty existed as to the additional volumes and masses of sludge produced when a conventional biological filter treatment works was upgraded for chemical phosphate removal. Uncertainty also existed considering properties of the mixed biological/chemical sludges formed in these processes. This information is crucial for the design of new works, as well as for upgrading existing works for phosphate removal. Of overall importance is the incremental cost associated with the introduction of phosphate removal.

During 1982 The Town Council of Boksburg commissioned a third 18Ml/d module of its Vlakplaats biological filter sewage treatment works. This module made provision for chemical phosphate removal and hence made it eminantly suitable for obtaining the information outlined above. An agreement to obtain this information was entered into between the Water Research Commission, the Town Council of Boksburg and Scott and de Waal Incorporated towards the end 1984. The experimental investigation lasted twenty seven months (from January 1985 to March 1987). During this period the Vlakplaats Works was intensively monitored, leading to a better understanding of the overall functioning of the biological filter process, both with and without chemical addition for phosphate removal.

The introduction of chemical phosphate removal at the Vlakplaats works resulted in significantly improved phosphate removal, i.e. from 25 to 79 per cent (as total phosphate). In terms of the ortho-phosphate load discharged to the water environment, chemical phosphate removal resulted in a decrease from 324 to 54 kg PO_4-P/d. The removal of organic and nitrogenous matter remained essentially unchanged. The use of ferric chloride did, however, result in an increased effluent chloride concentration and a decreased alkalinity.

Introduction of chemical phosphate removal at the Vlakplaats work to comply with the effluent phosphate standard resulted in an increase in the total treatment cost of about 30 per cent. The 95 per cent compliance with the effluent phosphate standard was considered too stringent and resulted in costly chemical overdosage and unnecessary increases in effluent dissolved solids. In order to minimize cost and chemical overdosage it was found essential to optimize chemical addition by adopting an appropriate chemical dosing strategy.

Three chemical dosing strategies were evaluated, viz. dosing proportional to flow with (a) a constant ratio for dosage rate to unit flow rate, (b) an increased ratio for dosage rate to unit flow rate on Thursdays and Fridays, and (c) dosage rate adjusted on a "day of the week four weekly moving average for phosphate concentration" strategy. The latter was the most successful requiring 2,0 - 2,5 times the stoichiometric $FeCl_3$ P amount of $FeCl_3$ to be dosed, whereas the other strategies required 3,5 - 4,5 times the stoichiometric dosages.

The introduction of chemical phosphate removal at the Vlakplaats works resulted in significantly increased masses of "humus" (biological/chemical) sludge. Provision had to be made for continuous sludge withdrawal from the humus tanks in order to ensure that no solids carry-over took place from these tanks. The increase in "humus" sludge mass had a negligible effect on the total sludge production of the plant. The physical characteristics of the mixed biological/chemical sludges did not significaly differ from conventional sludges and did not require any changes in terms of sludge drying or disposal.

The highly corrosive nature of ferric chloride used for phosphate precipitation necessitated the use of corrosion resistant materials for its handling and pumping. Loss of alkalinity in the effluent dosed with ferric chloride had to be counter-acted by addition of lime to prevent the production of an effluent which could be aggressive to concrete structures and corrosive to steel pipes and pumps.

The suitability and effectiveness of various items of mechanical plant were monitored during the project. The flow meters were found to be unexpectedly unreliable. In general, the back-up received from vendors of flow metering equipment was poor. A number of flow meter problems were addressed by this investigation, i.e. "hunting" with ultra-sonic flow meters, insufficient protection against electrical overload and lightning; and no provision for temperature compensation. Once these problems had been corrected, vendor back-up was required on average at about 3 to 6 month intervals.

An investigation of the South African Bureau of Standards (SABS) analytical method for suspended solids demonstrated that this technique was not suitable for the determination of suspended solids at concentrations below about 50 mg/l, and particularly for the 20 mg/l as specified by The General Standard for effluents. Improved suspended solids recovery was obtained when using Whatman GF/C or GF/D, or Rundfilter MN85/90, filter paper, although the recovery was still only 50 per cent.

It is recommended that:

(a) the authorities give consideration to a more overall effective phosphate control strategy. For example, the current fixed effluent phosphate standard could be replaced by a more cost-effective "receiving water" standard;

(b) the SABS be requested to investigate a standard for open channel flow meters so that the reliability and performance of these instruments, vital to sewage plant operation and control, can be regulated and improved, and

(c) the SABS also be requested to investigate a more suitable analytical technique for the determination of suspended solids at the relatively low concentrations specified for effluents.

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CHAPTER 1 : INTRODUCTION

1.1 BACKGROUND TO THE PROJECT

Approximately 53 per cent of the sewage treated in sensitive catchments in South Africa is purified by means of the biological filtration process (Brodisch, 1985). The reasons for the popularity of this process are the following :
Low maint. ance requirements, low energy usage, stability and reliability, and if designed and operated properly, will produce an effluent which complies with the General Standard for effluents. However, a serious limitation of the process is its inability to remove sufficient phosphate from sewage to ensure compliance with the 1 mg/l dissolved ortho-phosphate (as P) standard for the sensitive catchments.

Research on the removal of phosphate in biological filtration processes has been undertaken both locally and overseas. Chemical phosphate removal was developed for this purpose and was evaluated on an experimental basis by the City Council of Pretoria and the Town Council of Boksburg over the period 1979 to 1983. This evaluation, carried out in collaboration with the Water Research Commission, demonstrated that it is both technically and practically feasible to remove ortho-phosphate to concentrations of less than 1 mg/l (as P). The results of this research and development work were published by the Water Research Commission (WRC, 1987) in a publication entitled "Guidelines for Chemical Phosphate Removal from Municipal Waste Waters".

The abovementioned study identified a number of facets of chemical phosphate removal which required further research and development. Criteria needed to be developed for the optimal operation of the process at full-scale. Other aspects which required attention included the development of chemical dosing strategies to minimize chemical consumption but assured attainment of the effluent phosphate standard for at least 95% of the time. Scope also existed for optimizing the operation of the primary and secondary clarifiers, as well as the operation of the anaerobic digesters. The advantages of a process which was operated optimally were seen as the minimization of chemical usage which in turn would result in minimizing the sludge production, effluent salination and treatment costs.

Another facet identified as requiring urgent attention was the quantification of the additional volumes and masses of sludge produced when a conventional biological filtration works was upgraded for chemical phosphate removal. It was also considered necessary to investigate how the properties (e.g. the dewatering and drying) of the biological sludges changed when chemicals were used in the process. This information is required for the development of criteria for upgrading existing biological filtration works, as well as the design of new works. More explicit design and operation information was required for clarifiers, pumps, digesters and sludge drying beds. Since these items represent large capital investment, these criteria were considered to be of significant economic importance.

During 1983 the Town Council of Boksburg commissioned a third 18 Ml/d module of its Vlakplaats biological filter sewage treatment works. The design of this module, which was based on the findings and recommendations of the afore-mentioned research and development project, made provision for chemical phosphate removal. This works was therefore considered eminently suitable for obtaining the information and criteria outlined above and an appropriate agreement in this regard was negotiated between the Water Research Commission, the Town Council of Boksburg and Scott & De Waal Incorporated in 1984.

1.2 RESEARCH AND DEVELOPMENT PROGRAMME

The research and development programme for the project covered two main aspects viz. chemical phosphate removal from sewage, and chemical sludge production, sludge handling and treatment. The tasks addressed under each of these are set out below.

1.2.1 Evaluation and Optimization of Chemical Phosphate Removal

a) Compliance with effluent phosphate standard

An operational strategy had to be developed to ensure compliance (for at least 95 per cent, of the time) with the 1 mgP/l effluent standard. This entailed *inter alia* the optimization of chemical dosing taking into consideration the hourly, daily and seasonal changes in raw sewage flow and phosphate concentration in the design and operation of the precipitation and flocculation stages.

b) Optimal operation of secondary clarifiers

The operation of the secondary clarifiers was to be evaluated to define conditions for optimum solids removal and hence minimal solids carry-over. Aspects to be investigated were : hydraulic and sludge residence time in the settlers, as well as the linear upward flow velocity.

c) Optimal operation of the primary clarifiers

Operational procedures to minimize solids carry-over to the biological filters and thicken the mixed raw and chemical sludge sufficiently to minimize the hyraulic load on the anaerobic digesters was to be investigated. Parameters which were to be studied included the recirculation rate of chemical/humus sludge.

d) Evaluation of the efficacy of the plant as a whole

This was to be evaluated over the entire contract period. Alternative chemicals to ferric chloride for phosphate removal, such as ferric sulphate and aluminium polychloride, were to be evaluated where appropriate.

1.2.2 Evaluation of biological chemical sludge production, sludge handling and treatment

Sludge production (both on a volumetric and mass basis) in the primary and secondary clarifiers and that treated in the anaerobic digesters was to be evaluated as a function of volume flow rate and strength of sewage treated, chemical dosage rate and plant operational conditions.

Sludge characteristics including settleability, thickening, dewaterability, digestion and drying as functions of plant operating conditions, were to be established.

The operation and control of the anaerobic digesters were to be evaluated and optimized. The factors to be investigated were : feed sludge concentration, hydraulic residence time, removal of COD, solids and nitrogen, gas production and the stability and drying characteristics of the digested sludge.

1.3 D[illegible]CRIPTION OF THE VLAKPLAATS WATER POLLUTION CONTROL WORKS

The Vlakplaats works consist of three virtually identical self-contained biological filtration units (that is Units A,B,and C) operated in parallel, each designed to treat 1[illegible]l/d, i.e. 54 Ml/d in total. Each unit has its own inlet works, primary settlers, biological filters, humus tanks and anaerobic sludge digesters. The layout of the Works is shown in Figure 1.1 (Annexure A) and design details of the various unit processes given in Table 1.1. (Annexure B).

Unit C was operated with ferric chloride addition and Unit B was operated in the conventional mode, without chemical addition, as a control against which to compare the results of Unit C. Both these units were intensively monitored over the period of the contract. Figure 1.2 shows at which points in each unit flow rates of process streams were recorded continuously, as well as sample points. The accompanying Table I lists the various parameters analysed in the streams sampled, as well as the frequency of analysis, i.e. daily, weekly or monthly. Figure 1.3 shows sludge stream flow rates being monitored continuously as well as the points being sampled. The accompanying Table 1.2 shows the parameters analysed in the sludge, as well as the frequency of analysis , i.e. daily, weekly or monthly.

The experimental programme extended over the period January 1985 to March 1987. This report does not deal with the various aspects investigated in a chronological order, but rather on a topic basis, with the following aspects being covered : analytical techniques, plant equipment and instrumentation, optimization of efficiency of chemical usage, effect of chemical dosing on sludge management process evaluation, financial aspects, and conclusions and recommendations.

All figures and tables referred to in the text to be found in Annexures A and B respectively.

CHAPTER 2

SAMPLING PROCEDURES, ANALYTICAL TECHNIQUES AND MASS BALANCES

2.1 INTRODUCTION

In preparation for the execution of the experimental programme outlined in Chapter 1, Section 1.2, a number of data forms were developed to capture data in a uniform and consistent format, e.g. for flows, analyses, dosing rates, mass of ortho-P removed over Units B and C, stoichiometric relationships of chemically removed dissolved ortho-P and sludge analyses.

Prior to the initiation of the experimental programme, as well as during the programme, analytical techniques used were carefully scrutinized for accuracy and precision, particularly for parameters which had to be measured at low concentrations. Results which could not be explained as well as poor mass balances, particularly at the beginning of the test programme, indicated possible problems with sample preparation and analytical techniques for dissolved ortho-phosphate, dissolved and total iron, and suspended solids. Consequently, these were investigated in some depth.

2.2. DEVELOPMENT OF IMPROVED ANALYTICAL TECHNIQUES.

2.2.1 Dissolved Ortho-phosphate

Two aspects relating to sample pretreatment for analysis of "dissolved ortho-phospate" by means of the prescribed analytical technique (S.A. Bureau of Standards Method No. 198), were investigated. Firstly, the filter paper type used to remove particulate matter, and secondly, the necessity for pre-washing of the filter paper.

The SABS analytical method for dissolved ortho-phosphate specifies that the sample should be filtered prior to analysis. However, the filter paper type is not specified. Three types of filter paper were investigated (see Table 2.1), i.e. Whatman No. 1 (W1), Whatman GF/C microfibre (WGF/C), and MN80/90 Macherey Nagel Rund Glassfibre (MNGF). These types were selected because they were commercially the most readily available and they appeared to be suitable for the analytical method.

In addition to the three different filter paper types, the effect of filter washing was also investigated. Filters were either used as bought (referred to as "unwashed"), or, pre-washed (referred to as "washed"). The pre-wash technique comprised of a wash with 50 ml of a 2 per cent hydrochloric acid solution, followed by a rinse with 50 ml of distilled water in a Buchner funnel vacuum system.

For the purpose of testing the three filter paper types and the filter pre-wash technique, two effluent samples (20 l each) were drawn on the Vlakplaats works, i.e. 20 l at sampling point CP_6 (biological filter effluent from Unit C) and 20 l at sampling point CP_7 (humus tank effluent from Unit C). The results are given in Tables 2.2 and 2.3.

Neither the filter paper type nor the pre-treatment appears to have a significant effect on the determination of dissolved ortho-phosphate in biological filter effluent, i.e. the average value for this parameter is 2,3 $\pm$ 0,1 mg/l (as P). The only exception is the value for Wl/washed, although it is within 2 standard deviations of all the averages.

The analytical results for chemically treated humus tank effluent are all within one standard deviation (as well as the analytical precision of the technique, i.e. 0,1 mg/l as P) of one another i.e. 0,5 $\pm$ 0,1 mg/l (as P) excluding a number of obvious outliers. Again, it appears that neither the filter paper type nor the pre-wash have any significant effect on the values of the dissolved ortho-phosphate determined.

It is clear from these results that if greater accuracy is required at these low dissolved ortho-phosphate concentrations the analytical technique will have to be altered. However, an analytical accuracy of 0,l mg/l (as P) is sufficient for plant operational and legal requirements.

2.2.2 Dissolved Iron

The analytically determined dissolved iron levels in biological filter effluent were low (0,2 to 0,5 mg/l as Fe). The average for the different filter paper types and pre-wash, was 0,4 $\pm$ 0,2 mg/l (as Fe) (See Table 2.4). If an analytical accuracy of 0,2 mg/l is accepted at this low dissolved iron level, filter paper type and pre-wash do not significantly affect the analysis of "dissolved iron".

If a higher accuracy than ± 0,2 mg/l (as Fe) is required, the analytical technique will have to be refined. However, from plant operational and legal considerations this does not appear to be justified.

2.2.3 Suspended Solids

In contrast with the results for dissolved ortho-phosphate and dissolved iron, the results obtained with the standard analysis technique for suspended solid (Standard Methods, 1986) gave significant differences between the results for different filter paper types and pre-wash (see Table 2.5). Unwashed filter paper types W1 and MNGF gave negative results, indicating loss of filter paper material and, or, suspended solids. This seemed to indicate that it was essential that filter papers be washed prior to use for determination of suspended solids. However, even the results for the washed filter paper differed significantly, i.e. 101 ± 12, 8 ± 4 and 13 ± 6 for W1, WGF/C and MNGF, respectively. The results for the Whatman W1 (101 ± 12) appeared unrealistically high for the suspended solids concentrations normally found in Boksburg humus tank effluent - i.e. 5 - 25 mg/l, and hence Whatman No. 1 filter paper was rejected as a suitable filter paper for suspended solids determination. The glass fibre filter papers gave more acceptable results, although as can be seen, with large standard deviations.

Because of the poor precision of this analytical technique and the inherent difficulty of preparing and maintaining a standard solution with a defined suspended solids content, it was decided to evaluate the techniques using clay suspension, which are known to give better defined suspended solids suspensions, to determine the accuracy and precision of this analytical teechnique. Tests were conducted at two concentration levels namely 980 and 20 mg/l of Fuller's Earth and Sodium Bentonite, respectively (see Tables 2.6 and 2.8 for washed and Tables 2.7 and 2.9 unwashed filter paper.)

From the results listed in Table 2.8 and 2.9 i.e. tests at the 20 mg/l suspended solids level, the recovery of suspended solids was much poorer than at the high suspended solids level (See Tables 2.6 and 2.7). Recoveries for the lower concentration varied for the different filter paper types, i.e. from negative recoveries for Whatman No. 1 filter paper, to the best recovery of only 67 per cent. Pretreatment of the filter paper did not appear to significantly affect these results.

From these results it is clear that Whatman No. 1 filter paper is totally unsuitable for suspended solids determination, and that Whatman GF/C or GF/D or Rundfilter MN 85/90 could be used. However, it should be realized that at the 20 mg/l suspended solids concentration level this technique will only give a solids recovery of the order of 50 per cent.

2.3 IMPROVED ANALYTICAL TECHNIQUE FOR THE DETERMINATION OF $FeCl_3$ IN STOCK CHEMICAL SOLUTIONS

Initially the iron content of the $FeCl_3$ bulk solution was determined by an atomic absorption spectrophotometric technique. However because ferric chloride is supplied in a 43% solution as $FeCl_3$, or 14% as Fe, the solution had to be highly diluted to measure the iron content on an atomic absorption spectrophotometer, leading to considerable inaccuracies. A titrometric method was therefore adopted which can be used to determine the Fe concentration in undiluted bulk solution and has proved to be very reliable. The method is listed in Annexure E to this report.

2.4 SAMPLING TECHNIQUES ON PLANT

In order to evaluate and control the operation of the Vlakplaats works, a suitable water sampling programme had to be developed. This required a knowledge of the variability of each parameter of interest and an assessment of the sampling frequency which would give a representative data set. Previous short term studies, i.e. taking samples at two-hourly intervals over a period of 36 hours, demonstrated that most of the concentration of the parameters of interest (COD, phosphate, ammonia, nitrate, alkalinity) vary significantly over a 24 hour cycle, and that grab samples once a day (or even three times a day) gave an erroneous presentation of the average daily concentrations of parameters of interest.

A more satisfactory sampling strategy was to sample proportional to flow so that flow and concentration data can be correlated to produce representative load data.

Two types of samplers were used:

a) Samplers like the Phillips and Century 2000 that draw samples by means of a vacuum, and deposit the samples in a bottle rack with 24 individual bottles.

b) Samplers like the Isco and the American Sigma that withdrew samples by means of a peristaltic pump and deposit the samples in a bottle rack with 24 individual bottles.

All the samplers were equipped with a power source of 12 Volt and could also be connected to mains supply. The samplers are pre-set and programmed, as desired, i.e. to take samples either proportional to flow or at a constant rate.

The electrically driven samplers which sample proportional to flow require a 4-20 milliamp signal from the flow meter to activate sampling. The flow meter sends impulses to the sampler for fixed volumes of water passing the flow meter, e.g. one impulse after $1m^3$ has passed the measuring device. The sampler is then set to take a sample after a number of impulses have been received, e.g. 30 impulses which would be equivalent to $30m^3$. The volume of the sample drawn is fixed at 100ml. The sampler contains 24 bottles in its bottle rack with each bottle having a maximum capacity of 500mls. Using this sampler, 96 samples can be taken every 24 hours (4 x 100ml in each bottle), and subsequently the effluent in the 24 bottles can be combined to give one representative sample for the whole day. In the case of constant time interval sampling, the sampler need not be connected to the flow meter, with samples being taken at fixed time interval, independent of flow rate.

Figure 1.2 is a diagramatic representation of the Vlakplaats Water Pollution Control Works showing effluent flow measurement and sampling points. Sludge flow measurement and sampling points are shown in Figure 1.3. Samples were taken at daily, weekly or monthly intervals and analysed for a number of parameters (See Tables 1.1 and 1.2).

Problems were experienced with obtaining representative samples of effluents containing significant quantities of solids, e.g. for the raw sewage and sludge recycle streams. Mass balances around mixing point one (P_1, P_2 and P_3) (See figure 1.1) were not satisfactory (see next Section), particularly for solids. This lead to some doubt as to accuracy of the solids analysis and hence where those appear in the report, they should be viewed with circumspection.

"Poisoning" of samples was not practised at the beginning of the project. It became apparent, however, that samples in the automatic samplers which stood in the sun trough the day, could show bactereological and chemical interaction, resulting in faulty chemical analysis. The samples were subsequently poisoned using a saturated solution of $HgCl_2$ (mercuric chloride). One millilitre of this solution was added to each bottle in the automatic liquid sampler before sampling commenced.

As a result of the addition of mercuric chloride, analysis of chlorides was suspended although at that stage considerable data relating to chlorides was already available.

2.5 MASS BALANCES

In order to ensure that the data collected on the plant was sufficiently accurate and reliable to allow conclusions to be drawn from it, flow and mass balances (on selected parameters) were undertaken on a regular basis. Firstly, daily flow measurements were taken at points P_1, P_2, P_6 and P_7 (See Figure 1.2) and flow balances calculated for the flows at these points of both Units B and C. Secondly, weekly checks on mass balances of various parameters were determined at points of mixing of flows, i.e. between masses at P_1, P_2 and P_3 and between masses at P_4, P_5 and P_7 (see Figure 1.2). For simplicity these mixing points were referred to in the text as MP1 and MP2, respectively. Finally, phosphate mass balances were calculated on an hourly basis in an effort to detect reasons for poor weekly mass balances.

2.5.1. Flow balances

Throughout the project it was considered to be of fundamental importance that the flow measurements on the two modules (Unit B - control; Unit C - chemically dosed) should be as accurate as was practically feasible. As a result, daily flow rate readings were taken and checked against the following formula:

$$Q_1 + Q_2 + Q_9 = Q_6 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2.1)$$

Where Q_n is the flow rate at flow measuring point n.

The operational objective was to ensure an imbalance of less than 5 per cent between the two sides of Equation (2.1), with an imbalance of 10 per cent being considered unacceptable and requiring corrective action from the plant staff. This degree of flow rate balance was surprisingly difficult to maintain, mainly because some of the flow meters were unreliable and because service provided by the suppliers of these meters was unsatisfactory. A detailed account of the problems encountered in maintaining a satisfactory flow balance is given in Chapter 3, Section 3. It should be noted that many of the omissions in the data collected (listed in Appendix D) are due to the rejection of data sets because of unacceptable flow balances.

2.5.2. Mass balance for chloride

Since chloride is a conservative parameter for both mixing points MP1 and MP2, i.e. no chloride is either formed or removed from effluent at these points, it was used to determine the mass balance accuracy which could be expected at these points. The results are listed in Tables 2.10 and 2.11.

The mass balance over MP2 was excellent (see Table 2.11), with an average imbalance of only 3 per cent, demonstrating the accuracy of the chloride analytical technique and the flow rate measurements for MP2. The results for MP1 were not as good (see Table 2.10), although they were considered acceptable with an average imbalance of 9 per cent. However, imbalances as high as 30 per cent were recorded and this gave rise for concern.

2.5.3. Mass balance for dissolved ortho-phosphate

Mass balances of dissolved ortho-phosphate for MP1 and MP2 were calculated and the average weekly data is listed in Tables 2.12 and 2.13; respectively. Daily mass balances over a two week period were also determined and this data is listed in Tables 2.14 and 2.15 for the respective two points.

Analysis of the data shows that the mass balances obtained at MP2 are relatively good considering the scale on which the experiment is being conducted (average imbalance for whole period 8 per cent). In the case of the weekly average data (Table 2.13) two of the 11 week analyses are significantly out of balance whereas in the daily data (Table 2.15) three of the 10 days analysed are significantly out. However, the data on the remaining 7 days is remarkably accurate. It would appear therefore that the weekly averages tend to be distorted by outliers in the daily data. Such outliers are to be expected in data taken from a full scale experiment of this nature, and in general the data is considered to be satisfactory.

In contrast most of the mass balances at MP1 are significantly out of balance. It will be seen from the data in Tables 2.12 and 2.14 that in general the imbalance is caused by the fact that the mass calculated in the stream P_3 is considerably lower than the masses calculated in streams P_1 and P_2. This would indicate that soluble ortho-phosphate is removed from the P_1 stream by mixing it with the iron rich humus sludge in the P_2 stream. This supposition is borne out by the analysis of other data and is discussed in detail in Chapter 6.

It would appear from the foregoing that the unsatisfactory mass balances obtained at MP1 do not indicate a lack of accuracy in the dissolved ortho-phosphate data, and that based on the mass balances of data at MP2 reasonable reliance can be placed on the dissolved ortho-phosphate concentrations measured in all streams. However, because of the large variations which occur in the mass balances only relatively wide confidence bands can be placed in the individual data values; thus fine tuning of the optimisation of efficiency of chemical usage by means of small changes to operating parameters cannot realistically be analysed on a plant of this nature.

2.5.4 Mass balance for total phosphates

The mass balances of average weekly total phosphate data at MP1 is shown in Table 2.16 and at MP2 in Table 2.17. Daily mass balances calculated over a two week period at MP2 are listed in Table 2.18. It will be seen from the data that, as with dissolved ortho-phosphate, the mass balances at MP1 are significantly less accurate than at MP2, but that in this case the mass of total P measured in the P_3 stream is always much higher than that measured in the P_1 and P_2 streams. This observation can be ascribed to the difficulties inherent in obtaining representative sewage effluent samples in which most of the total phosphate is in a particulate form. However, why the data showed such a consistant trend in one direction only is difficult to explain, but could possibly be attributed to the point and method of sampling, although changes in these did not result in marked improvements on the mass balances.

With regard to the mass balances of total phosphate data at MP2, it will be seen that the results are significantly more accurate than at MP1. In Table 2.17 the average weekly results are considered to be well within the limits of experimental error (imbalance of 7 per cent) except for two weeks which would appear to be outliers. The same would apply to the daily balances shown in Table 2.18. Apart from two apparent outliers the results are considered to be remarkably good. The reason why the mass balances are more accurate at MP2 than at MP1 can be ascribed inter alia to the fact that most of the particulate material has been removed from the flows at MP2 and consequently the effluent samples taken are more representative of the streams sampled.

From the foregoing it will be evident that reasonable reliance can be placed on total phosphate concentration data for streams which do not contain large concentrations of particulate matter. However, it must again be pointed out that the bands of confidence for even this data are not narrow enough for running very refined optimization studies on the plant.

2.5.5 Mass balances for Chemical Oxygen Demand (COD)

The mass balances of COD at MP1 and MP2 are given in Tables 2.19 and 2.20, respectively. At MP1 (See Table 2.19) the data shows large imbalances. This can be attributed to sampling inaccuracy caused by the high concentrations of particulate material in the three streams being monitored. At MP2 (See Table 2.20) the average error over the whole period analysed was only 4 per cent, although large fluctuations in results were obtained. Again this was ascribed to unrepresentative sampling.

This data would tend to indicate that trends of COD removal through the two Units was identifiable but that care should be exercised in attributing absolute values to individual readings.

2.6 MASS BALANCES ON P DATA COLLECTED AT HOURLY INTERVALS

Filtered and unfiltered P mass balances at hourly intervals were conducted for sampling points P_1, P_2 and P_3 and points P_4, P_5 and P_9, both for the control Unit (Unit B) and the unit receiving chemical dosing (Unit C).

2.6.1 Mass Balance over Sampling Points P_1, P_2 and P_3

The filtered and unfiltered P mass balances were calculated as follows:

Calculated mass = mass at P_1 + mass at P_2

To achieve a successful balance, the calculated mass must equal the mass measured at P_3. The measured masses at P_1, P_2 and P_3, together with the calculated mass, are given in Tables 2.21 and 2.22 for Unit B and Tables 2.23 and 2.24 for Unit C. (In these tables, the sampling time is given at the half hour as the flows are determined over the hour, and the concentrations are the average of that measured at the beginning and at the end of the hour). In both units there appears to be minor variations (5 to 10 per cent) between the mass measured at P_3 and that calculated. Furthermore, no trend in variation is evident from the data. This minor variation can be ascribed to:

i) <u>Sampling technique and error</u>: The mass is calculated by multiplying the integral of the flow over the hour with the average of the instantaneous concentration at the beginning and the end of the hour. The different timing techniques used to determine the flows and the concentrations causes that they are out of phase and so will give rise to minor variation. Also, natural statistical sampling errors will occur in the instantaneous concentration sampling technique.

ii) <u>Measurement error</u>: Some error in determination of P concentrations will occur, either statistical error or error in techniques. The flow at P_3 is the sum of that at P_1 and P_2, so no variation due to errors in flow measurement will be evident.

Taking these two points into consideration, the differences between the calculated and measured P masses at P_3 are within statistical variation and no assignable cause can be identified.

2.6.2. Mass Balance over Sampling Points P_4, P_5 and P_9

The filtered and unfiltered P mass balances were calculated as follows:

Calculated mass = mass at P_4 + mass at P_9

Neither the P concentrations nor the flows were available for P9; therefore, the concentrations at P_9 were accepted to be the same as those at P_7, and the flow at P_9 to be (P_5-P_4).

To achieve a successful mass balance, the calculated mass must equal the mass measured at P_3. The measured filtered and unfiltered P masses at P_4, P_9 and P_5, together with the calculated masses are given in Tables 2.25 and 2.26 for Unit B, and Tables 2.27 and 2.28 for Unit C.

For Unit B, Tables 2.25 and 2.26, reasonable P mass balances were obtained - the differences between the measured and calculated masses are minor (5 - 10 per cent) with no trend in variation evident. The same reasons for these differences, as given above, apply.

For Unit C, Tables 2.27 and 2.28, significant variation between calculated and measured filtered and unfiltered P masses is evident. The variation cannot be ascribed to the flow measurement, as flow balances are used to calculate the flow at P_9. Therefore, the variation must be due to the P concentration component of the mass. Furthermore, there is a trend in the variation in that both the calculated filtered and the unfiltered P masses are consistently lower than the measured filtered and unfiltered P masses. Reasons for the variation are not clear. Possibly, the very low P concentrations at Point P_7 (and therefore at P_9) make difficult the accurate determination of the P concentration, and thus P concentration is consistantly undermeasured in this low range.

2.7 FINAL CHOICE OF ANALYTICAL TECHNIQUES FOR PROJECT.

2.7.1 Ortho-phosphate

Total and dissolved ortho-phosphate were analysed for using the method recommended by the S.A.B.S. It was decided to use the Macherey Nagel Rund Glassfibre (MNGF) filter papers for removing solids for the dissolved ortho-phosphate analyses.

2.7.2 Iron Analysis

Atomic absorption spectrophotometry was used for iron determinations, using the SABS method. Total Iron analysis were done on unfiltered samples and dissolved iron after filtering through the MNGF filter papers.

2.7.3 Alkalinities and Chlorides

Alkalinities and chloride samples were filtered through a Whatman No. 1 paper, before analysis.

2.7.4 Other Analytical Techniques

All other parameters analysed were done using the Standard Method (198) techniques.

CHAPTER 3

PLANT EQUIPMENT AND INSTRUMENTATION

3.1 INTRODUCTION

The efficient operation and control of sewage works requires reliable and often technically advanced equipment and instrumentation. This chapter describes the equipment and instrumentation used for chemical phosphate removal in the Vlakplaats works, as well as the various problems encountered and solutions arrived at. The specific aspects which will be dealt with are flow measurement of various wastewater streams, chemical dosing systems, plant control instrumentation, on-line automatic analyses, humus tank effluent recirculation, humus/chemical sludge recirculation, corrosion resistant materials of construction, aggression of acidic waters to concrete and structures and raw sewage flow distribution to Units B and C.

3.2 WASTEWATER STREAM FLOW MEASUREMENT

The Vlakplaats works was originally equipped with float type (Kent) flow meters for measuring the flow of incoming sewage. When the plant had to be modified for chemical dosing, it was decided to use ultrasonic flow meters because of their reputably reliable functioning as well as the advantage of easy installation in open channels. In order to assess the characteristics of a variety of flow meters within the sewage works context, three types of ultrasonic flow meters were purchased; Miltronic, Wesmar and Warren and Jones.

Each of the four flow meters used is described in detail below.

a. Kent float type flow meter

This meter was installed at point P_1 on the plant. It is a mechanical flow meter with a float in a stilling chamber just before the flume.

The flow chart recorder as well as the kilolitre meter are driven by means of a mechanical clock that is manually wound. The same type of flow meter was installed on the chemical plant at CP_1; but this meter is electrically powered.

Type of flow chart: These meters are provided with round flow charts.

Advantages: No ambient temperature fluctuations or water wave movements influence the flow measurement. Round flow charts are more easily stored and checked than strip charts.

Disadvantages: As this flow meter is not equipped with a 4-20mA electrical signal, an automatic sampler could not be activated and a special modification had to be carried out. A light source electronic pulse system powered by a 12 volt battery was installed.

b. Miltronic Ultrasonic flow meter

The meter is an electronic instrument equipped with an ultrasonic sensor. Flow measurement occurs by measuring ultrasonic waves that are transmitted and reflected back. These readings are processed in the instrument and displayed in digital form.

Flow chart: The flow meter is equipped with a Strip chart recorder.

Advantages: Changes in the flow programme can be adjusted or amended by changing the programme contained in the electronic chips. The instrument is equipped with a 4-20mA signal to activate a sampler or external system.

Disadvantages: Ultrasonic flow meters need to be installed in a protective box to eliminate external factors such as weather and temperature variations which influence the readings. Strip charts are not easily handled for checking and storage.

c. Wesmar Ultrasonic flow meter

This flow meter is essentially the same as the Miltronic and is also equipped with a strip chart recorder and a 4-20mA signal to activate an external system. This type of meter was installed at dosing point CP_6.

d. Ranger Ultrasonic flow meter (Warren and Jones)

This is a computerised portable flow meter equipped with the necessary electronics that can measure, store and process flow readings. Data can be retrieved from the memory by means of an Epson computer. Flow graphs can be drawn and the meter is equipped with a 4-20mA pulse facility to activate a sampler.

Advantages:

The apparatus can store important information over a long period. Flow figures and flow graphs can be retrieved from the memory. The meter is portable and can be installed at any chosen point in a system by feeding in the required information concerning the channel and flume.

Figure 1.2 shows the various points within the plant where wastewater flows were measured. These were; raw sewage influent stream (P1); humus recirculation to the primary clarifiers (P2); biological filter effluent (P6); secondary settling tank effluent (P7) and humus tank effluent recirculation (P9). Both Units B (Control) and Unit C (ferric chloride dosing) were equipped with flow meters as indicated above, whereas Unit A which did not form part of the experimental programme only had flow measurement of the raw incoming sewage and at the chemical dosing point P6.

All the flow meters were equipped with chart recorders, thereby generating a permanent record of flow as a function of time. All the flow meters had an electrical signal output of 4-20 mA which corresponded to the full chart recorder range. The flow charts were calibrated to read instantaneous flowrates in units of litre/second. The Kent meters were equipped with round flow charts, each recording either 1 or 7 days data. The ultrasonic flow meters were equipped with strip chart recorders, each role of chart covering up to 3 weeks data. The round charts were found the more convenient for data storage and retrieval.

3.2.1 Standard Depth Flow Curves

On testing and calibrating the various flow meter types on the Vlakplaats works, it was found impossible to get identical flow rates for the same wastewater stream using different makes of flow meters. It was established that the flow curves programmed into the various flow meters were not identical. Some used the SIA flow formula for a thin plate rectangular weir, whereas others made use of the Kindswater-Carter formula. Figure 3.1 shows the differences in calculated flow rates when using the different flow meters under the same conditions.

As a result of the above described inconsistancies for the different makes of flow meters, it was not possible to obtain a flow balance over the plant (points P_1, P_2, P_6 and P_9) even under ideal conditions. To overcome this problem all the flow meters were converted to using the same standard flow curve, i.e. Kindswater Carter flow formula (see Fig. 3.2). This necessitated the replacement of existing camshafts on the Kent meters and installation of new programmes on the Miltronic and Westmar ultrasonic flow meters. A flow meter test bench was constructed and installed at the Vlakplaats Works workshop and used to standardize and calibrate all the flow meters to the same flow curve formula. A diagram of this test bench is shown in Fig. 3.3.

3.2.2 Intallation and calibration of flow meters and weirs

In order to make flow measurement possible at points P_1, P_2 and P_9, flumes were installed at these points.

a) Point P_1 already had an existing Venturi flume which measured the raw sewage inflow.

b) At point P_2 a fibreglass flume was installed to measure the flow of recirculated humus/chemical sludge from the humus tanks to the raw sewage inflow.

c) At point P_9 a thin metal plate rectangular weir was installed for measuring the flow of recycled humus tank effluent.

d) At point P_6, just downstream of the biological filters a rectangular weir was installed to measure the flow from the biological filters.

A flow meter was installed at each of the abovementioned points, after its calibration against the standard flow curve had been checked on the flow test rig. Once installed all the flow meters on both Units B and C were read at exactly the same time each day in order to establish whether a reasonable flow balance existed, i.e. the sum of flow rates at P_1, P_2 and P_9 were equal or at least within 5 per cent of the flow rate measured at P_6. When a flow imbalance was detected, all the flow meters were checked and recalibrated to again establish a flow balance.

It was found that in order to obtain accurate flow measurements, the flow meters had to be installed such that the average flow resulted in about a 75 per cent reading on the 0-100 per cent range on the flow chart. In order to facilitate easy checking of the flow calibration, a swing plate device was developed (see Figure 3.4). The plate was installed at the height corresponding to 100 per cent flow and once a day was swung to intercept the ultrasonic beam. If the 100 per cent reading was significantly different from the 100 per cent calibration point, the meter was recalibrated. In addition the flow balance over the plant was also checked, and if necessary all the flow meters were checked and recalibrated. When all these actions failed to bring about an acceptable flow balance, the flow meter suppliers were contacted to attend to the faulty meters.

3.2.3 Major problems encountered with flow meters

At the beginning of the experimental programme numerous problems were experienced with the flow meters. Meter vendor service was often slow, resulting in the loss of valuable data. Lack of adequate instrumentation for accurate calibration and standardization resulted in further delays. Several of the vendors relied heavily on overseas technical back-up, which lead to further delays.

One of the major problems experienced with the ultrasonic flow meters was hunting. It was established that wind induced wave action on the wastewater stream surfaces used to deflect the ultrasonic beam, resulted in the beam not being reflected to the flow meter head, resulting in a temporary loss of signal which was manifested as meter hunting. This was particularly serious in the case of the flowmeter which was used to control the chemical dosage rate based on a signal from the flow meter.

Hunting was also brought about by turbulent flow, floating foam, humus scum and poor earthing of the flow meter. A typical example of a strip chart under "hunting" conditions is shown in Fig. 3.5.

To overcome the meter problems with water turbulence, wave action, scum and foam on the wastewater surface, a stilling cylinder (200mm) was developed and tested. This stilling cylinder had an immediate beneficial effect on the hunting action. As a result of the success with the experimental stilling cylinder, an off-line stilling box was installed permanently at CP_6. It was used to compare different flowmeters at the same sampling point. The stilling box was equipped with a zero to 100 per cent swing plate system, a float height measuring stick, a mechanical float flow meter, as well as the P_6 control ultrasonic flow meter and enough space for an additonal flow meter for test and comparison purposes. A diagram of the stilling box system is shown in Fig. 3.6.

The ultrasonic flow meters were equipped with replaceable circuit boards to facilitate easy and rapid repair of electronic faults. However, these systems were found to be very sensitive to overload and lightning, and protective devices had to be installed.

Variation in seasonal and diurnal air temperatures, had a significant effect on the ultrasonic flow meters. To overcome this problem all the flow meters were fitted with temperature compensators.

3.2.4 Flow records

At the start of the experimental programme numerous problems were experienced with the flow meters, as detailed above. It took about six months before these problems were adequately resolved and consistent, reliable flow data was being generated. Using the procedure outlined in Section 3.2.2, adequate flow balances were maintained for long periods. The flow meters have a tendency to drift, requiring checking and recalibration with the swing plate device on a daily basis. Recalibration of all the meters on the flow meter test rig was required at about two or three monthly intervals. On average vendor back-up for a meter failure repair was required at three to six monthly intervals.

3.3 MEASUREMENT OF GAS FLOW FROM DIGESTERS

The gas volume meters were set by placing different sized orifices in the pipe-lines. A problem experienced was the interconnection of the digesters which caused a back pressure on some meters as the gas production varied from one digester to another. Condensate in the lines caused a pressure difference.

When the main gas holders' level varied, it resulted in a back pressure on the volume meters. Because of the problems stated above, reliable gas production figures could not be produced during this project.

3.4 CHEMICAL DOSING SYSTEM

The choice of chemical dosing system is pivotal to the whole process of chemical phosphate removal. Factors which need to be taken into consideration are: the chemical dosing requirements for the sewage works under consideration - a variety of approaches are possible, as will be detailed below; dosage pump type and material of construction; control instrumentation; bulk storage tanks for chemicals in design, material of construction and safety features; equipment and instrument supplier back-up services, and cost.

For the purpose of the Boksburg Vlakplaats experiment it was decided to acquire a flexible chemical dosage system for Unit C which would allow the testing of a variety of chemical dosage strategies i.e. from the most simple approach - addition of a constant volume of chemical, to varying the dosage as a function of flow and phosphate concentration in the wastewater stream being treated. Figure 3.7 shows schematically the various components of the chemical dosage system installed at the Vlakplaats Works.

3.4.1 Chemical Dosing Pumps

It was decided to use Mono O-range positive displacement chemical dosing pumps for both ferric chloride a poly-electrolyte dosing. A polypropylene head was selected rather than the standard stainless steel head in order to withstand the extremely corrosive ferric chloride.

The dosing pumps, comprised two gang single headed metering pumps with individually adjustable mechanisms.

The two mechanisms are long coupled to a D.C. motor for variable speed operation.

One pump head is manufactured from polypropylene fitted with 22mm diameter teflon valve balls with a teflon diaphragm, all suitable for pumping a 43% solution of ferric chloride.

The second pump head is manufactured from Grade 316 stainless steel fitted with 22mm diameter Grade 316 stainless steel valve balls and seats with a teflon diaphragm, all suitable for pumping polyelectrolyte solution.

The mechanism stroke length is 12mm at 100% of stroke setting and it is infinitely adjusable through a cylindrical wedge mechanism whilst the pump is in operation or at rest.

In order to ensure accurate chemical delivery rates it is essential to maintain the pump in good operating condition at all times. It was found by trial and error that a daily check of pump delivery was necessary to ensure reliable operation. Furthermore, a weekly check had to be undertaken to ensure that the maximum speed of the motor driving the pump did not exceed its rated maximum, i.e. 1700 r.p.m. at its maximum dosage rate. A monthly check of the pump diaphragm was necessary to ensure that its wear was within acceptable limits.

The $FeCl_3$ dosing pump calibration was tested at flow measuring point P_6. The swing plate assembly installed on the stilling cylinder at P_6, and simulating 100 per cent flow at this point (i.e. the maximum anticipated biological filter effluent flow and hence also the maximum chemical volume dosage requirement) was used to calibrate the chemical dosage pump to pump its maximum delivery rate. The volume of chemical pumped over a fixed period was measured with a measuring cylinder. This actual volume discharged was compared with the volume required as based on that calculated for the effluent flowrate and phosphate concentration under consideration. A difference in volume of up to 5 per cent was considered acceptable. However, larger difference were considered unacceptable and the pump was recalibrated.

3.4.2 $FeCl_3$ Bulk Storage Tanks

Criteria to be considered in the selection of chemical bulk storage tanks include the following: chemical requirements for phosphate removal, corrosivity of the chemicals to be stored, bulk volumes in which the chemical are supplied, and cost.

Ferric chloride supplied by AECI is currently delivered by tanker in 25 tonne (20 m^3(l)) loads of a 43% $FeCl_3$ solution. In order to accommodate this large volume a bulk storage tank of about one and a half times this volume or two tanks of at least 20 m^3 are required, to make provision for delays in supply.

Because of the danger associated with the acidic and extremely corrosive ferric chloride solution, extreme care should be taken with the design and construction of the bulk storage tank for this chemical.

The tanks were manufactured of glass reinforced polyester in accordance with the following specification and standards:

a) S.A.B.S. 141-1971 (as amended): Glass Reinforced Polyester (G.R.P.) laminated products, A.E.C.I. Specification No. EB 212.

b) The material of the tank is resistant to degradation by the following chemical : 43% Ferric Chloride Solution of pH 0, specific gravity 1,47 at 30 deg. C and maximum temperature at 40 deg. C.

c) The exterior of the tank was pigmented to an off-white colour with an ultra-violet inhibitor.

d) A safety factor of 10 was applied to the strength of the tank.

e) The tanks are circular in section, 2,5 metre in diameter and have a capacity of 30 cubic metres.

f) The tanks have a flat base and conical top.

g) The tanks have the following openings and fittings:

   i) 600mm diameter round manhole with cover on top of the tank
   ii) 100mm diameter vent with insect proof cover
   iii) 63mm diameter inlet pipe
   iv) 40mm diameter drain pipe
   v) A suitable float type level indicator

The tank should be placed on a steel reinforced floated concrete foundation. The tank should be placed within retaining walls, to make provision for spillage or tank failure to retain all spilled chemical within a confined area. The necessary safety precautions should be observed at all times, for example during calibration of the dosing pumps, cleaning of in-line filters and transfer of chemical from tankers to the bulk storage tank. These include the following:

a) warning signs must be displayed to make persons within the dangerous area aware of the risk in this particular area.

b) gloves, face masks and overalls must be warn, when working with ferric chloride.

c) an emergency shower and eye wash must be installed within close but safe proximity of the bulk storage tank.

d) a water supply and hosepipe must be readily available to hose down spilled chemical.

3.4.3 In-line $FeCl_3$ solution screens and filters

The commercially supplied $FeCl_3$ is not always completely free from suspended solids. For this reason it is essential that a roughing screen (2mm mesh) be installed between the dosage pumps and the bulk storage tanks. This will ensure that coarse objects still present in $FeCl_3$ solution do not cause obstruction to the dosage pumps. In addition to the screens, it has been found beneficial to protect the dosage pumps with 5 micron in line PVC filter cartridge elements. A dual filter system was used to obviate the need for system shutdown during filter washing or replacement.

3.4.4 Pipework

The pipework used in the ferric chloride dosage system needed to be corrosion resistant and robust. PVC piping was decided on. Couplings were made using Nitrile rings. For the flow rates which had to be maintained at the Vlakplaats Works (0,06 l/s), 40mm inner diameter pipes were used, since 20mm diameter pipes resulted in unacceptable pressure drops over distances in excess of 10m, as well as formation of air pockets which caused obstruction in these lines.

3.4.5 $FeCl_3$ Balancing Tank

Operation of the system as described above, i.e. pumping of $FeCl_3$ from bulk storage tanks to the biological filter effluent channel (P_6), resulted in errors in volumes of chemical dosed. The dosing rate calculated from pump settings as compared to the actual volume of $FeCl_3$ used, as measured by the drop in level in the bulk storage tank, did not match up. A small balancing tank (see Figure 3.8) was introduced between the bulk storage tank and the chemical pump to supply a constant head. This resulted in accurate dosing of $FeCl_3$, with dosage rate figures from the pump matching the volume pumped from the bulk storage tank within (or better than) 5 per cent. A further advantage of this system was the removal of air bubbles trapped in the bulk storage delivery line. An additional set of 5 micron cartridge filters were introduced to filter out any fine suspended solids which were still in $FeCl_3$ solution leaving the balancing tank.

3.4.6 $FeCl_3$ Dosing Procedures:

a) Constant volume dosing

Various chemical dosing strategies were considered. The simplest method, constant volume dosing, was not implemented because of the wide variations in flow and phosphate concentration experienced over daily 4-hour cycles, at the Vlakplaats Works and associated large wastage of chemical by either under- or over dosing.

b) Dosing proportional to flow

The major variables affecting the volumetric chemical dosing rate were biological filter effluent flow rate and dissolved ortho-phosphate concentration. Compensation for flow variations is not technically difficult, since many commercial chemical dosing systems exist which can control volume dosing rate proportional to wastewater flow rate. An ultrasonic flow meter (Wesmar type) was installed in the biological filter effluent canal just upstream of the division channel. The flow meter measured water height through a rectangular weir. The ultra-sonic meter pulse was transmitted to an AC/DC convertor which in turn controlled the speed of the dosing pump motor, i.e. the delivery rate of chemical. The dosing pump's plunger stroke could be adjusted from 0 to 100 per cent, and was set according to the required plunger stroke for 100% biological filter effluent flow. The plunger stroke was then controlled to pump proportional to the varying flow measured in the channel. This system was found to operate satisfactorily with only minor adjustments from time to time.

3.4.7 Chemical Dosing System

The chemical dosing system used on Unit C was constructed by the Boksburg Municipality technical staff using individual components which were commercially available. Another approach, to buy a complete chemical dosage system, presented an alternative option. A local company, Lektratek, supplied such a chemical dosage plant to the project for evaluation of its technical capabilities and economic viability. The system is compact and has a number of novel features, e.g. an automatic polyelectrolyte make-up system, a chemical dosage control system which, through prior settings, controls chemical dosage and volume of chemical pumped, making pre-set hourly and daily dosage variations possible.

3.5 ON-LINE CONTINUOUS MONITORING OF PHOSPHATE.

An automatic phosphate analyser supplied by Hach (Pty) Ltd was tested for use as an on-line continuous monitor for dissolved ortho-phosphate, with the intention of coupling this instrument to the $FeCl_3$ dosage system, to ensure a more effective use of chemicals. This instrument functioned satisfactorily, but the chemically treated humus tank effluent pumped to the instrument for phosphate analysis gave rise to problems.

Fine suspended solids present in the effluent stream adhered to the thin pipes and plastic tubes in the analyser. With time the solids dislodged sporadically, causing abnormally high phosphate readings. Although this problem was overcome by means of filtration system, continuous monitoring of phosphate required an excessive amount of the plant chemist's time if the system was to be operated successfully. This system is therefore not recommended for sewage works which do not have staff skilled in the operation and maintenance of analytical instrumentation, and with the necessary time to keep the system operational on an on-going basis. Similar views have been expressed by overseas sewage works personnel on chemical phosphate removal works (WRC, 1987).

The approach found to be the most practical on the Vlakplaats Works and which was used throughout the experimental period, was sampling of point P_7 proportional to flow, using an automatic sampler (ISCO) and then analyzing the samples in the laboratory.

3.6 ON-LINE CONTINUOUS MONITORING OF pH

The pH of the chemically treated humus tank effluent was monitored and recorded continuously using a Radiometer pH meter and stripchart recorder. As a rule the pH varied very little, in the range between 7,0 and 7,3. However, during periods of low flow (at night), high recirculation rates of humus tank effluent resulted in the chemical dosing of the mainly recirculated humus tank effluent which had already been treated with $FeCl_3$ and as a result the high dose of acid ferric chloride reduced the alkalinity of the stream, with a resultant drop in pH to as low as 6,2.

3.7 HUMUS TANK EFFLUENT RECIRCULATION

Unit C of the Vlakplaats Works is equipped with four pumps for recirculating humus tank effluent to a point upstream of the biological filters. The reason for this recirculation is to insure a minimum flow of 28 Ml/d through the biological filters in order to keep the settled sewage distributor arms moving over the filters. A secondary advantage is the dilution of settled sewage with an unacceptably high COD content. Furthermore, the humus tanks are protected against sudden flow surges and can thus operate more consistently. This became particularly important when $FeCl_3$ dosing was introduced, since the ferric phosphate and hydroxide flocs are relatively light. The electrodes which controlled the recirculation pumps were positioned upstream of this measuring weir at CP_6 in the filter effluent channel.

3.8 HUMUS/CHEMICAL SLUDGE RECIRCULATION.

Each unit on the plant has two centrifugal pumps for withdrawing sludge from the humus tanks and pumping it to the head of the works. On units A and B humus sludge is withdrawn on a continuous basis from the Dortmund settling tanks by means of the hydrostatic head of the tank (see Figure 3.9). On Unit C, the mixed humus/chemical sludge is settled in four 22m diameter clarifiers. Sludge withdrawal is accomplished by means of a mechanical arm system that revolves once every 20 minutes and activates a sludge valve withdrawal system.

On all the units the sludge flows into a sump from where it is recirculated to point P_2 by humus sludge pumps controlled by electrodes in the humus sludge sumps. In order to ensure that these pumps do not switch on and off continuously, plates with orifices (27 mm) were fitted in the sludge lines on the delivery side of the humus sludge pumps to control the sludge flow rate to about 1 Ml/d which more or less kept the sludge pumps in continuous operation. This modification leads to a more even spread of humus/chemical sludge on the primary clarifiers.

3.9 CORROSION RESISTANT MATERIALS OF CONSTRUCTION

Experience at the Vlakplaats Works showed that all metal components (pipes, pumps and tanks) which came into contact with the 43 per cent $FeCl_3$ solution, corroded severely. Suitable materials of construction for the dosing system were the following:

(a) All pipework and valves - PVC or similar corrosion resistant material.

(b) The $FeCl_3$ bulk storage tanks - glassfibre reinforced polyester (SABS standard 141, 1971) and glass fibre reinforced polyester laminated products (AECI specification EB212).

(c) The $FeCl_3$ dosing pump heads polypropylene and fitted with teflon valve balls and a teflon diaphragms.

3.10 AGGRESSION OF ACIDIC WATER TO CONCRETE AND CEMENT STRUCTURES

Removal of phosphates with acidic ferric chloride can result in waters which are undersaturated with respect to calcium carbonate, i.e. they have a negative Langelier Saturation Index and will dissolve concrete and cement type materials. This has in fact been observed in the channel transporting biological filter effluent, downstream of the point of $FeCl_3$ addition and in the humus tanks.

This problem can be controlled or minimised by the following means:

(a) Closely monitoring the Langelier Saturation Index of the water and dosing an alkali (lime or soda ash).

(b) Minimise $FeCl_3$ overdosing by developing a suitable dosing strategy; particular attention needs to be given to raw sewage low flow periods so that overdosage of $FeCl_3$ during these periods does not take place.

(c) A well designed system for introducing the $FeCl_3$ into the biological filter effluent stream; a drip feed is unacceptable.

(d) In existing plants concrete can be protected by coating with bituminous epoxy paint; in new plants more acid resistant concrete types should be used.

3.11 RAW SEWAGE FLOW DISTRIBUTION TO UNITS B AND C

For purposes of the experiment, it was important to have an even distribution of the raw sewage flow and quality to Units B and C in order to make a valid comparison between the two units possible. Sewage from Vosloorus, was mixed sewage from Boksburg's residential and industrial areas, well ahead of the division point to Units B and C, to ensure proper mixing. The division was made by means of a swing sluice. Flow and quality distribution was on average fairly even as will be seen from Tables DB1 and DC1 in Annexure D.

CHAPTER 4

OPTIMIZATION OF THE EFFICIENCY OF CHEMICAL USAGE

4.1 INTRODUCTION

One of the main objectives of the investigation was to optimize chemical usage. This optimization process was to include investigation of various aspects of chemical addition, i.e. the mixing intensity and method of mixing chemicals wi the effluent stream, flocculation time, method of operation of the secondary clarifiers and recycling of chemical sludge to the head of the works. Probably the most important of all was the need to develop a cost-effective chemical dosing strategy which would ensure compliance with the phosphate standard 95 per cent of the time.

4.2 ASSUMPTIONS USED IN ESTIMATION OF EFFICIENCY OF CHEMICAL USAGE

The measure by which the efficiency of chemical phosphate removal is normally assessed is the molecular weight ratio of the amount of P removed against the amount of $FeCl_3$ dosed. The stoichiometric ratio is 1 mg P : 5,24 mg $FeCl_3$ and the efficiency of chemical dosage is expressed as the multiple number of times the stoichiometric chemical requirement must be exceeded in order to lower the P concentration down to the required effluent standard of 1 mg soluble Ortho-P/l.

It has become clear during the course of this project that the efficiency of chemical usage is not a simple matter to assess for the following reasons:

a) P removal occurred by both physical and biological means on the control Unit B; it will be seen from the data in Tables DB1 and DB10 in Annexure D that on average over the entire test period the Total P concentration in the influent (BP_1) is reduced from 12 mgP/l to 9,6 mgP/l in the humus tank effluent (BP_7) - a reduction of 20%. This must naturally be taken into account if chemical usage efficiency on Unit C is to be meaningfully assessed.

b) Chemical P removal does not occur only at the point of chemical dosing. By comparing the Total P concentrations plotted in Figs. 4.1 and 4.2 and Ortho P concentrations in Figs. 4.3 and 4.4 it will be clear that on Unit C where chemicals are dosed the concentration of P reduces significantly between points P_1 and P_4 through the primary settlers, between points P_4 and P_5 where it is diluted by recycled humus tank effluent and between points P_6 and P_7 where dosing takes place resulting in removal in the humus tanks. In contrast on Unit B the concentrations of P at the various points show very little discernable trend except that the values are lower at P_7 than at P_1 confirming that some P removal does occur without chemical dosing. From the foregoing it will be evident that the efficiency of chemical usage cannot be assessed merely by the removal rate observed at the dosing point because cognisance must be taken of the chemically induced P removal occurring at the other points in the plant.

To overcome these problems it was decided to compare the phosphate removal on the two Units as a whole.

Considering the similar nature of the sewage streams entering Units B and C (compare the data in Tables DB1 and DC1 in Annexure D) it is reasonable to hypothesise that the concentration of Total P in the effluent from Unit C would be similar to that from Unit B if chemical dosing was not being practiced. Therefore the daily mass of Total P removed chemically on Unit C can be estimated as the difference between the concentrations at BP_7 and CP_7 multiplied by the flow through Unit C. Using this hypothesis the ratio of the mass of $FeCl_3$ dosed to the mass of chemically removed P can be calculated; this ratio has been the basis for measuring the relative efficiency of chemical usage for the different strategies investigated during this project.

4.3 EFFECT OF INTENSITY OF RAPID MIXING OF $FeCl_3$ WITH BIOLOGICAL FILTER EFFLUENT

The mixing energy at the chemical dosing point (CP_6 on Fig. 1.2) was provided by means of flow over a weir. The weir served a dual purpose in that it was also used to measure the flow rate at the dosing point so that the chemical dosing rate could be controlled to be proportional to the flow rate. The mixing intensity at the dosing point could be varied by changing the height of the weir, and it was originally proposed that weir heights of 200 mm, 400 mm and 600 mm be tested.

However, it was found that if the weir level was lower than 400 mm, the flow over the weir was drowned out by the tailwater and this resulted in inaccurate flow measurement (as indicated by a deterioration in the flow balance). It was therefore decided to test weir heights of 400 mm, 500 mm and 600 mm.

For the period over which these tests were carried out the $FeCl_3$ was dosed proportional to the biological filter effluent flow rate and the $FeCl_3$ dosage was kept constant at 32,3 mg/l (as $FeCl_3$) at dosing point, CP_6. The concentrations of Ortho-P measured at points P_1, P_4, P_6 and P_7 over the whole period are shown in Figure 4.5.

Unfortunately, the daily ortho-phosphate concentration in the biological filter effluent varied significantly, i.e. between 2,4 and 6,3 mg/l, (as P) over the period of the test, making meaningful comparison of removal efficiencies for the different weir heights impossible. These inconclusive results made it clear that realistic comparisons are not possible on full-scale work for parameters which only have marginal or relatively small effects. However, the data did show that the phosphate removal at all weir heights was relatively good, with $FeCl_3$: P values of 1,8 times the stoichiometric (requirement for $FePO_4$ precipitation which is considered quite effective (WRC, 1987). In all probability the mixing intensity resulting from the minimum weir height (400 mm) was more than sufficient for mixing the $FeCl_3$ with biological filter effluent.

Because of the plant limitations and the sampling and analytical errors inherent in tests on this full-scale plant, as well as the apparent relative insensitivity of phosphate removal to the degree of mixing intensity, above a certain level, this phase of the work was considered to be inconclusive and was terminated.

4.4 EFFECT OF FLOCCULATION TIME

The time taken for the flow to pass from the point of chemical addition to the discharge of the treated effluent into the humus tank stilling wells, i.e. the flocculation time, could be varied between 73 and 128 seconds by changing the position of the dosing point within the filter effluent channel. An experimental run of two weeks at each of the two extreme settings was undertaken and the ortho-phosphate concentrations monitored at sampling points P_1, P_4, P6 and P_7 (Figure 4.6). For the period of the test the $FeCl_3$ dosage was maintained constant at 42 mg/l.

As in the case of the tests with different mixing intensities, the dissolved ortho-phosphate concentration in biological filter effluent varied significantly, i.e. between 2,0 and 4,4 mg/l (as PO_4-P), making comparison between the two different flocculation times unrealistic. However, the data showed that for both the flocculation times studied the phosphate removal was quite effective, with $FeCl_3$: P values of 2,0 times the stoichiometric requirement to precipitate $FePO_4$. Hence even the minimum flocculation time of 75 seconds appeared to be more than sufficient.

Because of the abovementioned problems, further flocculation time studies were discontinued.

4.5 EVALUATION OF THE EFFICIENCY OF THE SECONDARY CLARIFIERS FOR INCREASING HYDRAULIC AND SOLIDS LOADS

Experiments were undertaken on Unit C of the Vlakplaats works to establish if the secondary clarifiers (humus tanks) would produce a clear overflow water with suspended solids less than 20 mg/l, under increased hydraulic loads which would result in increased sludge loading rates and linear upflow rates of clarified water. The method by which these increases were brought about, was by passing the same volume of biological filter effluent (11 - 12 Ml/d) through a progressively reduced number of clarifiers. The tests was started by operating the normal 4 secondary clarifiers for about two weeks (test period 1), reducing to 3 clarifiers for about two weeks (test period 2) and finally treating the total flow in only 2 clarifiers for just over one week (test period in Table 4.1).

As more clarifiers were removed from operation, the upflow rate increased, i.e. from 0,84 m/h to 1,12 and 1,67 m/h (for periods 1, 2 and 3, respectively); similarly the quantity of sludge which had to be removed by the remaining settlers also increased. This resulted in unacceptably high solids carry-over, i.e. suspended solids in the overflow water in access of 20 mg/l. It was attempted to remedy the situation by increasing sludge withdrawal rates from 0,33 Ml/d (period 1) to 0,87 and 1,21 Ml/d (for periods 2 and 3, respectively).

~~It was not, however, possible to achieve acceptable clarifier effluent under~~ the increased hydraulic loads during the period set aside for this purpose in the experimental programme, and consequently it was temporarily abandoned at this stage (July 1986).

During 1987 it was again attempted to run the secondary clarifiers at hydraulic loads in access of the design conditions. During this set of tests, periods of 3 to 4 weeks were allowed for stabilization of plant operation prior to assessment of clarifier efficiency. Results for these tests are given in Table 4.2.

The difficulties in measuring suspended solids concentrations are dealt with in detail in Chapter 2 of this report. Because of these difficulties it was not possible to quantify the performance of the humus tanks under the increased hydraulic loadings, but visual inspection of the effluent indicated that it is possible by judicious operation to produce a secondary clarifier effluent that meets the effluent phosphate standard with secondary clarifiers operating at hydraulic loads 1,6 times in excess of their design loads. In order to achieve this, humus/chemical sludge withdrawal rates had to be significantly increased over normal operation. Furthermore, to consistantly meet the effluent standard poly-electrolyte had to be dosed, of the order of 0,11 mg/l when 3 clarifiers were in operation and 0,23 mg/l with only two clarifiers in operation.

4.6 EFFECT OF HUMUS TANK EFFLUENT RECYCLE RATE

Part of the overflow from the humus tanks is recirculated to a point just upstream of the biological filters (CP_7 on Fig 1.2). The purpose of the recirculation stream is to ensure that there is at all times sufficient flow to the filters to keep the distributor arms moving thereby preventing the filter drying out and hence killing off the purifying biomass on the filter media. For the Vlakplaats biological filters this is estimated to be 28 Ml/d per Unit. Subsidiary aims are to dilute the incoming settled sewage in order that the COD concentration exposed to the filter is not excessive (for the Vlakplaats works the aim is to keep the COD feed to the filters less than 400 mg/l). Normal operation is to set the flow rate at CP6 after the biological filters to about 28 Ml/d, i.e. an average recycle rate of 0,6 times the incoming flow sewage of 18 Ml/d.

It has been reported in the literature (U.S. EPA 1976; Rabinowitz and Marais (1980) that chemical phosphate removal is at its most efficient in terms of mass of P removed per mass of chemical added for effluent with high P content, the reason being that P removal at low concentrations (2 mg/l and lower) requires much higher chemical dosages. Consequently, in biological filtration plants the recirculation of filter effluent to the head of the filters and the resultant reduction of the phosphate concentration may be deliterious in terms of chemical usage.

Initially it was proposed to study the effect of varying the humus tank effluent recycle rate so that the efficiency of chemical removal could be assessed at recycle rates to raw sewage flowrate ratios of 0,5:1 1:1 and 2:1. However, it soon became clear that, as with the investigation of the effects of mixing intensity and flocculation time, the effect of the humus tank effluent recycle on chemical usage efficiency was not a sensitive enough parameter to be measured at full scale.

It therefore is concluded that the recycle rate should be determined by the factors listed in the introduction to this section. One constraint on high recycle rates is the attendant high upflow rate in the secondary clarifiers and hence minimum recycle rate to ensure proper filter wetting and COD dilution appear to be the main factors to be considered in selecting the humus tanks effluent recycle rate.

4.7 EFFECT OF RECIRCULATION OF HUMUS/CHEMICAL SLUDGE TO THE HEAD OF WORKS

Normal operation of humus tanks on the Vlakplaats Water Pollution Control Works comprised *inter alia*, humus sludge withdrawal once per shift. With the introduction of chemical dosage the mass of humus sludge formed increased significantly (See Chapter 5). In order to effectively deal with this increased sludge load, the sludge had to be withdrawn more regularly and even twice per shift was found to be inadequate. The most satisfactory strategy was found to be continuous humus/ chemical sludge withdrawal and recirculation to the head of the works. Notwithstanding the significantly high volumes of humus/chemical sludge recycled to the head of Works, the Unit C primary settlers functioned more effectively, with consistently better phosphate removal in the primary settlers than in control unit B (See Chapter 6).

It is therefore considered of prime importance that the iron-rich humus sludge be recycled to a point upstream of the primary settles on a continuous basis if chemical usage is to be optimised.

4.8 EFFECT OF DILUTION OF $FeCl_3$ DOSING SOLUTION

Originally it was envisaged that the effect of dosing different concentrations of $FeCl_3$ would be analysed. However, in the light of the experience with testing of different mixing intensities and flocculation times described in Sections 4.3 and 4.4 above, as well as the anticipated problems of controlling the dilution rate under full scale conditions, it was considered unlikely that this set of experiments testing the effect of dilution of the $FeCl_3$ dosing solution would produce conclusive data and hence it was decided not to proceed with them.

4.9 OPTIMIZATION OF CHEMICAL DOSING

The objective of chemical phosphate removal at the Vlakplaats Works, is to meet the 1 mg/l dissolved ortho-phosphate standard 95 percent of the time using the minimum amount of chemical to achieve this goal. During this study various chemical dosing strategies were investigated to identify a practical means to achieve the above-mentioned objective in a cost-effective manner.

The simplest procedure for adding chemicals is to dose them at a constant feed rate, i.e. using a constant feed dosing pump. The next simplest procedure is to have a dosing pump with a variable speed motor connected through a speed controller to a flow meter. In this way the dosing rate can be made proportional to the flow rate of the stream being dosed, and it is in this mode that most of the experimental work was done at Vlakplaats. The adoption of this strategy was justified by the fact that the phosphorus concentration at the dosing point remained remarkably constant over the day when hourly tests were run over 36 hours (see Chapter 6).

In the first attempt to optimise the use of chemicals the plant was run for a period of 12 weeks between May and July 1986 and the dosing rate was reviewed and adjusted weekly in order to find the lowest rate which would consistantly produce an effluent with an ortho-P concentration below 1 mgP/l. The data for that period is plotted in Fig. 4.7 and it will be seen that the effluent P concentration was consistently over the limit.

Data from a run of 13 weeks between June and October 1985, analysed on a daily basis, are shown in Table 4.3. In this table all daily concentrations at CP_7 which are higher than 1,0mgP/l have been highlighted by underlining. The most striking feature of this data is the fact that the quality of the plant effluent with regard to Ortho-P generally deteriorates progressively over the week. The standard is never exceeded on a Monday but is exceed 8 times, or 57% of the time on Fridays, and the average value on Mondays is approximately half the value for Thursdays and Fridays. It will be seen that even for weeks 7 and 9 during which the highest dosing rate was used and the stoichiometric relationship was at its worst, the standard was not met every day, a value of 3,6 mgP/l being measured on the Friday of week 7 and 1,2 on Thursday of week 9.

It was clear from the foregoing that the optimisation of chemical usage on biofilter plants is a very complex matter which is far from simple to analyse. Not only does it occur in different stages of the plant but it appears to be subject to daily variations. Furthermore it is clear that the physical parameters on the plant which were originally to be investigated to optimise the chemical usage for P removal are of secondary importance compared to the sewage characteristics and therefore a reappraisal of the programme for the project was required.

As a result of this reappraisal the dosing strategy was changed in that chemical was dosed at a relatively low rate on Saturdays to Wednesdays and then increased on Thursdays and Fridays. This strategy was operated for 13 weeks from July to September 1986 with limited success, as will be seen from Fig. 4.8.

It was finally decided that the only way to take account of daily, weekly and seasonal changes in the sewage quality was to adjust the dosing rate on a daily basis to a rate calculated from historical data. This gave rise to what was known as the "daily four week moving average" strategy, and is described below.

a) On each day of the week the Ortho-P concentration in the biological filter effluent is averaged for the same day in the previous four weeks.

b) A target humus tank effluent Ortho-P concentration of 0,8 mgP/l was adopted. This figure was subtracted from the average concentration calculated in (a) above and gave the target amount of Ortho-P to be removed.

c) A target dosing relationship of 2X the stoichiometric chemical requirement was adopted and this was used to calculate the dosing rate required to remove the amount of Ortho-P calculated in (b) above.

A typical example of this calculation is given in Table 4.4.

Although this method is somewhat tedious in that the dosing rate has to be adjusted daily on a regular basis it brought about a dramatic improvement in the effluent quality during the 33 weeks this strategy was employed between September 1986 and February 1987. This is clearly indicated in Figure 4.9.

Table 4.5 gives a comparison of the performance of the three dosing strategies adopted. Within the range of 1,8 - 2,2 times stoichiometric $FeCl_3$ dosages at which Unit C was operated, none of the strategies achieved the legal requirements for dissolved ortho-phosphate. Nonetheless, the "four day moving average" strategy was significantly better than the, "Thursday/Friday" strategy, which in turn was a marked improvement on the constant dosage strategy. With an increase in the $FeCl_3$ dosage rate to about 2,5 times the stoichiometric $FeCl_3$ requirement for $FePO_4$ precipitation, the legal dissolved ortho-phosphate standard would probably have been met by the "daily four week moving average" dosing strategy. However, an increase of about 3,0 - 3,5 times the stoichiometric $FeCl_3$ dosing requirement would be required for the "Thursday/Friday" dosing strategy and an increase of about 3,5 - 4,5 times the stoichiometric $FeCl_3$ dosage requirement for the "constant dosage" strategy. From these estimates it appears that cost savings for chemicals of the order of 15 - 30 percent for the "Thursday/Friday" strategy and 30 - 45 percent for the "four day moving average" strategy are possible.

The 95 percentile compliance to standard is an extremely stringent requirement, i.e. not more than 1 in 20 samples may contain more than 1 mg/l (as P). In effect this requires the average effluent dissolved ortho-phosphate concentration to be much lower than 1 mg/l (as P). This point has been made by Pitman <u>et al</u>. (1986) for biological phosphate removal. However, in the case of chemical phosphate removal the consequences are even more severe. To constantly achieve below 1 mgP/l in the effluent, the average concentration would have to be say 0,4 mgP/l which will require significantly higher chemical dosage (say 20 - 30 percent higher) than achieving an average of 1,0 mgP/l.

This higher chemical dosage results in higher sludge production rates, higher chemical and other treatment costs and a higher salt content in the water. Probably a more effective means of achieving the ultimate objective of effluent phosphate load control, i.e. a specific phosphate load which may be discharged, is to set monthly phosphate loads for each sewage treatment works and allow chemical dosage adjustment to meet the set load. This would ensure compliance with standard but with some flexibility in plant control to minimize chemical cost and the deliterious effects associated with chemical phosphate removal.

CHAPTER 5

EFFECT OF CHEMICAL DOSING ON SLUDGE MANAGEMENT

One of the major concerns of local authorities with regard to implementing chemical phosphate removal has been that it will lead to a dramatic increase in sludge production and may lead to disruption of sludge treatment facilities. For this reason monitoring of sludge production and quality parameters formed a large part of this investigation. The findings are discussed below.

5.1 SLUDGE PRODUCTION

5.1.1. Raw Sludge Production

Raw sludge production in the primary settling tanks at the Vlakplaats Works was primarily a function of the solids in the raw sewage, the solids returned in the humus tank sludge recycle to the primary settlers, and the efficiency of solids removed in the primary settling tanks. Since the solids in the raw sewage were of such a nature that they could not be representatively sampled (see Chapter 2, Section 2.6.5.), raw sewage solids were not routinely determined. Consequently, the efficiency of the solids removal by the primary settlers could not be determined.

Sludge production rates in the primary settlers were determined as follows. Grab samples were taken daily of the raw sludge withdrawn from the primary settling tanks. The sludge was thoroughly mixed in the sludge sump before sampling in an attempt to ensure that as representative a sample as possible was obtained. Sludge production rates were calculated by multiplying the sludge concentration by the volume withdrawn. In order to produce figures which could be compared with daily sludge production rates on the various different Units, this mass production rate was divided by the volume of raw sewage treated on the respective Unit, giving the sludge production rates in units of kg/d per Ml/d or kg/Ml. The sludge production rates vary over a large range, i.e. 130 to 1470 kg/Ml. The reason for this large variability was, *inter alia* the inability to representatively sample raw sewage sludge solids. In an attempt to reduce this variability, and smoothing the data, weekly averages of sludge production rates were calculated and used for comparison purposes in this chapter. Weekly averages of daily sludge production rates are listed in Table 5.1 for both Unit B, (control) and Unit C, ($FeCl_3$

dosed). Even these weekly averages show significant variability, with a standard deviation of 124 kg/Ml about the average of 489 for Unit B, and a standard deviation of 103 kg/Ml about the average of 533 kg/Ml for Unit C. Average figures for the total experimental period for both Units B and C are listed in Table 5.3.

The unit operated with $FeCl_3$ addition produced 11% more raw sludge on a volumetric basis and 9% more raw sludge on a mass basis. When comparing these figures with the standard deviations in the sludge production rates, it is clear that these increases are considerably smaller than the variability in the data, i.e. 44 kg/Ml difference compared to the standard deviation of 124 kg/Ml for Unit B. In terms of sludge management these differences are not significant.

The average increase in sludge production as a result of $FeCl_3$ usage, 44 kg/Ml of sewage treated (i.e. 489 kg/Ml increasing to 533 kg/Ml), is considerably less than the increased "humus" (humus plus chemical sludge) production of 67 kg/Ml sewage treated. However, since standard deviation of these sludge production rates is so high ($\pm$ 124 kg/Ml), the difference is not significant.

The weekly average for daily raw sludge production rates displayed a marked amount of scatter (see Table 5.1). No significant seasonal trends were discernable.

5.1.2 Humus Tank Sludge Production

Humus tank sludge was recycled to a point upstream of the primary settler on a continuous basis and 24 hour composite samples were taken daily relative to flow. Weekly averages of sludge production figures so obtained, are listed in Table 5.2, both for Unit B (Control) and Unit C ($FeCl_3$ dosed). Again the sludge production rates vary significantly and weekly averages of daily sludge production rates were used for comparing sludge production rates between Units B and C. The averages and standard deviations for all the humus sludge production data for the whole experimental period are listed in Table 5.4.

Although the data displays a significant amount of scatter, for example the humus/chemical return sludge concentrations vary between 0,6 to 5,7 g/l, there are significant differences between humus sludge production in Unit B, 107 ($\pm$ 49) kg/Ml of raw sewage treated, as against the humus/chemical sludge production in Unit C 174 ($\pm$ 83) kg/Ml of raw sewage treated, i.e. on average an additional 67 kg biological/chemical sludge as produced for every megalitre of raw sewage treated.

The average mass dosage rate of ferric chloride was 83 kg $FeCl_3$/Ml of sewage treated, which is equivalent to the formation of 77 Kg $FePO_4$/Ml or 54 Kg $Fe(OH)_3$/Ml. Assuming half of the iron to form $FePO_4$ and half $Fe(OH)_3$, this would represent 66 kg sludge/Ml sewage treated. The actual average measured value was 67 kg/Ml, i.e. in good agreement with the measured amount of "chemical" sludge formed in Unit C with $FeCl_3$ dosage.

No significant correlation could be found between the daily amount of additional sludge formed in the humus tanks and the daily $FeCl_3$ dosage rate, probably because the sludge data had a large margin of error associated with it due to problems of representative solids sampling.

At first glance a surprising finding of the study is the only marginal increase in volume of humus/chemical sludge (1147 $\pm$ 439 m^3/d) withdrawn from Unit C as compared to humus sludge (1064 $\pm$ 247 m^3/d) withdrawn from Unit B, the latter would be expected to be much lower. However, this was an artifact of the way in which the plant was operated, in that sludge from the humus tanks on Unit B was withdrawn continuous as on Unit C, whereas normal practice would be to only withdraw humus sludge intermittently, say three times per day.

5.2 SLUDGE QUALITY

5.2.1 Raw Sludge

The raw sludge quality was monitored on a weekly basis. Parameters measured were total COD, dissolved ortho-phosphate, dissolved iron, fatty acids, alkalinity and pH. The analytical results are listed in Annexure C, which cover about one year period (3/2/86 to 2/3/87). The quality of the sludge varies significantly over the period studied, but there does not appear to be any significant difference between Units B (Control) and C ($FeCl_3$ dosed), except for concentrations of dissolved Ortho-phosphate and iron. In the case of Unit B these are 40 mg/l (as P) and 23 mg/l (as Fe) respectively and in the case of Unit C they are 28 and 36 mg/l, respectively. The relatively high dissolved ortho-phosphate level is attributed to phosphate release from the raw sludge. However the presence of iron precipitates ($Fe(OH)_3$ and $FePO_4$) reduce the level of dissolved ortho-phosphate and slightly increase the dissolved iron level in raw sludge from Unit C.

5.2.2 Digested Sludge

Digested sludge quality was monitored on a weekly basis, with the same parameters being measured as for raw sludge. The analytical results are given in Annexure C. Again, the quality of the digested sludge varies significantly over the period studied, but there appears to be no significant differences between the quality of digested sludge from Units B and C, except in terms of dissolved ortho-phosphate. The digested sludge from Unit B has a dissolved ortho-phosphate content of about 40 mgP/l as compared to 7 mgP/l for the digested sludge from Unit C. It would appear that the presence of iron precipitates ($Fe(OH)_3$ and $FePO_4$) under anaerobic conditions result in a substantial removal of dissolved ortho-phosphate from the digester supernatant. The reasons for this have not been investigated but it could be due to adsorption of the dissolved orhto-phosphate on the iron precipitates or a transformation of the iron hydroxide to an iron phosphate under the long reaction times reigning in the digesters.

5.3 SLUDGE DRYING CHARACTERISTICS

No in-depth studies were undertaken on the sludge drying characteristics of digested sludges from Units B and C. In general, however, normal sludge drying procedures were practiced with no special handling or treatment requirements being necessitated for the sludge containing precipitated iron salts.

5.4 FINDINGS AND REMARKS

The only major consequence of chemical dosing on a biological filtration sewage purification system, is the significant increase in the mass of humus sludge generated. Provision has to be made for continuous sludge withdrawal from the humus tanks to ensure that solids carry-over does not occur. The increase in humus sludge mass has a negligible effect on the total sludge production for the plant.

CHAPTER 6

PROCESS EVALUATION

One of the objectives of this investigation was to establish the effect of chemical phosphate removal on the biological filtration sewage purification process as a whole over an extended period.

In this chapter the average performance of Units B and C over the whole experimental period (about 2 years) are evaluated and compared. However, as will become clear from the data to be presented, the differences observed between Units B and C cannot be ascribed to chemical dosing alone, since there are a number of differences between Units B and C other than chemical dosing. Firstly, the designs of Units B and C are not identical, e.g. Unit B has Dortmund tanks as secondary clarifiers, whereas Unit C has flat bottomed scraped clarifiers. Secondly, differences also exist on the sludge treatment side in that direct steam injection is used in Unit B digesters whereas indirect hot-water heat exchangers are used in Unit C. Therefore, in comparing differences in performance between Units B and C, the aforementioned differences in plant design and operation as well as the chemical dosing should be considered.

The Vlakplaats works was extensively monitored over the contract period i.e. January 1985 to March 1987. As described in Chapters 2 and 3, various problems were experienced at the beginning of experimental period, e.g. flow measurement and analytical techniques. Reliable data on flow rates, concentrations of various critical parameters and hence pollutant loads on the various unit processes, were only determined from about June 1985 onwards. Because of periodic problems with the flow meters, as indicated by flow rate imbalances over the Units as a whole of greater than 10 per cent, there are certain periods for which accurate load data is not available.

6.1 Process P - removal evaluation over 36 hour period

A special series of tests were run over a 36 hour period in which hourly samples were taken at the various sampling points on both Units B and C to obtain profiles showing the diurnal variation of ortho P and total P concentration and loads. The major finding of the tests was that, although the concentration and loads showed a marked diurnal cyclicity in the raw sewage at sampling point P_1, this was to a large extent damped out by the time the flow reached the chemical dosing point at P_6. This observed phenomenon is discussed in more detail below:

Unit B (Control)

Comparison of the influent (BP_1) and effluent (BP_7) 36 hour profiles for the unfiltered P concentrations and the unfiltered P masses shows some smoothing, principally due to the removal of the higher peaks and lower troughs (see Figures 6.1 and 6.2). This smoothing occurs mainly at the recycle points and probably is due to the dilution effect of the recycles. Also some smoothing occurs across the primary settling tank, probably due to dilution at the mixing point. The smoothing of the primary settlers is more pronounced for the unfiltered P profiles, indicating P removal through settling, and perhaps resolubilization of P from the settled solids through breakdown in the primary sludge (Figure 6.3). Very little smoothing occurs between the primary settler effluent and the humus tank effluent recycle (Figure 6.4) or through the biofilter (Figure 6.5).

Unit C ($FeCl_3$ dosed unit)

Comparison of the influent (CP_1) and biofilter effluent (CP_7) 36 hour P profiles shows pronounced smoot g and flattening of the profiles (See Figures 6.6 and 6.7). In contrast to Unit B, this does not occur between primary settled effluent and humus tank effluent recycle (See Figure 6.8). Quite considerable flattening is evident across the primary settler (See Figure 6.9), probably for the same reasons given above for Unit B. However, the most pronounced flattening of the profiles in Unit C appears to occur across the biological filters (See Figure 6.10). Although the reasons for this occurrence are not expliciteiy known it is probably due to the following phenomena:

(a) Precipitation/redissolution: The apparent lack of flattening of the profiles across the biological filters in Unit B (See Figure 6.5) would indicate that the chemical dosing of Unit C is related to the phenomenon. In this regard the large surface areas present in the biological filters would stimulate precipitation of P by acting as an absorption/precipitation surface during periods of high P concentration and "dissolution" due to desorption during periods of low P concentration. These would give rise to a smoothing and flattening of the P profiles.

(b) **Dilution and back-mixing:** Dilution and back-mixing in the biological filters possibly could account for some of the smoothing and flattening observed.

(c) Variable COD load: The COD load to the biological filters will vary in a similar fashion to the P loads. The higher COD loadings will result in more growth and a larger P demand for metabolism and cell synthesis. However, the apparent lack of smoothing and flattening of the profiles across the biological filters in Unit B, would tend to indicate that this particular phenomenon does not play a significant role.

6.2 Process Evaluation Over Total Project Period

The rest of the process evaluation was done on data which has been averaged over the total period of the experiment to give an overall comparison between process operation with and without $FeCl_3$ addition. The daily (weekday) water quality data at the seven sampling points for Units B and C (see Chapter 2) varied significantly. In order to get smoothed and more representative data, analyses of daily composite samples taken relative to flow were reduced to weekly averages (See Annexure D). For the purpose of the overall evaluation of process performance an average and standard deviation of the weekly averages for all relevant parameters were calculated for the period June 1985 to March 1987. The main emphasis of this chapter, however, falls on an evaluation of the various pollutant loads on the various unit processes of the works and the removal of pollutants in terms of load. Again the comparisons between Units B and C are on the average load over the whole experimental period.

6.2.1 Raw sewage feed to Units B and C

The raw sewage treated by Units B and C have the same origins i.e. a mixture of domestic sewage from Vosloorus and a mixed industrial and domestic sewage from Boksburg. These two streams are thoroughly mixed and the combined stream is then split into two more or less equal fractions to Units B and C.

The composition of the raw sewage is highly variable, from hour to hour, day to day, and even week to week. Table 6.1 gives the overall average and standard deviation for all the quality parameters measured from the raw sewage feed Units B and C. The weekly averages can be found in Tables DB1, DB2, DC1 and DC2 in Annexure D.

Because of the non-homogeneous nature of raw sewage, with highly variable concentrations of suspended solids (with a range of specific gravities - from floating matter to grit and sand), this stream was sampled after screening and grit removal. Nontheless, it was not possible to obtain truly representative samples by the limited practical means available to the research team. The results listed in Table 6.1 should therefore not be considered absolute values, but rather a semi-quantitative indication of the order of magnitude the various parameters measured. Although the average values for the various parameters for Units B and C are not identical, they do not differ significantly when taking the variability of the data, indicated by the standard deviation into consideration.

The COD of the raw sewage was extremely variable, maximum values up to 2081 mg/l and minimum values of 328 mg/l were measured. The COD concentrations did not show a marked seasonal trend (See weekly average values in Tables DB1 and DB2 in Annexure D) but the low values recorded from time to time are usually associated with heavy rainfall events and were probably due to stormwater intrusion into the sewage reticulation system. The extremely high COD concentrations observed from time to time were probably as a result of sporadic industrial discharges.

The total and ortho-phosphate concentration in the sewage feed to the plant was quite variable. This aspect is dealt with in depth in Chapter 4. High alkalinity concentrations were also observed from time to time. Interestingly, these were not associated with corresponding increases in pH and hence could not be attributed to industrial discharges of caustic soda, soda ash, tripolyphosphates or ammonia but must have been due to the sporadic discharges of a low pH alkaline material such as bicarbonates. The chloride concentration (only measured on a weekly basis), was also found to be quite variable. Again, this can be ascribed to sporadic industrial discharges. The same was found for total and dissolved iron in the sewage feed.

Table 6.2 lists the overall average pollutant loads on Units B and C for the study period. The average loads for all three of the major pollutants, i.e. C,P and N, were within 5 per cent of each other for the two Units and hence for all practical purposes, the loads on Unit B and C can be assumed to have been equal. The variability in the weekly averages was of the order of 20 per cent about the overall averages. There were no distinct seasonal trends (See Tables DB2 and DC2 in Annexure D). The relation of loads of COD to NH_4-N to Total P was 64,2:2,4:1,0 for Unit B and 69,8:2,5:1,0 for Unit C, i.e. a with sewage a relatively low nitrogen to COD and P content. The relatively low nitrogen can be attributed to the industrial component of the sewage, where this works serves industries which produce high COD and high phosphate waste-waters. The phosphate load was predominantly (72 per cent) in the ortho form, also a sign of a significant industrial contribution.

6.2.2 Primary settlers

The feed to the primary settlers (Dortmund tanks) comprised a mixture of raw sewage and recycled sludge withdrawn continuously from the humus tanks. The only major difference between Unit B and C was that the sludge recycled from Unit C contained precipitated ferric salts ($FePO_4$ and $Fe(OH)_3$). As explained in Chapter 2, problems were experienced in obtaining a proper mass balance about the mixing point of raw sewage with the recycled sludge. Consequently, it was decided to use the concentrations and flows and thus the pollutant loads contained in the raw sewage to estimate the load on the primary settlers. This then shows the effectiveness of the primary settlers in reducing the raw sewage loads on the remainder of the plant.

Table 6.3 list the overall average concentrations of COD, Total P, Orhto P and total and dissolved Fe in the effluent from the primary settlers from Unit B and C for the study period. The recycling of iron-rich sludge had a significant effect on the removal of various pollutants, based on overall average concentrations, e.g. better COD removal (45 as against 35 per cent) and improved total phosphate removal (25 as against 9 per cent). However, the iron content of the primary settling tank effluent from Unit C was higher than that from Unit B, due to the recycling of iron-rich humus tank sludge.

The results for pollutant load reduction in the primary settling tanks, calculated as described above, are given in Table 6.4. As expected they showed a similar trend to the concentrations given in Table 6.3.

6.2.3 Biological filters

The feed to the biological filters comprised a mixture of the effluent from the primary settlers and recycled humus tank effluent. There were significant differences between Unit B (control) and Unit C (ferric chloride dosed). In Unit C the recycled humus tank effluent had been depleted of its phosphate and the primary settler effluent was also lower in phosphate as a result of some removal in the primary settlers due to humus/chemical sludge recycled upstream of the settlers.

Table 6.5 lists the overall average concentrations of the main parameters in the influent to and effluent from the biological filters for both Units B and C for the total study period. Table 6.6 gives the loads in and out of the biological filters. As with the evaluation for the primary settlers, the concentration and load data reflected more or less identical pollutant removal trends.

COD removal in both units was nearly identical (63 per cent), but the removal in Unit C was to a lower level, i.e. 101 mg/l in effluent from Unit C as against 123 mg/l in Unit B. There was significant phosphate removal in Unit C, of the order of 10-12 per cent, whereas there was no significant phosphate removal in Unit B. This removal is ascribed to the residual iron (both dissolved and suspended) recycled with the humus tank effluent (see Table 6.5). The alkalinity of the biological filter influent was significantly reduced (about 30 per cent) due to nitrification in both Units B and C. The implication of this for Unit C is more serious because the addition of acidic ferric chloride to an effluent already low in alkalinity may depress its pH to an undesireably low level. The ammonia content in both the effluents from Units B and C was low, of the order of 4,0 mg/l, indicating excellent nitrification - i.e. reduction from about 29,0 mg/l in the raw sewage. The use of ferric chloride does not appear to effect the nitrification process in any significant way. The nitrate levels are low in both units, i.e. of the order of 4,0 mg/l, where one would expect about 15,0 mg/l. This indicated that denitrification has taken place, probably in the biological filters. Again the use of $FeCl_3$ did not appear to affect the denitrification process in any significant manner.

6.2.4 Chemical phosphate removal and secondary clarification

In the case of Unit C, ferric chloride was dosed into the influent stream to the humus tank at CP_6 whereas Unit B (control) was operated in the conventional mode.

Table 6.7 indicates the effect of ferric chloride on the overall average effluent total Phosphate concentration (2,0 mg/l as against 9,6 mg/l) and ortho-phosphate concentration (1,2mg/l as against 8,8 mg/l), both of which were significantly reduced in Unit C. For the operational conditions chosen during the experimental run, the effluent dissolved ortho-phosphate concentration did in fact not meet the regulatory standard of less than 1,0 mg/l (as P). This is discussed in detail in Chapter 4. The application of ferric chloride resulted in a significant increase in the chloride concentration in the final effluent (171 mg/l in Unit C as against 124 mg/l in Unit B), as well as depressing the alkalinity to lower levels (111 mg/l as against 146 mg/l (as $CaCO_3$)). Furthermore, the iron content in the final effluent was slightly higher (2,0 mg/l in Unit C as against 0,7 mg/l as Total-Fe in Unit B). Advantages of the ferric chloride phosphate removal technique, are the lower effluent COD (51 mg/l as against 61 mg/l), and apparently lower suspended solids (although these were not monitored regularly due to difficulties with this analytical method).

The overall quality improvement brought about by the biological filtration sewage purification process as a whole, with and without ferric chloride phosphate precipitation, is indicated by the overall average load reductions over Units B and C for the total study period, i.e. June 1985 - March 1987. These are listed in Table 6.8. The conventional works (Unit B) removes about 10 tonnes/d of COD from the raw sewage (93% efficient), 40 kg P/d total-phosphate (25% efficient) and 7 kg ortho-phosphate phosphorus (6 per cent efficient) and 306 kg ammonia and nitrate nitrogen /d (79 per cent efficient). Introduction of the ferric chloride phosphate removal process improved the total phosphate removal to 121 kg P/d (79 per cent efficient). The COD and nitrogen removal were not significantly altered, although slightly improved COD removal was evident.

In the case of the Vlakplaats Water Pollution control Works as a whole, application of the chemical phosphate removal technique will result in a significant reduction of the dissolved ortho-phosphate load on the water environment, i.e. instead of 324 kg P/d only 54 kg P/d will be discharged. Strict compliance with the effluent standard (< 1,0 mg/l PO_4-P) will reduce this load to about 45 kg P/d.

CHAPTER 7

FINANCIAL ASPECTS

7.1 INTRODUCTION

The experimental study on the impact and implications of chemical phosphate removal in a biological filter sewage purification works did not include an exhaustive study of associated financial aspects. Nonetheless, some cost figures have been collected and are presented in this chapter to give an indication of financial implication of chemical phosphate removal at the Vlakplaats Water Pollution Control Works.

7.2 CAPITAL COSTS

The Vlakplaats Works comprises three parallel units, i.e. Unit A completed during 1969 at a total cost of R500 000, Unit B completed during 1975 at a cost of R1 500 000 and Unit C completed during 1982 at a cost of R4 500 000. A detailed description of the various units is given in Chapter 1. Units A and B are essentially identical, whereas Unit C is different in that the secondary settlers are scraped-bottom clarifiers with an linear upflow rate of 1 m/h as against the Dortmund tanks with upflow rates of 2 m/h used in Units A and B. In addition indirect warm water heating of the digesters are used in Unit C, rather than direct steam heating as used in Units A and B. Furthermore, Unit C was designed for chemical phosphate removal and included the necessary equipment required for this. The capital cost associated with this equipment is set out in Table 7.1. (in Jan. 1987 Rands).

The capital cost of the chemical dosing system will depend on the choice of dosing system decided on. The research reported in Chapter 4 on process optimization, indicated that dosage proportional to flow and dosage adjustment related to historic data on phosphate concentrations in the biological filter effluent is desirable. This can be achieved in many ways, one being by way of the equipment used at the Vlakplaats Works. An alternative approach may be to buy a custom built dosing system to achieve this objective; one such system is currently (1986) being manufactured and sold in South Africa at about R90 000.

7.3 RUNNING COSTS

The running cost associated with chemical phosphate removal include cost items such as chemicals, electricity, maintenance and staff.

7.3.1 Chemical Costs

A large variety of chemicals are available in South Africa for chemical phosphate removal, including ferric chloride, ferric sulphate, ferrous sulphate, aluminium sulphate and poly-aluminium chloride. Laboratory and full scale tests indicated that ferric chloride gave the most cost-effective results at the Vlakplaats Works. The price of ferric chloride as delivered at the Vlakplaats Works was R220/tonne of 43 percent solution (1986/7). The price of ferric chloride has increased on average about 13 percent per annum over the last seven years (see Figure 7.1).

In order to control solids carry-over from the secondary clarifier it was necessary to use poly-electrolyte. Again there are numerous potentially suitable poly-electrolytes available in South Africa. Three types were used during the experimental investigation, Magnafloc LT 27 and Superfloc A130 (both powders) and Anikem 540 (a liquid). The price of Superfloc A130 as delivered at the Vlakplaats works was R7,00/kg (1986/87).

Based on the above chemical prices, the chemical cost per kilolitre for 1986/87 were as follows:

(a) $FeCl_3$: During 1986/87 an average 1 375,2 kg/day of 43% solution $FeCl_3$ would have been used to maintain the standard in an average raw sewage flow of 13,63 Ml/d. The purchase price of $FeCl_3$ per tonne of 43 percent solution was R220. Hence the $FeCl_3$ cost per kilolitre was

$$FeCl_3 \text{ cost} = \frac{1\ 375 \quad (\text{Kg/d})}{13,63\ (\text{Ml/d})} \times 10^{-3}\ \frac{(\text{Ml})}{(\text{kl})} \times \frac{22000}{1\ 000}\ \frac{(\text{C})}{(\text{kg})}$$

$$= 2,22 \text{ c/kl}$$

b) Poly-electrolyte : Druing 1986/87 poly-electrolyte was dosed at 0,2mg/l at a purchase price of R7,00/kg. Hence the poly-electrolyte cost per kilolitre was

$$\text{Poly-electrolyte cost} = 0{,}2\ \frac{(\text{mg})}{(\text{l})} \times 10^{-3}\ \frac{(\text{l})}{(\text{kl})} \times 700\ \frac{(\text{c})}{(\text{kg})} \times 10^{-6},\ \frac{(\text{kg})}{(\text{mg})}$$

$$= 0{,}14\ \text{c/kl}$$

(c) Total Chemical Cost = 2,22 + 0,14 = 2,36 c/kl.

It has been found that in general the alkalinity of raw sewage is sufficiently high not to result in significant pH depression (lower than 6,0) in the final effluent. Nonetheless, this effluent is undersaturated w.r.t. calcium carbonate as indicated by Langelier saturation indices of -0,5 to -1,5 and hence pH correction is necessary with lime to protect the concrete structures. No lime was dosed during the experimental programme, but assuming a maximum of 50 mg/l commercial lime is necessary to produce a water saturated w.r.t. calcium carbonate, at a lime purchase price of R160/tonne this would add 0,8 c/kl.

Total chemical cost will therefore be 3,16 c/kl.

7.3.2 <u>Electricity Costs</u>

The electrical power consumption by Units A, B and C on the Vlakplaats Works was measured individually. Typical figures are given in Table 7.2. During period 29/10/86 to 30/11/86 the number of digesters operated per unit were 3, 3 and 2 for Units A, B and C respectively, whereas during the period 1/12/86 - 1/2/87, 3, 2 and 2 digesters were operational. For this last period the electricity consumption per megalitre raw sewage influent per day was 76,3 69,8 and 64,2 kWh/Ml/d for Units A, B and C, respectively. The major differences between the various units was:

a) the use of a steam injection for heating of digesters on units A (3 digesters operational) and Unit B (2 digesters operational) as against hot water Unit B (2 digesters operational) as against hot water circulation in Unit C (2 digesters operational).
b) Units A and B have Dortmund settling tanks whereas Unit C has flat bottom clarifiers with mechanical sludge withdrawal.
c) chemicals are added to Unit C resulting in increased humus and combined raw/humus sludge masses.
d) age of equipment and probably fall-off of efficiency : Unit A (1959), Unit B (1975) and Unit C (1982).

7.3.3 Staff Costs

For the purposes of the research and development programme and the additional workload to cope with extensively increased plant monitoring and specialised experiments, it was necessary to appoint one additional chemical analyst. No additional operational staff were required above the normal staff complement of one superintendent, an operator and 49 staff (tractor drivers, workshop assistants, shiftmen and manual labourers). It can therefore be said that although chemical phosphate removal does require additional attention and work from plant staff of a conventional biological works, this can be dealt with quite adequately with existing staff.

7.4 TOTAL COST - VLAKPLAATS WORKS

In order to place chemical phosphate removal costs in context, total plant costs are briefly delineated.

Table 7.3 lists the various expenditures incurred for the Vlakplaats Works during the 1986/87 financial year. The average volume of raw sewage treated over this period was 43,13 Ml/d. Chemical phosphate removal was only practiced on Units A and C during this experimental period with Unit B being used as a control, i.e. 28,65 Ml/d was chemically treated. Using this information the following unit costs were calculated:

- Total cost for sewage purification (treatment + interest & redemption) 16,67 c/kl

- Total treatment cost for sewage purification (excludes interest & redemption) 10,46 c/kl

- Chemical phosphate removal costs (marginal cost associated with chemical treatment only)* 3,16 c/kl

* Lime costs are included here once it was demonstrated that lime dosage is essential to stabilize the aggressive effluent produced when dozing $FeCl_3$.

7.5 DISCUSSION

The introduction of chemical phosphate removal on an existing or new biological filtration sewage purification works has a significant effect on the cost of treatment, i.e. of the order of 30 per cent increase was found for the Vlakplaats Works. This increase costs is predominantly associated with the cost of chemicals. The capital outlay for chemical dosing equipment, as well as the impact on sludge handling, treatment and disposal facilities at Vlakplaats, was minimal. From the above it is clear that in order to minimize increased costs associated with chemical phosphate removal, chemical usage must be minimized. The research undertaken at the works has indicated ways and means to optimize chemical usage; the most important being the selection and vigilant operation of a suitable chemical dosing strategy.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

a) The project for the evaluation and optimisation of full-scale chemical phosphate removal in biological filtration sewage purification processes began on January 1985 and ended in March 1987. During this period the performance of the Vlakplaats Water Pollution Control Works was intensively monitored, not only from a chemical phosphate removal point of view, but also with regard to general process considerations and relative performance of individual units such as primary settlers and anaerobic digesters, biological filters and humus tanks, as well as the role played by various recycles within the process. This has led to a greater understanding of the overall functioning of biological filtration process both with and without chemical dosing for phosphate removal.

b) Introduction of chemical phosphate removal to the biological filtration sewage purification process at Boksburg resulted in significantly improved phosphate removal, i.e. from 25 to 79 per cent total phosphate removal. In terms of ortho-phosphate load on the environment, the conventional unit discharged 324Kg P/d, whereas the chemically treated unit only discharged 54Kg PO_4-P/d/PO_4. The removal of organic and nitrigenous matter remained essentially unchanged. However, chemical treatment resulted in an increased chloride content and decreased alkalinity of the treated water, as well as slightly higher iron concentrations.

c) Introduction of chemical phosphate removal at the Vlakplaats works, to comply with the effluent phosphate standard, resulted in an increase of about 30 per cent in the total treatment cost. In order to minimize these costs it is essential to optimize chemical addition by means of an appropriate dosing strategy.

d) When the project was first conceived it was intended that a major aspect would be the testing of the sensitivity of chemical usage efficiency to design and operational parameters such as initial mixing intensity at the dosing point, flocculation time between dosing and settling, variation in recycle rates and concentration of the chemical being dosed. In practice however, it was found that the large hourly, daily, weekly and seasonal variations in the flows and composition of the incoming sewage was the dominating influence on the chemical usage efficiency and the scatter in the data caused by these variations completely masked the more marginal effects caused by trying to fine-tune design and operational parameters on the plant. Therefore this aspect of the project was inconclusive in itself, but it did highlight the fact that simplistic dosing strategies are unlikely lead to optimised chemical usage efficiency on full-scale plants.

e) On-line continuous phosphate monitoring for phosphate was found to be labour intensive requiring staff qualified in operating and maintaining suitable equipment. Analysis of daily composite samples was found adequate for controlling chemical dosage.

f) Three chemical dosage strategies were evaluated, viz. dosing proportional to flow with (i) a constant ratio for dosage rate to unit flow rate, (ii) an increased ratio for dosage rate to unit flow rate on Thursdays and Fridays, and (iii) dosage rate adjusted on a "day of the week four-weekly moving average for phosphate concentration" strategy. The latter was the most successful requiring only 2,0-2,5 times the stoichiometric $FeCl_3$: P amount of ferric chloride to be dosed, whereas the other strategies required 3,5 and 4,5 times stoichiometric dosages.

g) The 95 per cent compliance with the current effluent phosphate standard is considered too stringent and results in costly chemical overdosage and unnecessary increases in effluent total dissolved solids.

h) Because of the highly corrosive nature of the phosphate precipitant used, a 43 per cent $FeCl_3$ solution, all materials which come into contact with this solution must be corrosion resistant. Chemically dosed water may have a low alkalinity and may dissolve concrete on cement structures; the necessary precautions against this needs to be taken.

i) One of the major potential concerns of local authorities with regard to implementing phosphate removal has been that it will lead to a dramatic increase in sludge production which would cause disruption of sludge treatment facilities. For this reason monitoring of sludge production and quality parameters formed an integral part of this investigation. The findings of the investigation can be summarised as follows:

- The unit operated with $FeCl_3$ addition produced on average 11 per cent more raw sludge on a volumetric basis and 9 per cent more on a mass basis. These increases however, are considerably smaller (about 2 to 3 times) than the variability in the sludge production data, and hence in practical terms had no significant effect on sludge management at the Vlakplaats Works.

- The unit operated with $FeCl_3$ addition produced 63 per cent more sludge in the humus tanks than the control unit. This additional mass of sludge resulted from the precipitation of approximately equal portions of ferric phosphate and hydroxide as a result of ferric chloride addition to this unit.

- The raw sludge withdrawn from the primary settlers of the chemically treated unit contained slightly lower dissolved phosphate and slightly higher iron concentrations than that from the control unit. Digested sludge from the chemically dosed unit contained significantly less phosphate than the control unit, probably as a result of further dissolved orthophosphate precipitation in the digesters in the presence of iron salts.

- The drying characteristics of the sludges were not studied in depth, but in general no marked differences were observed in terms of sludge drying or handling.

- The only major consequence of chemical dosing on a biological filtration sewage purification plant is the significant increase in the mass of humus sludge generated. Provision has to be made for continuous sludge withdrawal from the humus tanks to ensure that solids carry-over does not occur. The increase in humus sludge mass has a negligible effect on the total sludge production on the plant.

j) The overall differences in performance between the control and the chemically dosed unit were as follows:

- Some phosphate removal occurs in the biological filter unit even in the absence of chemical addition.

- The diurnal variations in phosphate concentrations in the influent raw sewage is to a large degree smoothed out by the time the flow has passed through the biological filters.

- Chemically induced phosphate removal does not only occur at the dosing point, but in the primary settlers and biological filters as well. A main contributor to the removal in the primary settlers appears to be the mixing of the iron-rich humus sludge with the raw sewage before it enters the primary settlers. It is therefore recommended that the humus sludge be drawn-off from the humus tanks and recycled to this point on a continuous basis in order to optimise chemical usage in this way.

- The performance of the plant in general is enhanced by chemical phosphate removal. Organic matter removal is somewhat improved in the primary settlers as well as in the biological filters. Nitrification and denitrification do not appear to be significantly affected.

- A major problem which emerged during the project is the corrosion of concrete due to the chemically induced loss of alkalinity in the effluent. This can be overcome by either conditioning the water by the addition of lime or by protecting the concrete and using salt glazed clay pipes and biological filter tiles.

k) By judicious operation secondary clarifiers can be operated to meet the effluent phosphate standard at hydraulic loads 1,6 times in excess of design loads. To achieve this, humus/chemical sludge withdrawal rates have to be signifgicantly increased over normal operation. To consistanly meet the effluent standard at this higher hydrualic loading rate, polo-electrolyte has to be dosed at about twice the normal dosage (0,1 mg/l).

l) It was found beneficial to recirculate iron-rich humus sludge to a point upstream of the primary settlers on a continuous basis in order to optimize chemical usage. This resulted in an additional 2 to 3 mg/l (as P) phosphate removal.

m) Care was taken during the course of the project to ensure that the data collected was representative of the sewage quality at the various monitoring points in the plant. To this end daily flow balance calculations were done and periodic mass balance calculations at mixing points were undertaken. Data which did not display reasonable mass balances was discarded. Mass balances for two mixing points on the plant for chloride, a conservative parameter, demonstrated that flow rates and chemical analyses were accurate to better than 5 per cent. However, for streams containing particulate matter, the mass balances were relatively poor, i.e. imbalances of 10 per cent and higher were measured, making optimization based on such parameters (e.g. suspended solids, and suspended organic and phosphorous matter), not possible.

n) The suitability and effectiveness of various items of mechanical plant were monitored during the project. The most revealing aspect of this part of the project was the unreliability of flow meters. Data had to be discarded repeatedly because satisfactory flow balances could not be achieved. In general the back-up support received from vendors of flow metering equipment was unsatisfactory. The problem with ultrasonic flow meters was "hunting" as a result of water turbulence, wave action, scum and foam. It was overcome by the incorporation of a stilling box. It was also found necessary to install protective devices against electrical overload and lightning. Furthermore, it was necessary to install temperature compensators to make the necessary corrections as a result of diurnal and seasonal temperature fluctuations. After resolving commissionary problems, flow meter vondor back-up for meter repair was required, on average, at three to six monthly intervals.

o) Investigations of the standard SABS analytical techniques for dissolved ortho-phosphate, and total and dissolved iron showed that these techniques were suitable for analyses of these parameters in the various process streams of the Vlakplaats works. The SABS analytic technique for suspended solids, however, was demonstrated to be totally unsuitable for analysing low concentrations (< 20 mg/l) of suspended solids. Improved solids recovery was found possible by using Whatman GF/C or GF/D, or Rundfilter MN85/90, filter papers, although solids recoveries were still only of the order of 50 per cent when applied to the analysis for low suspended solids concentration (about 20 mg/l).

8.2 RECOMMENDATIONS

a) It is recommended that the authorities give consideration to a more overall effective phosphate control strategy, i.e. by replacing the current "fixed effluent" standard for phosphate by a "receiving water" standard. This could be achieved by setting monthly phosphate loads for each sewage works and allowing chemical dosage adjustment to meet this set load. This would ensure compliance with the receiving water standard, but with some flexibility in plant control to minimize chemical cost and the deliterious effects associated with chemical phosphate removal.

b) It is recommended that the SABS be requested to investigate a standard for open channel flow meters so that the reliability and performance of these vital pieces of equipment can be regulated and improved.

c) It is recommended that the SABS be requested to investigate a more suitable and accurate analytical technique for suspended solids at the low concentration specified by the General Standard for effluents.

CHAPTER 9

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ANNEXURE A

Figures

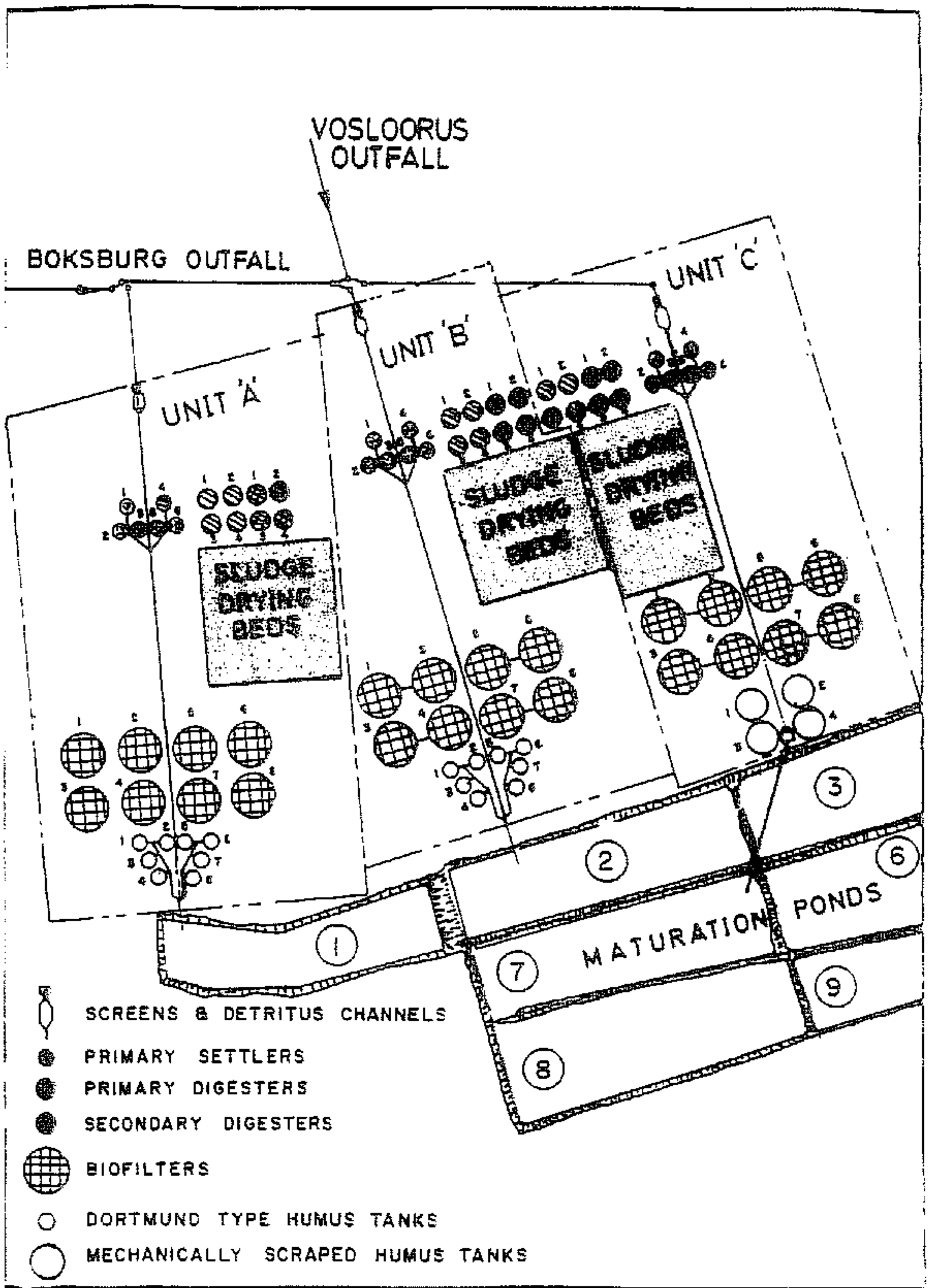


FIGURE 1.[illegible] : LAYOUT OF BOKSBURG'S VLAKPLAATS WORKS

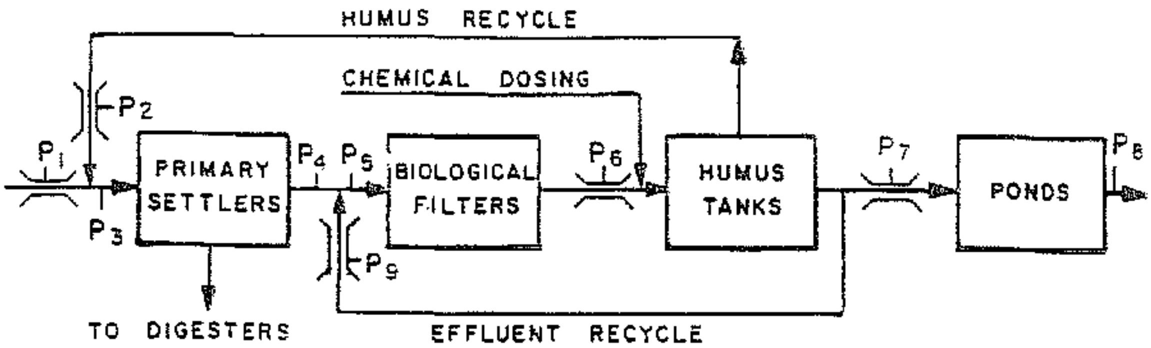


FIG. 1.2 : FLOW DIAGRAM FOR CHEMICAL DOSING SHOWING METERING AND SAMPLING POINTS

Table I : Analyses of Water Samples

Para-	P1		P2		P3		P4		P5		P6		P7		P8	
meters	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
Ph	D		D		D		D		D		D		D		W	
C.O.D.	D		D		D		D		D		D		D		W	
T.K.N.	M								M		M		M		M	
NH_3	W								W		W		W		W	
Total P	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Ortho P		D		D		D		D		D		D		D		D
Tot. Fe		D		D		D		D		D	D	D	D	D	D	D
Cl												W		W		W
Alk												W		W		W
SS													D		D	
T D S		W									W		W			
Conduc	W								W				W			
NO_2+NO_3												W		W		W
Ca Hard														M		M
Flows	D		D								D		D			
Flux			W		W						W					

D = Daily W = Weekly M = Monthly

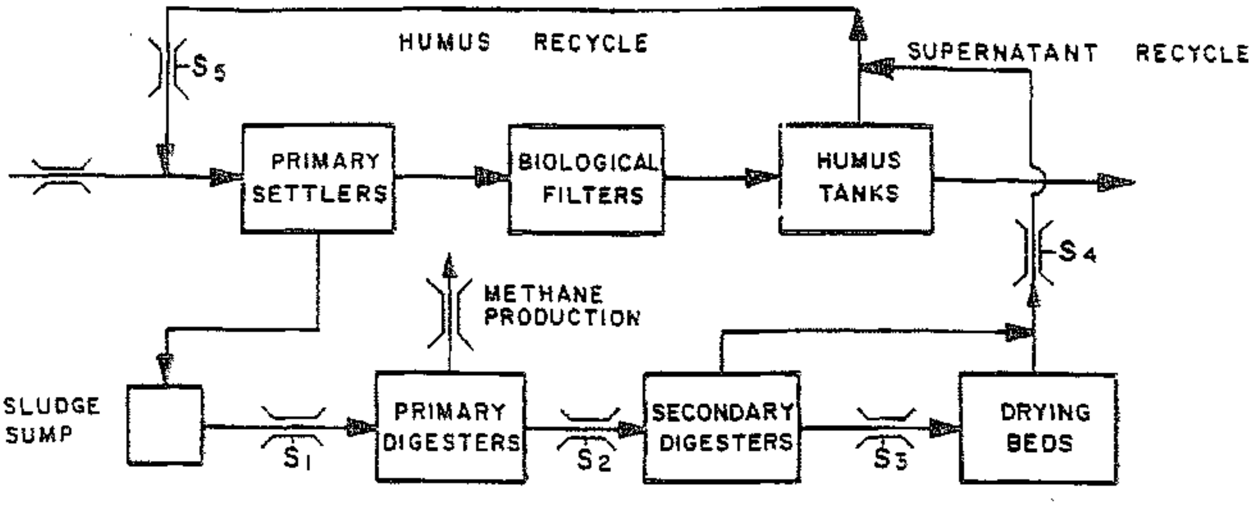
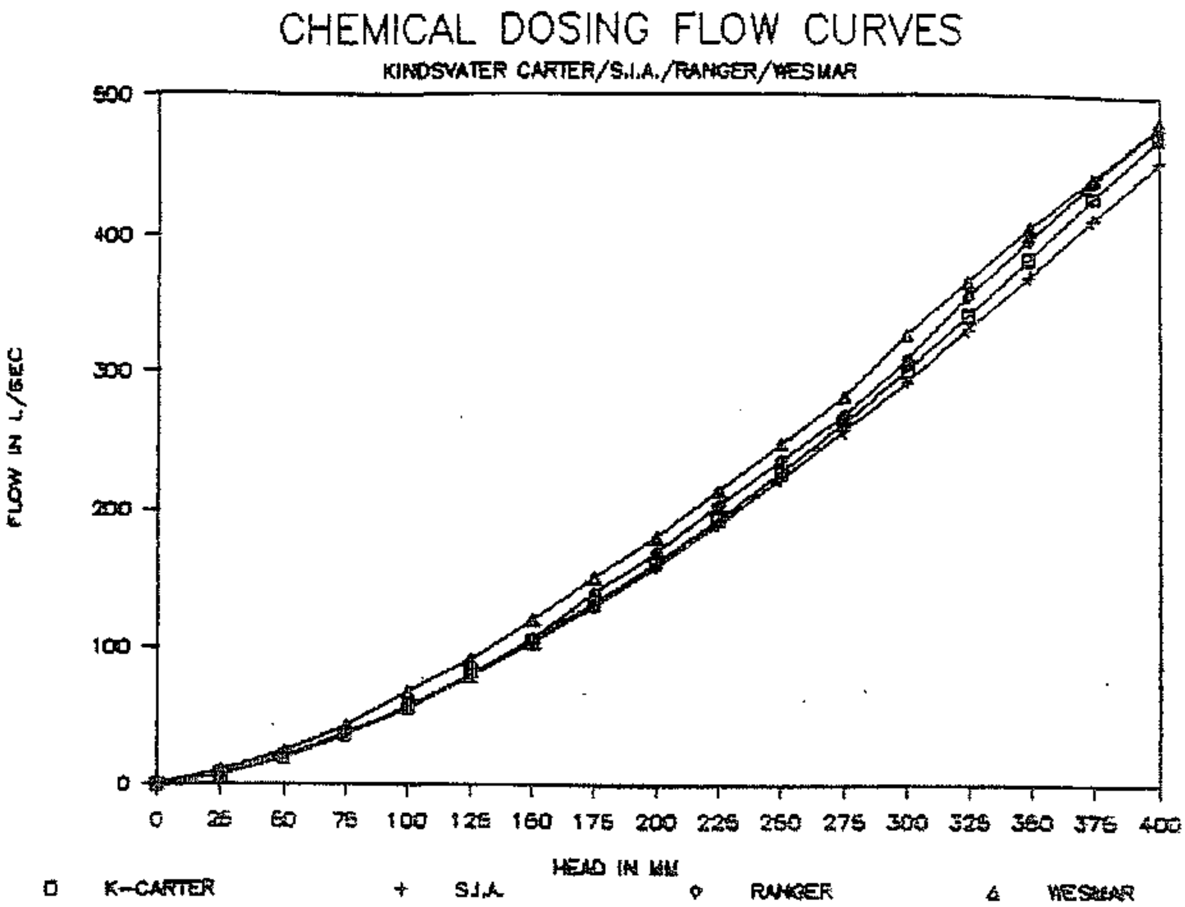


FIG. 1.3 : FLOW DIAGRAM FOR SLUDGE DISPOSAL SHOWING METERING AND SAMPLING POINTS

Table II : Analyses of Sludge Samples

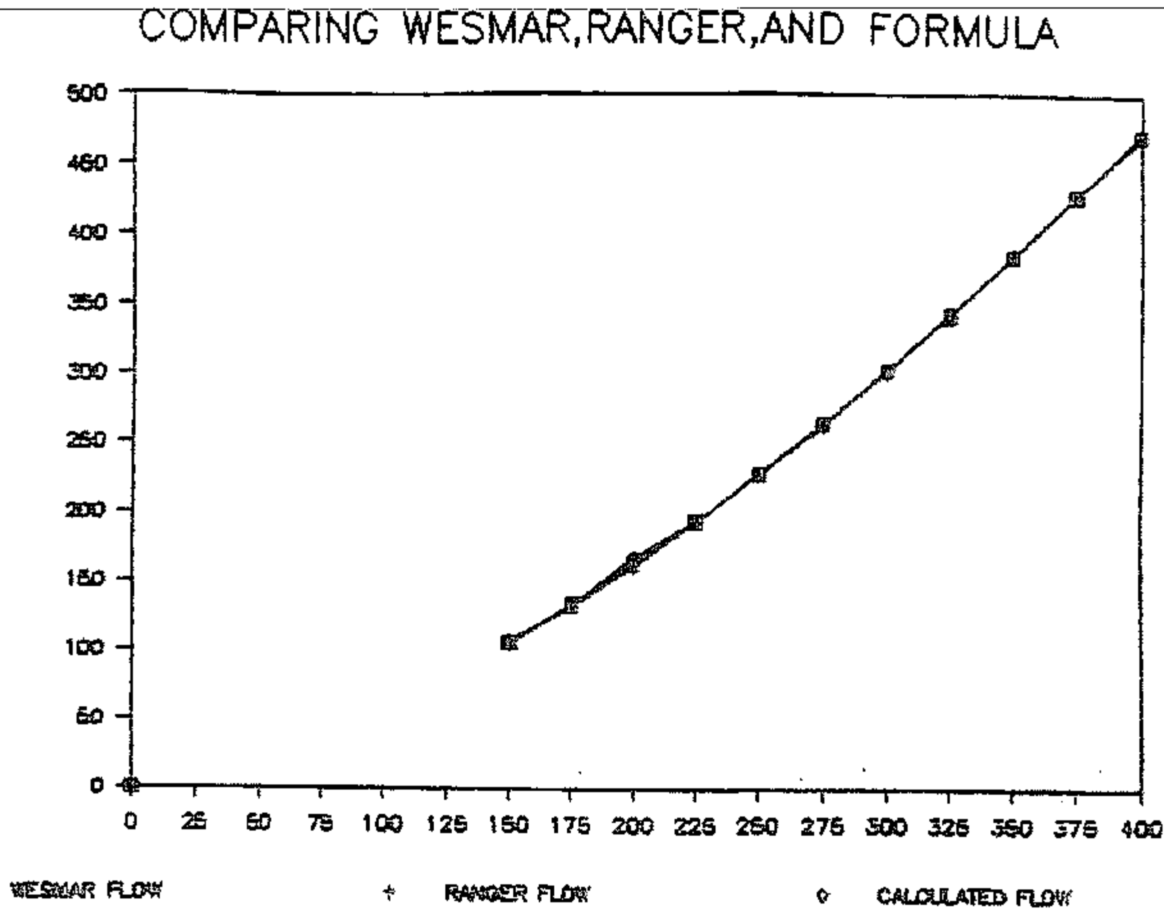
Parameters	S1	S2	S5	S3	S4
Volume	D	D	D	D	D
Total Solids	D	W	D	D	D
C O D	D	W	D	D	D
Total P	D	W	D	D	D
Soluble P	D	W	D	D	D
Volatile Acids	W	W		M	
Alkalinity	W	W		M	
pH	D	W	D		D
Fe	D	W	D	D	D

D = Daily W = Weekly M = Monthly



INSTRUMENT TYPES:	RANGER WESMAR DFM300
FORMULA TYPES:	KINDSVATER CARTER S.I.A.
WEIR WIDTH:	1000 mm
CHANNEL WIDTH:	1200 mm
NOTCH HEIGHT:	500 mm
MAX HEIGHT:	400 mm
MAX FLOW RATE:	480,6 l/sec

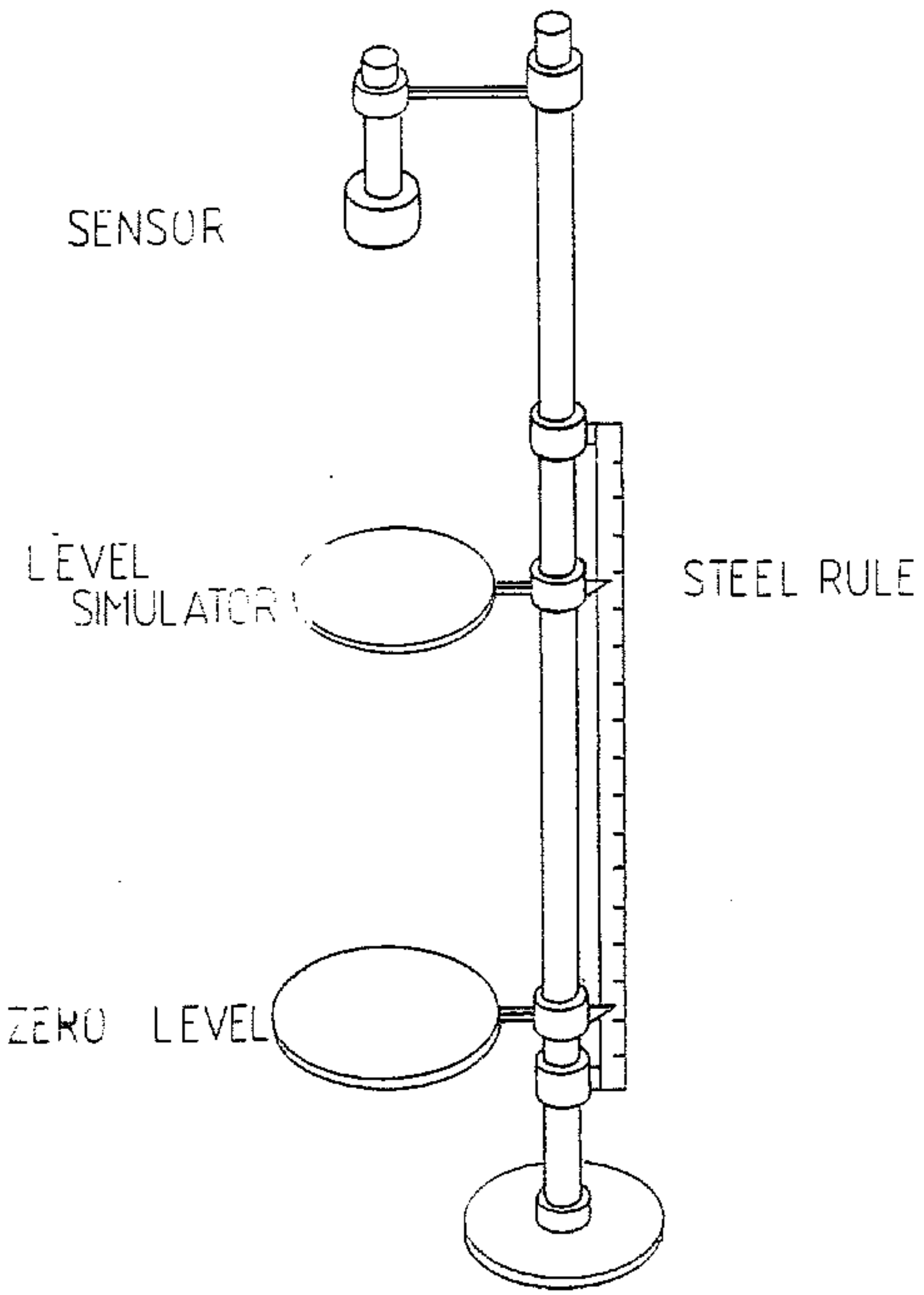
FIG. 3.1 : Comparison of measured flow meter curves with theoretical curves.



INSTRUMENT TYPES:	RANGER / WESMAR DFM300
WEIR WIDTH:	1000 mm
CHANNEL WIDTH:	1200 mm
NOTCH HEIGHT:	500 mm
MAX HEIGHT:	400 mm
MAX FLOW RATE:	480,6 l/sec

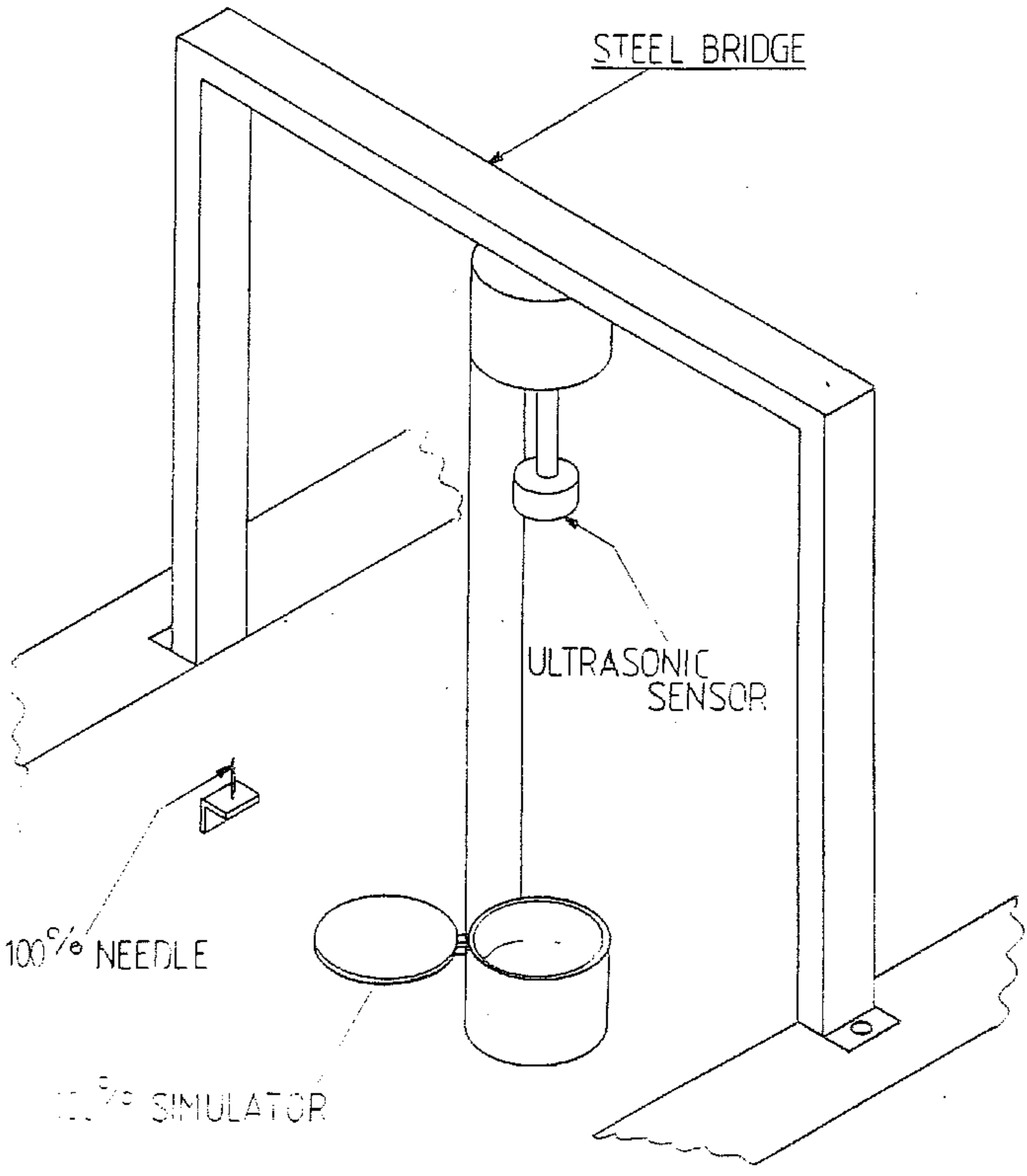
FIG. 3.2 : Comparison of measured flow meter curves after modification with the theoretical Kindswater Carter Curve.

FIGURE 3.3 : Flow Sensor Calibration Device

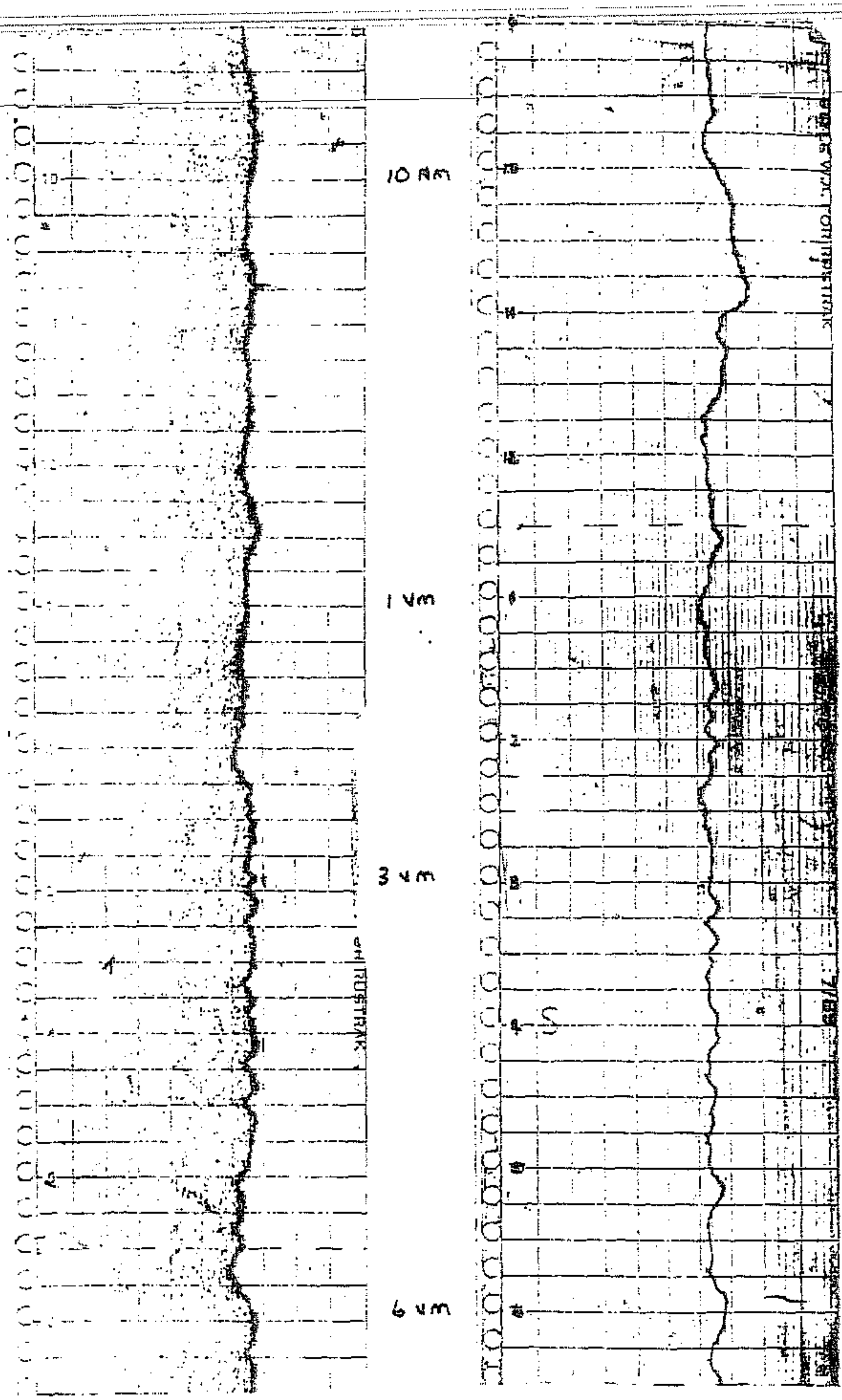


WATER POLLUTION CONTROL WORKS
WATER BESOEDELINGSBEHEER WERKE
BOKSBURG

FIG. 3.4 ULTRA SONIC TRANSDUCER MOUNTING INCORPORATING STILLING BASIN AND 100% FLOW SIMULATOR.



POLLUTION CONTROL WORKS BOKSBURG



HUNTING SATISFACTORY

FIG. 3.5 : Examples of continuous flow chart recordings demonstrating "hunting" and satisfactory operation

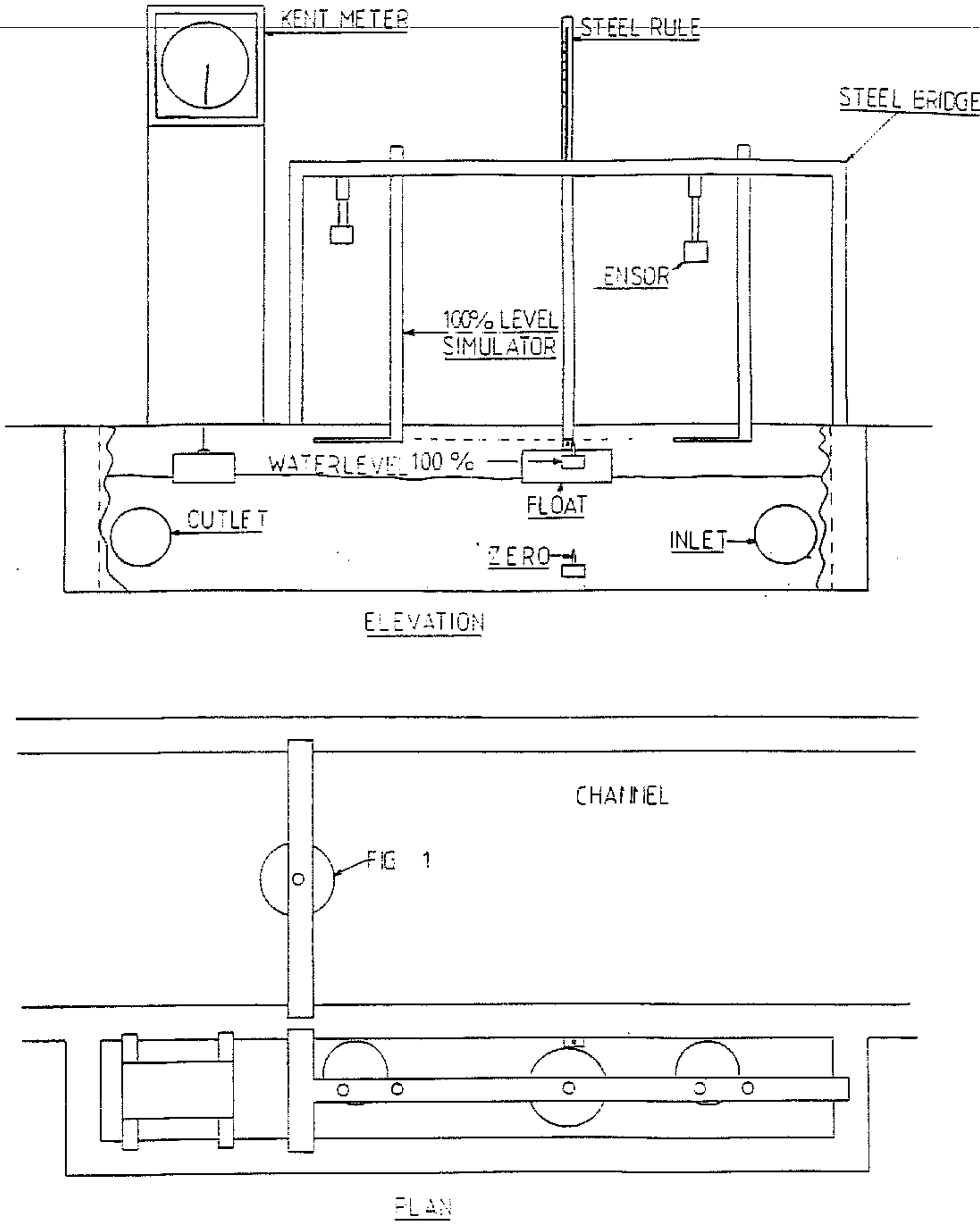


FIG. 3.6 : Elevation and Plan of the in situ test bed for comparison testing of flow meters.

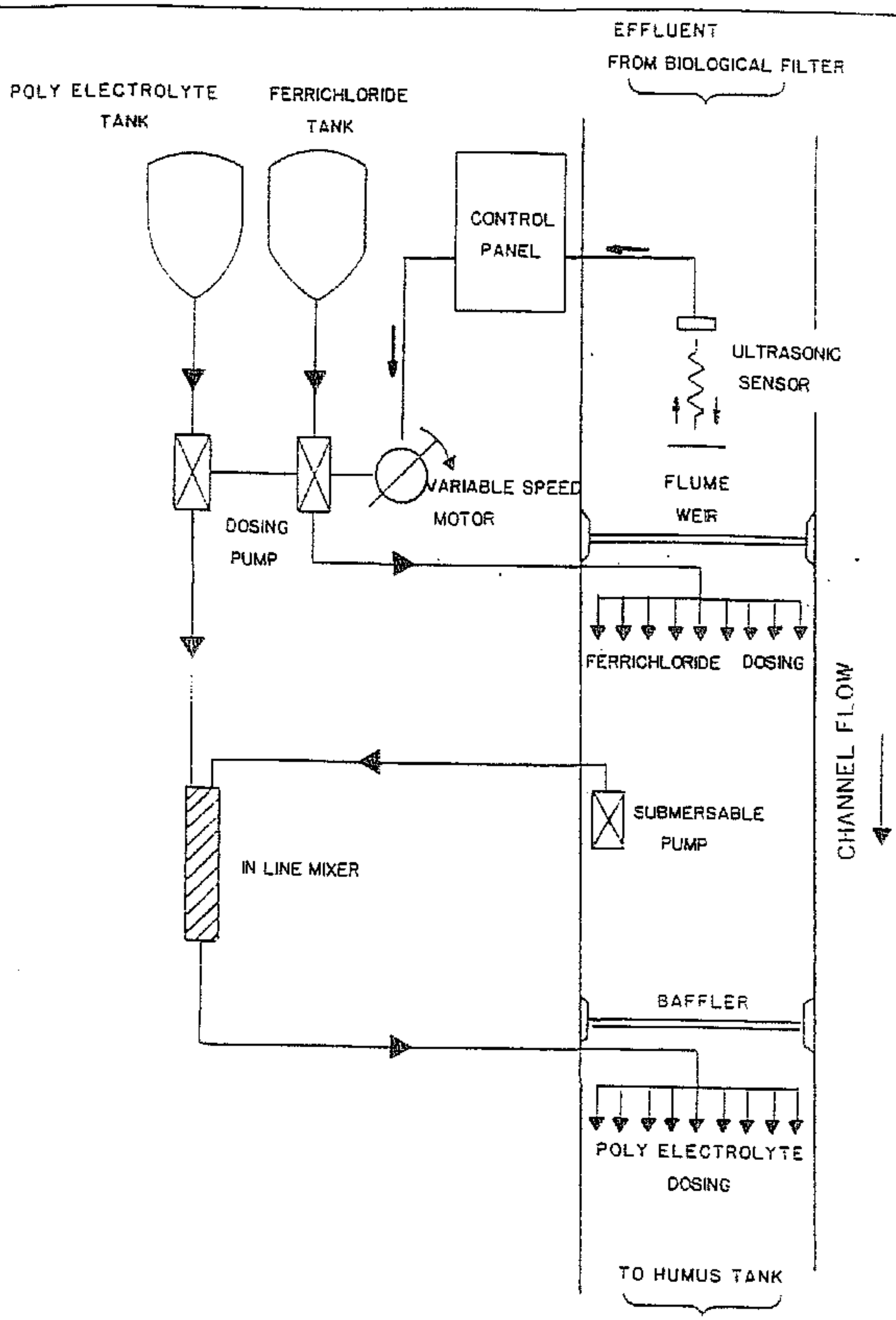


FIG. 3.7 : Diagram of the chemical dosing plant used at Vlakplaats.

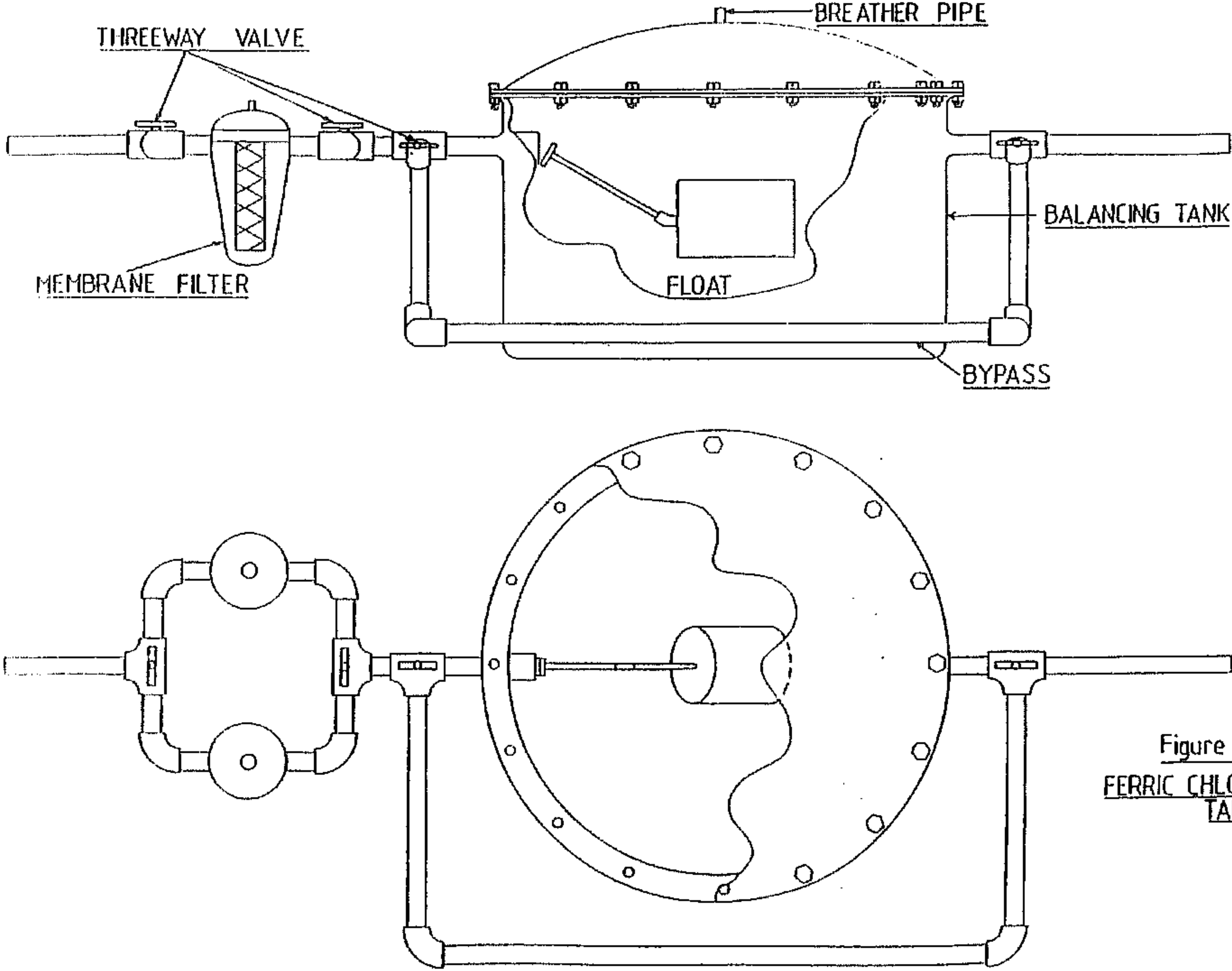


Figure 3.8

FERRIC CHLORIDE BALANCING TANK

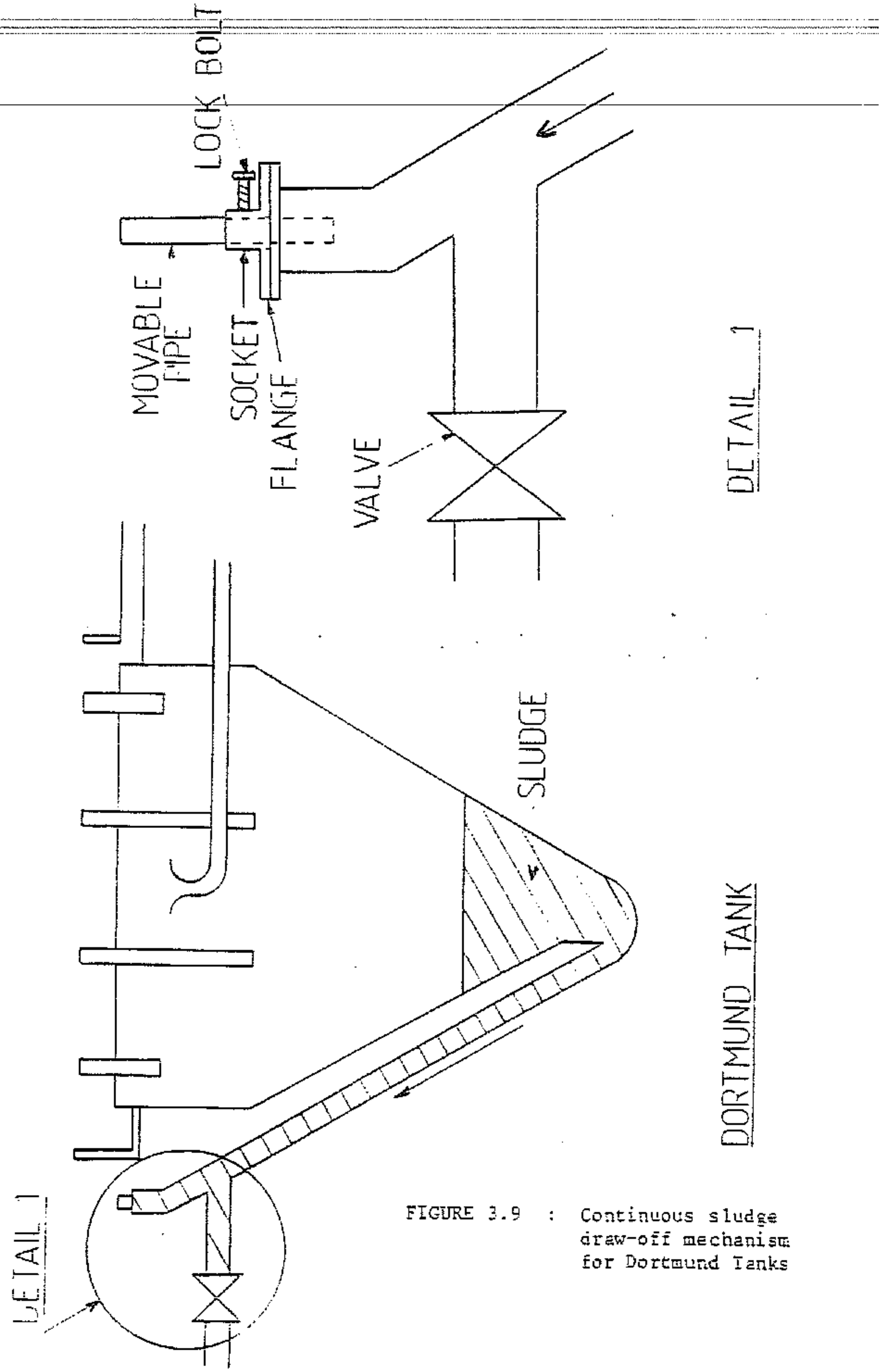


FIGURE 3.9 : Continuous sludge draw-off mechanism for Dortmund Tanks

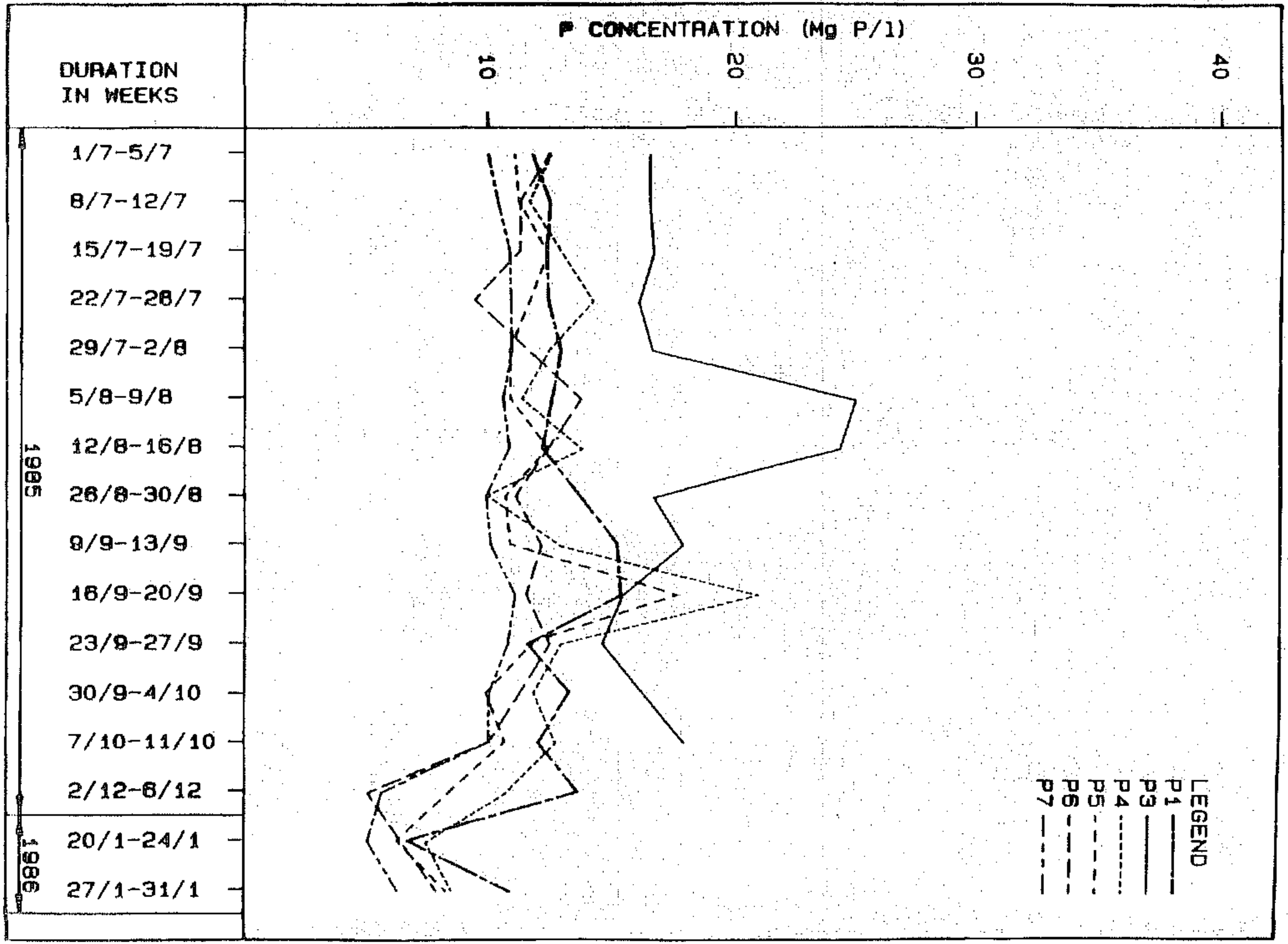
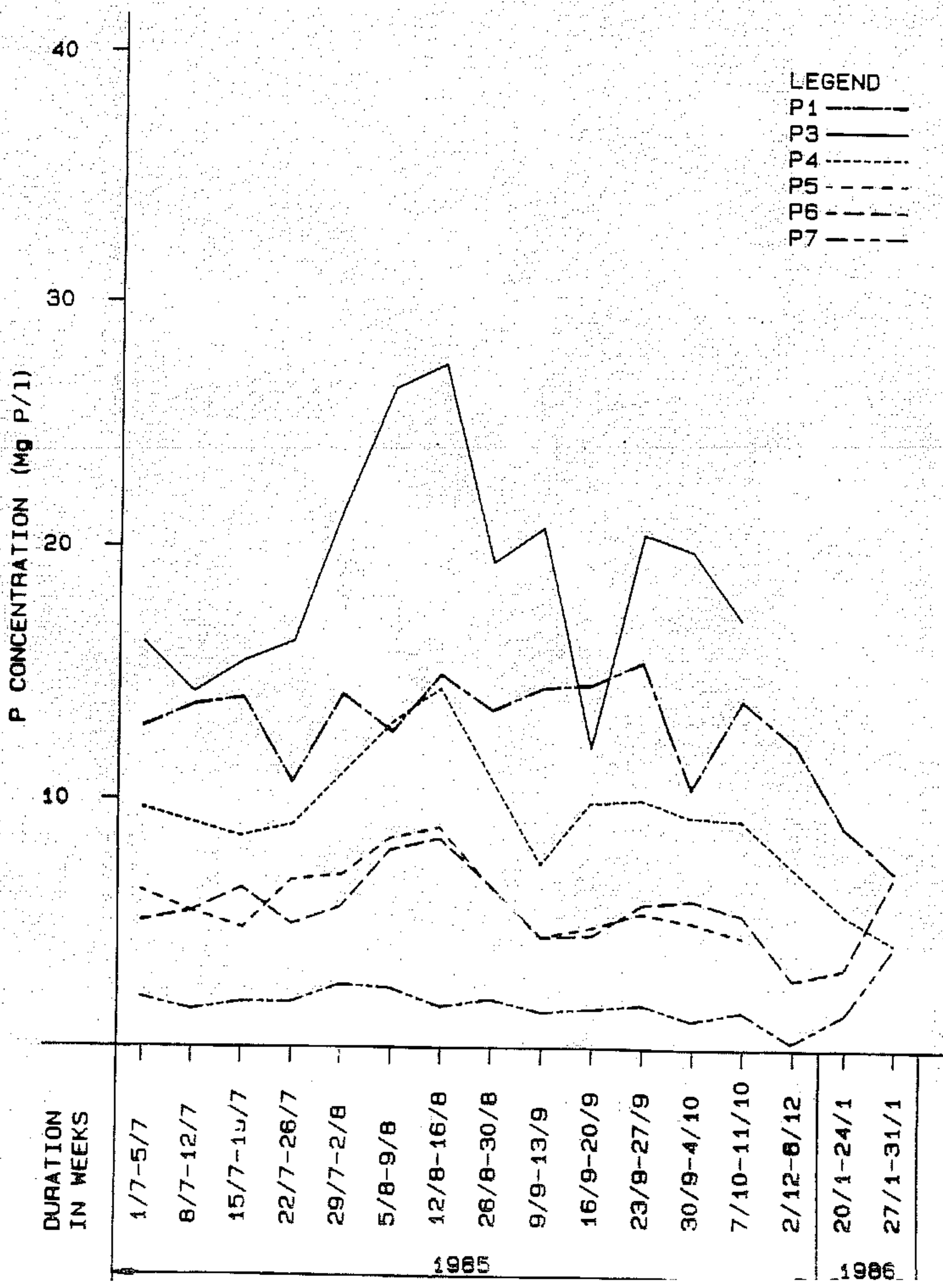


FIGURE 4.1 : Average Weekly Total Phosphate Concentration on Unit B

FIG. 4.2 : Average Weekly Total Phosphate Concentration on Unit C.



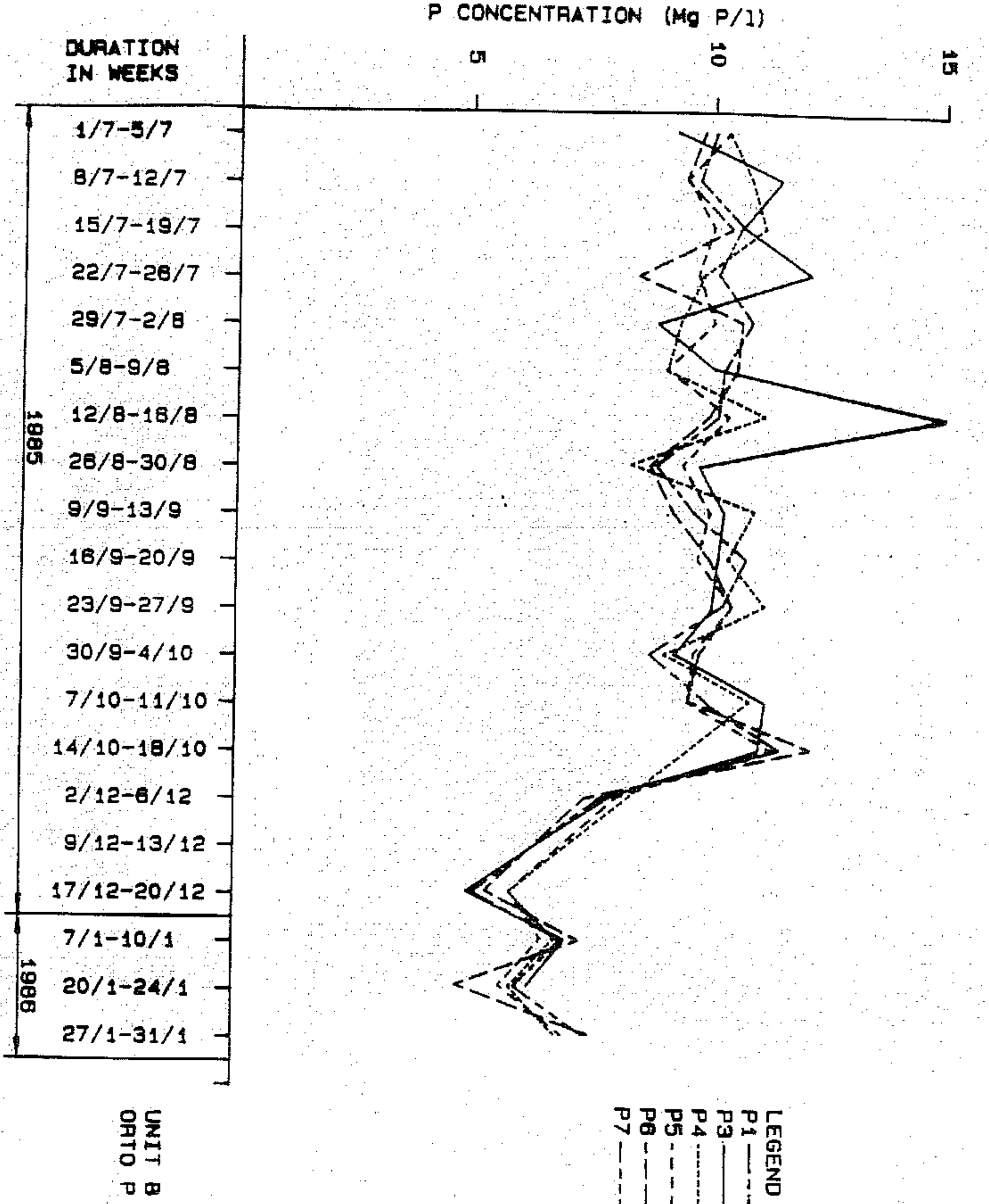


FIG. 4.3 : Average weekly Ortho-Phosphate Concentration on Unit B

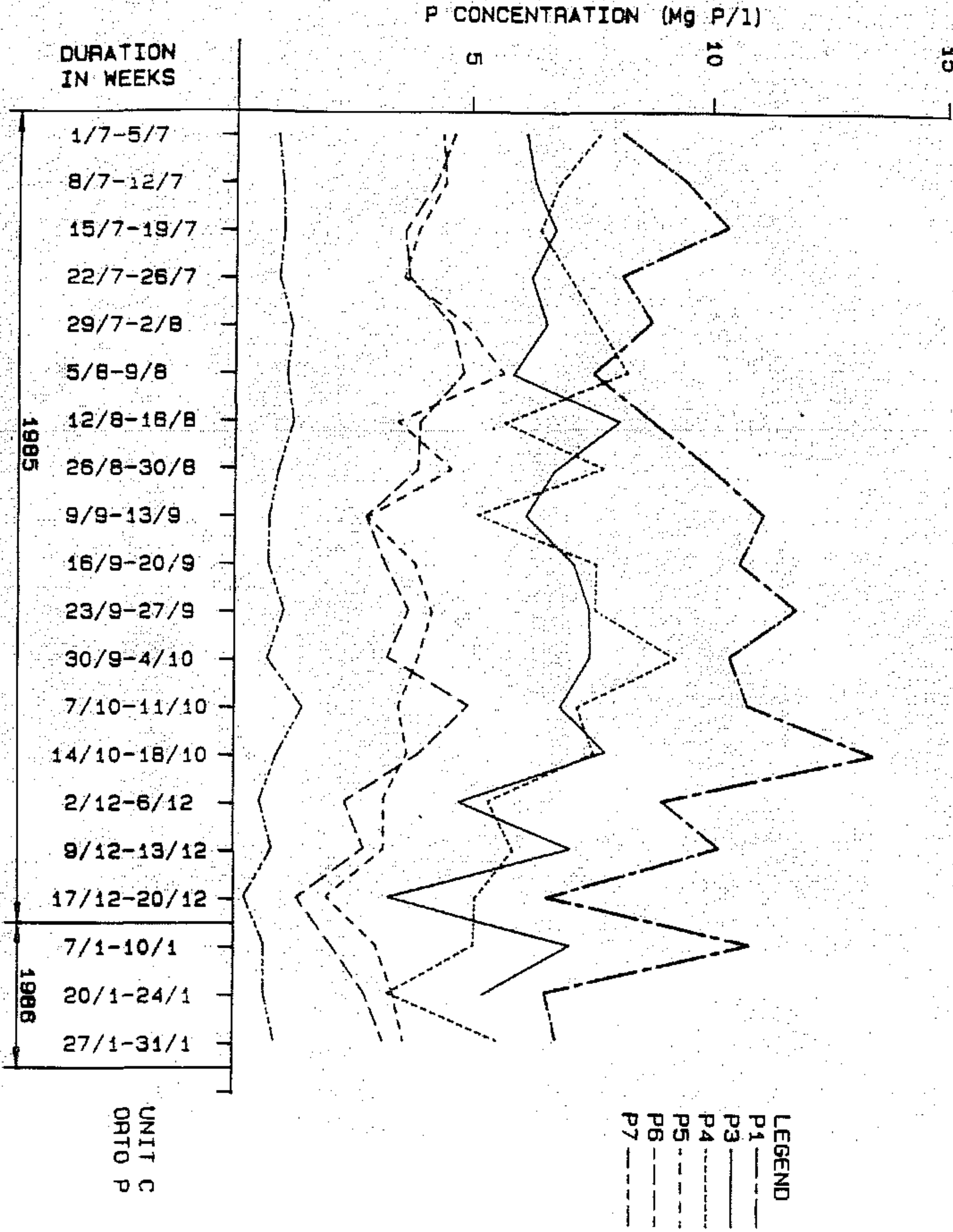


FIG. 4.4 : Average weekly Ortho-Phosphate Concentration on Unit C

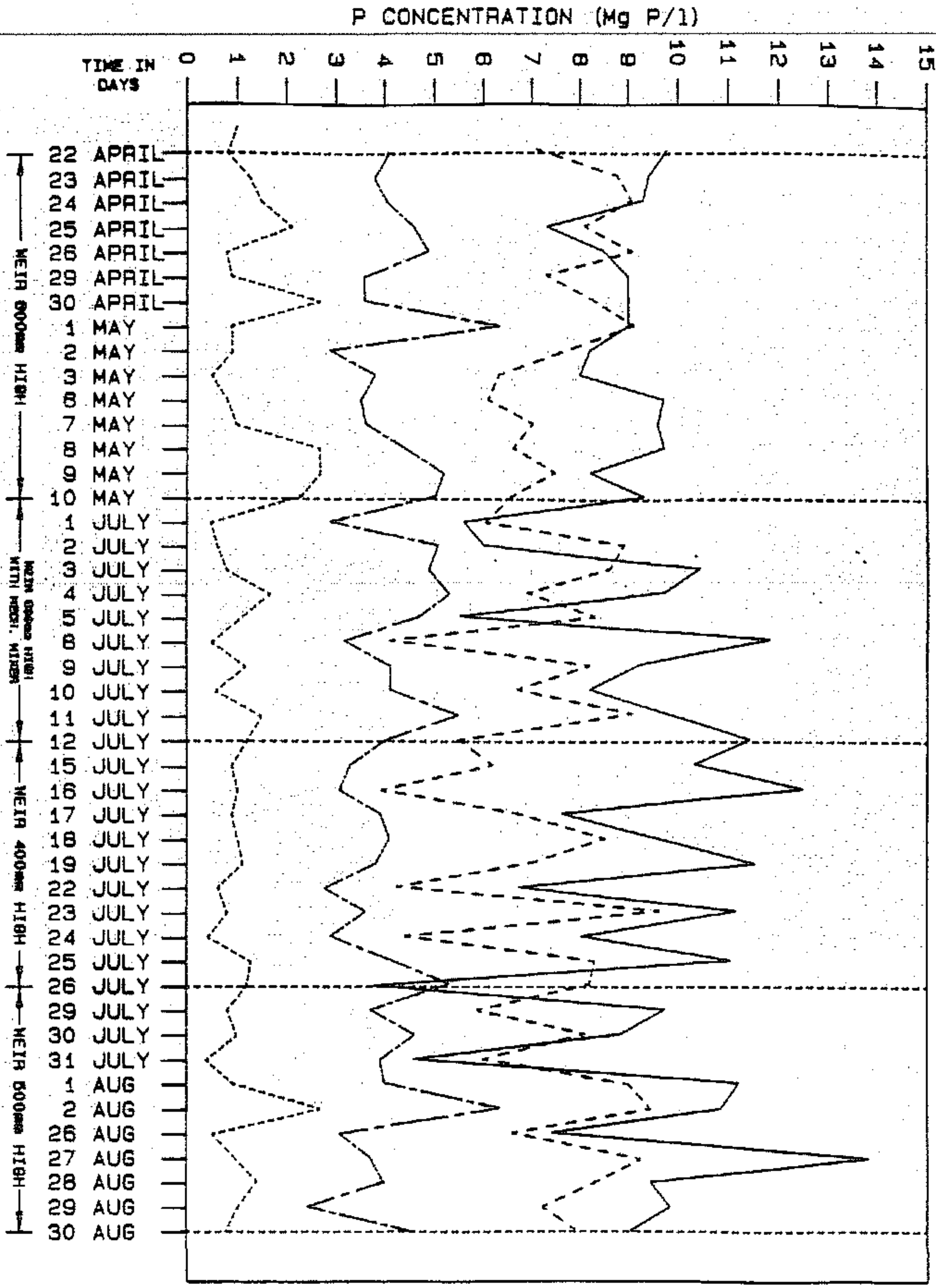


FIG. 4.5 : Daily Ortho-Phosphate Concentrations for different mixing intensities at Point CP6

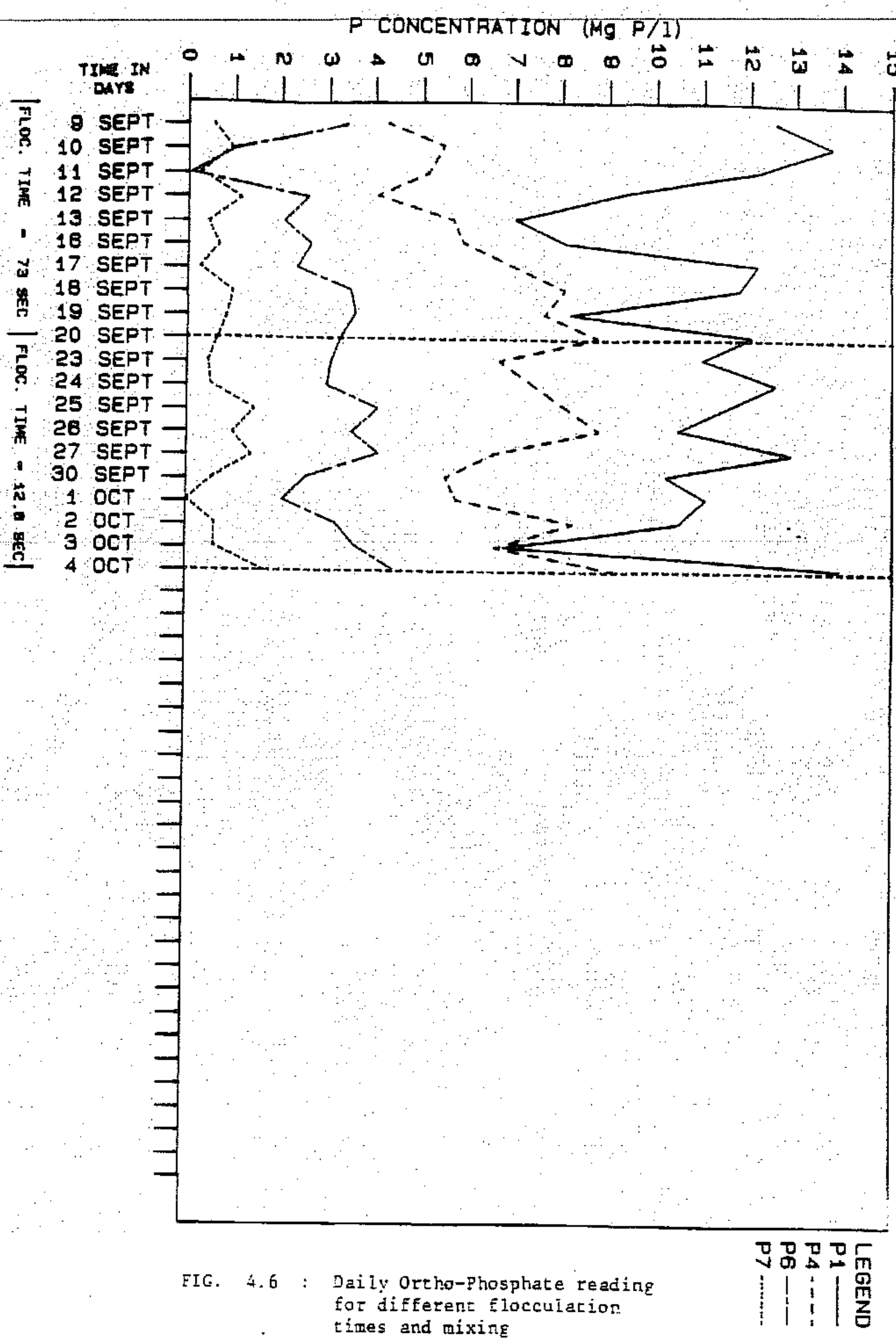


FIG. 4.6 : Daily Ortho-Phosphate reading for different flocculation times and mixing

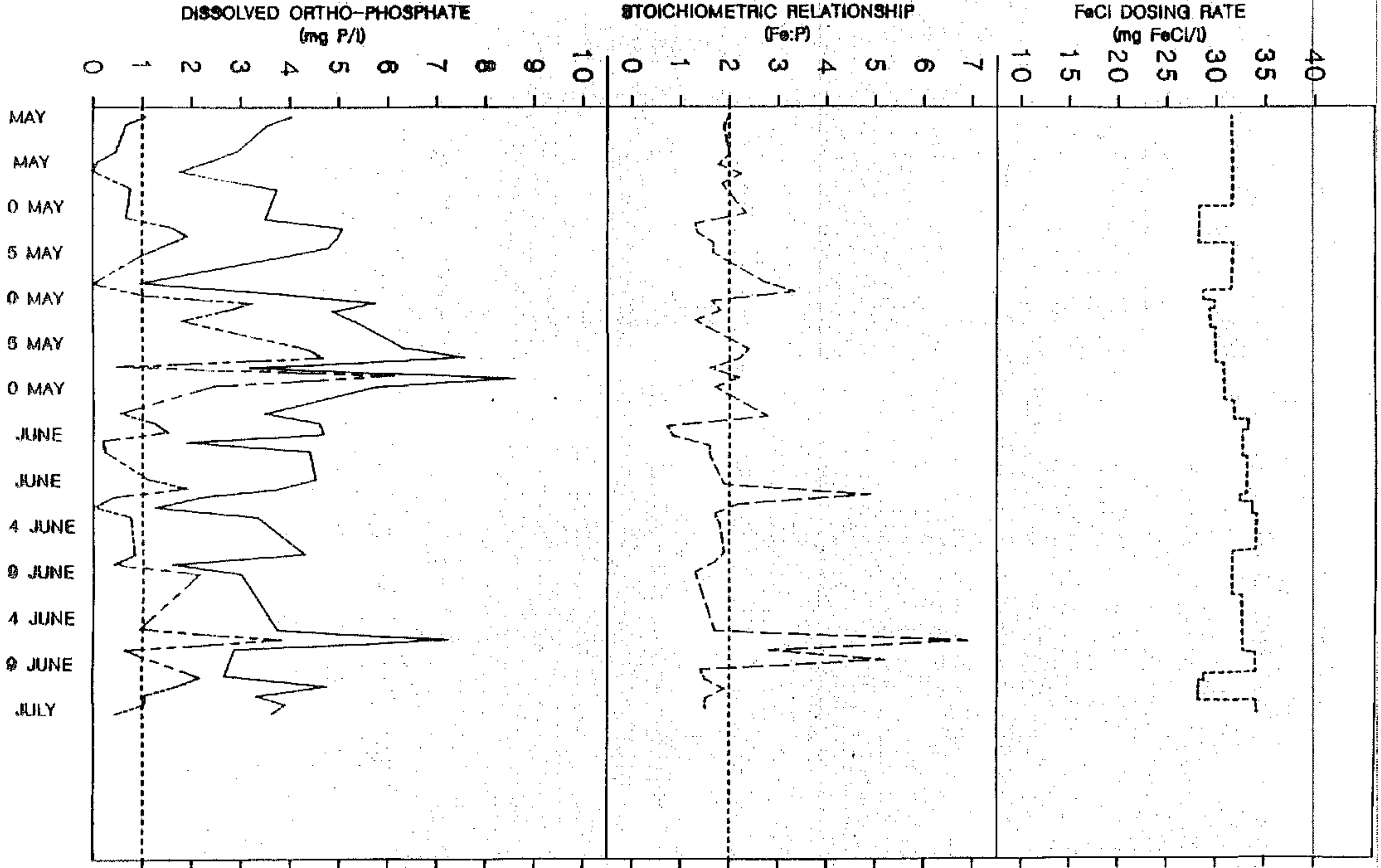


FIG. 4.7 Results using constant dosing strategy

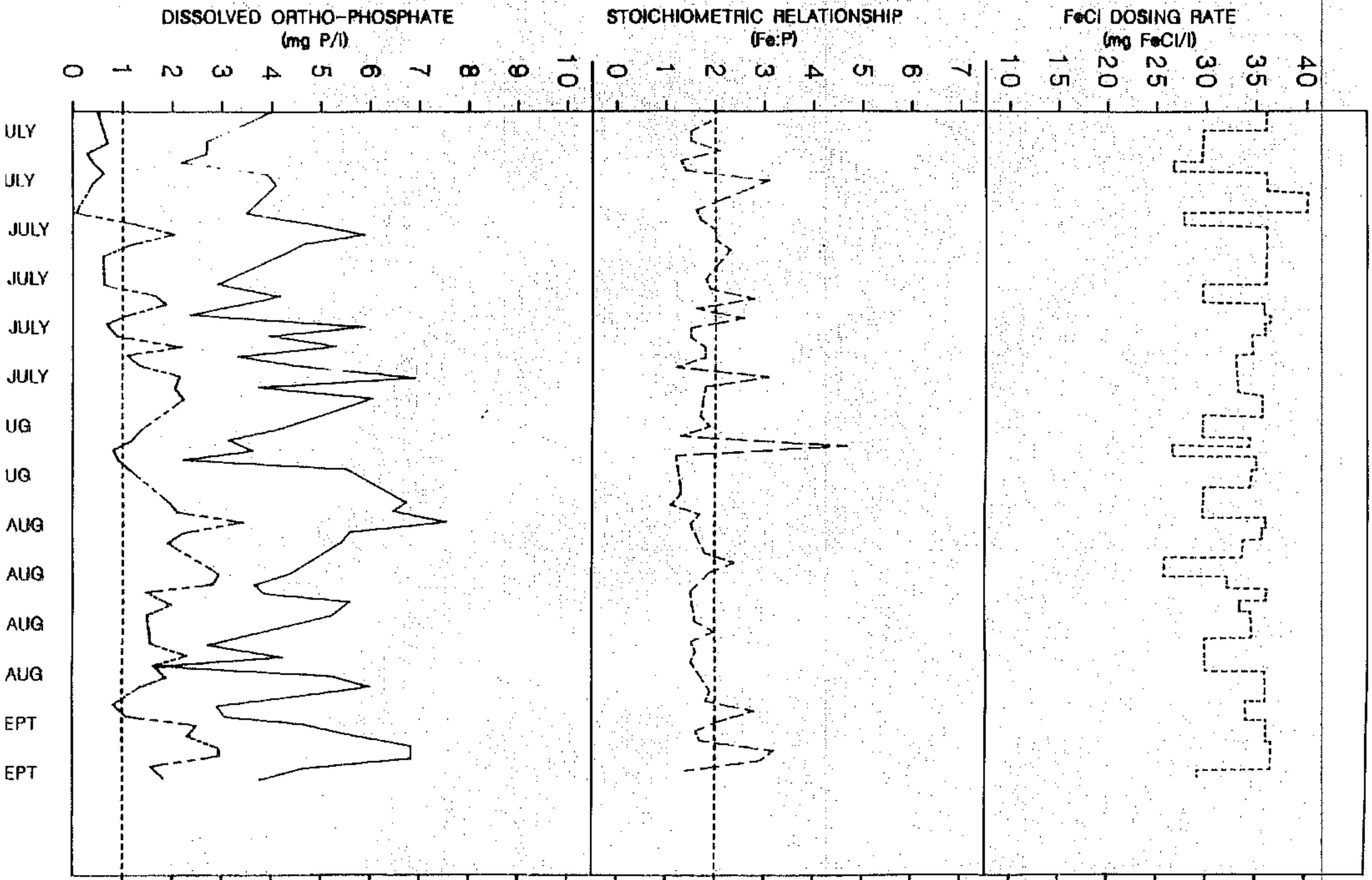


FIG. 4.8 : Results using "Thursday, Friday" Strategy.

FIG. 4.9 : Results using the daily four week moving average strategy.

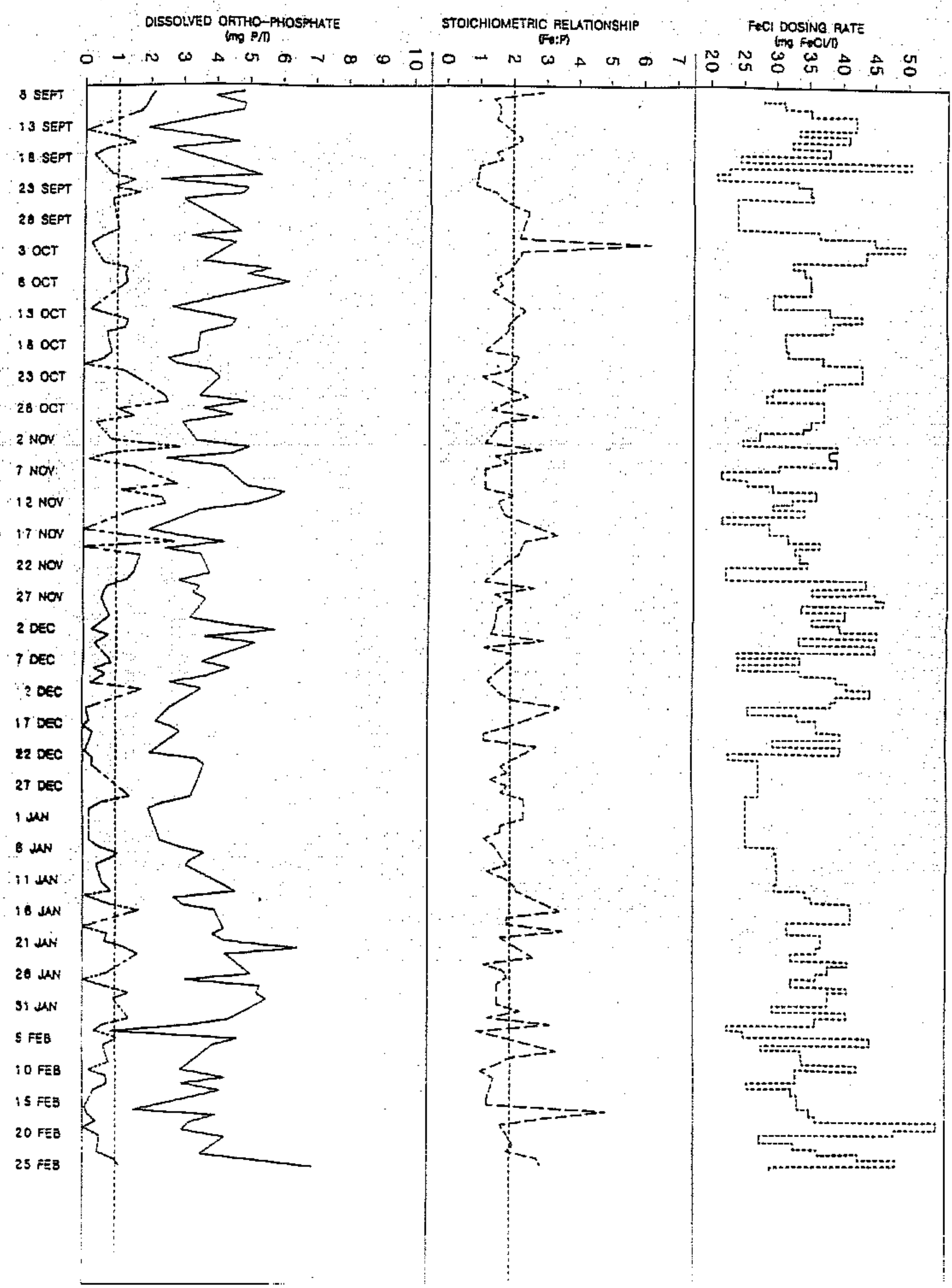


FIG.6.1 PROFILE OF TOTAL P CONC. AT BP1 AND BP7

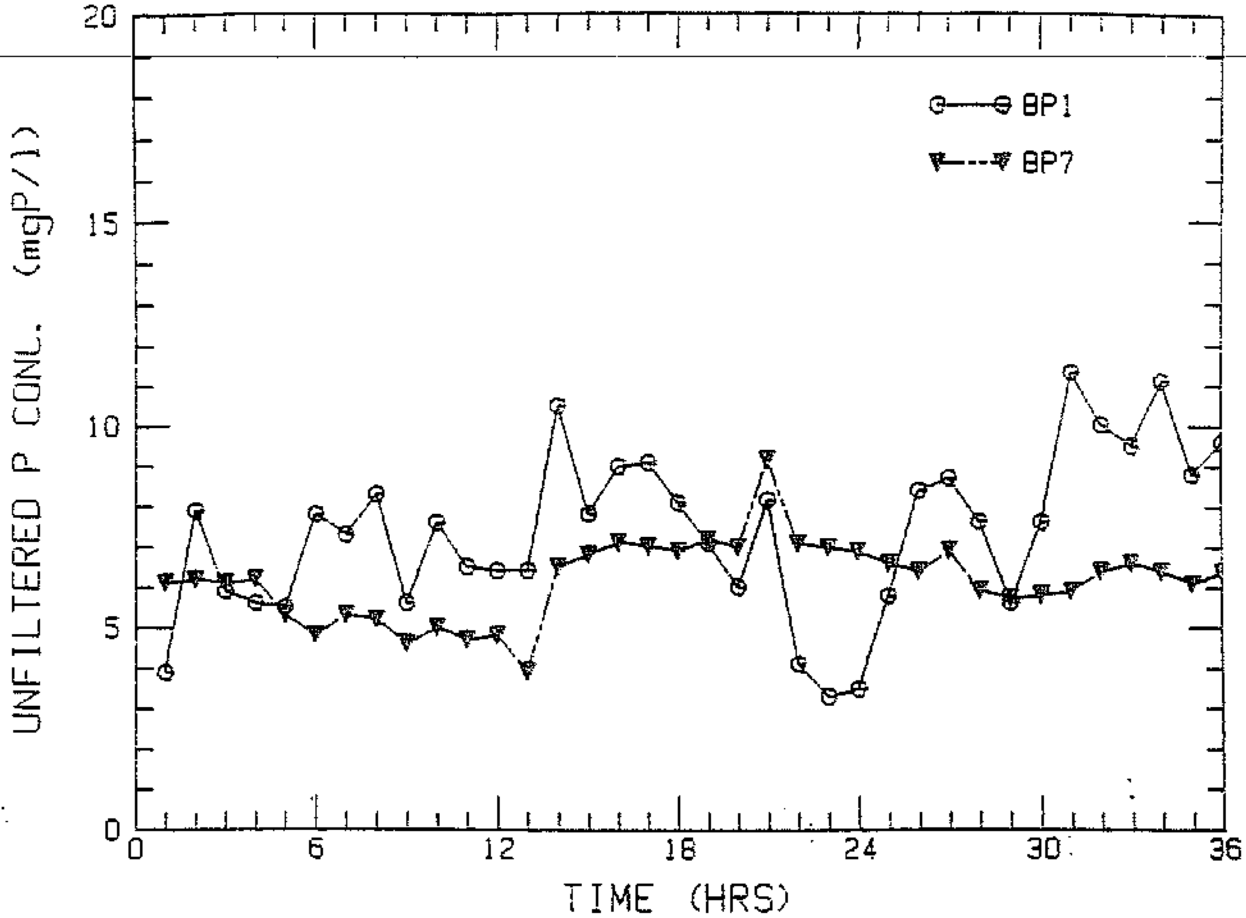


FIG.6.2 PROFILE OF TOTAL P MASS AT BP1 AND BP7

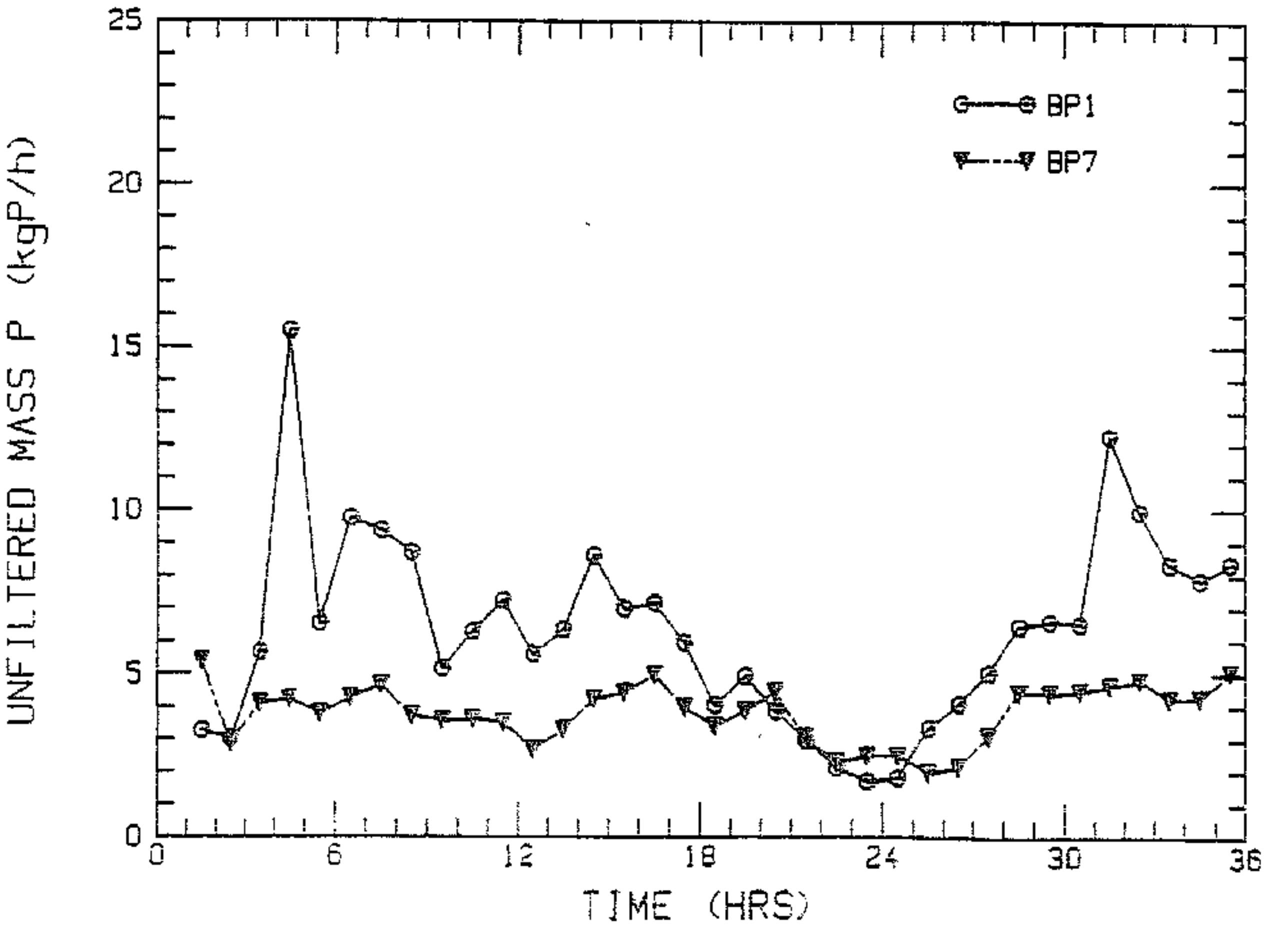


FIG.6.3 PROFILE OF TOTAL P CONC. AT BP3 AND BP4

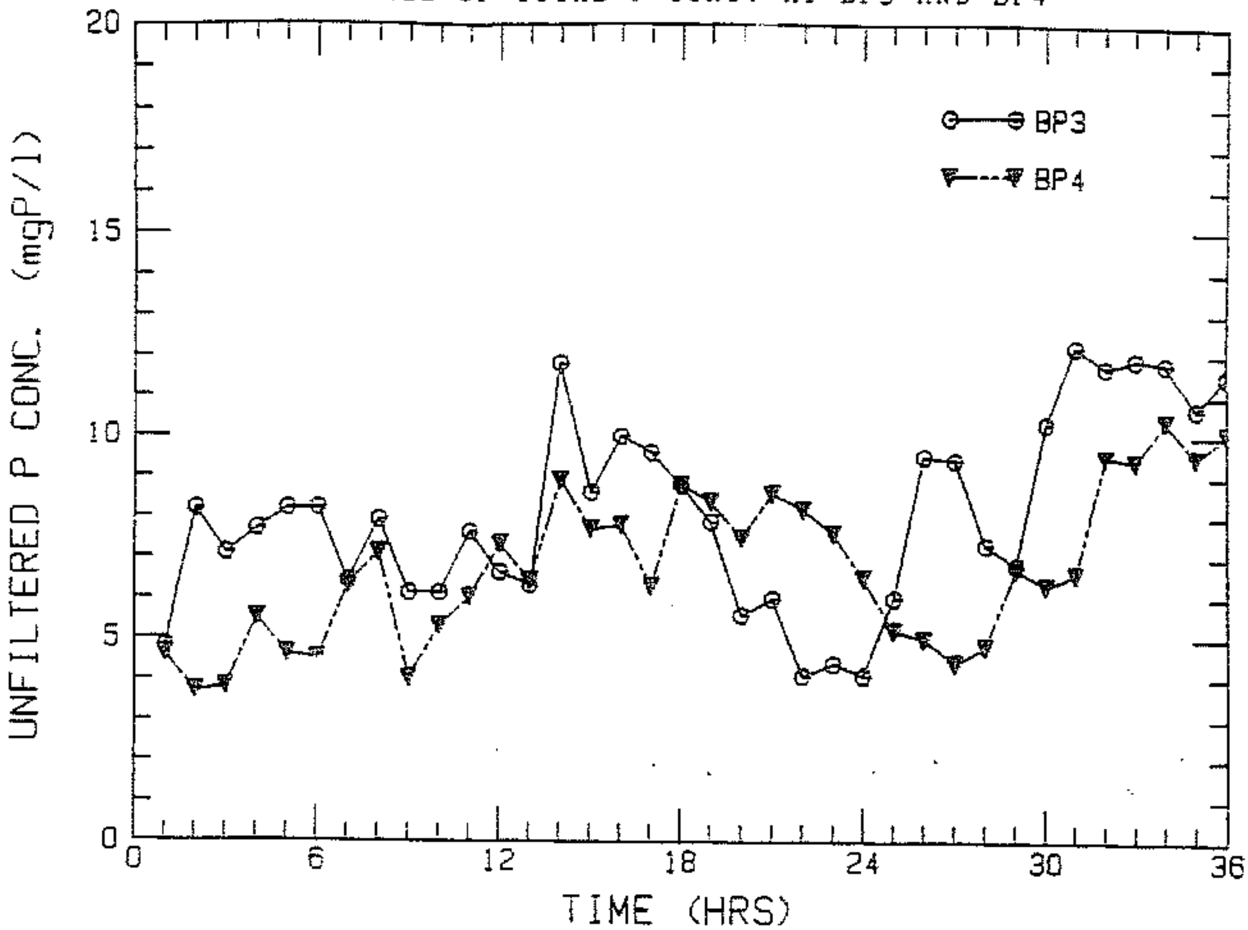


FIG.6.4 PROFILE OF TOTAL P CONC. AT BP4, BP5 AND BP9

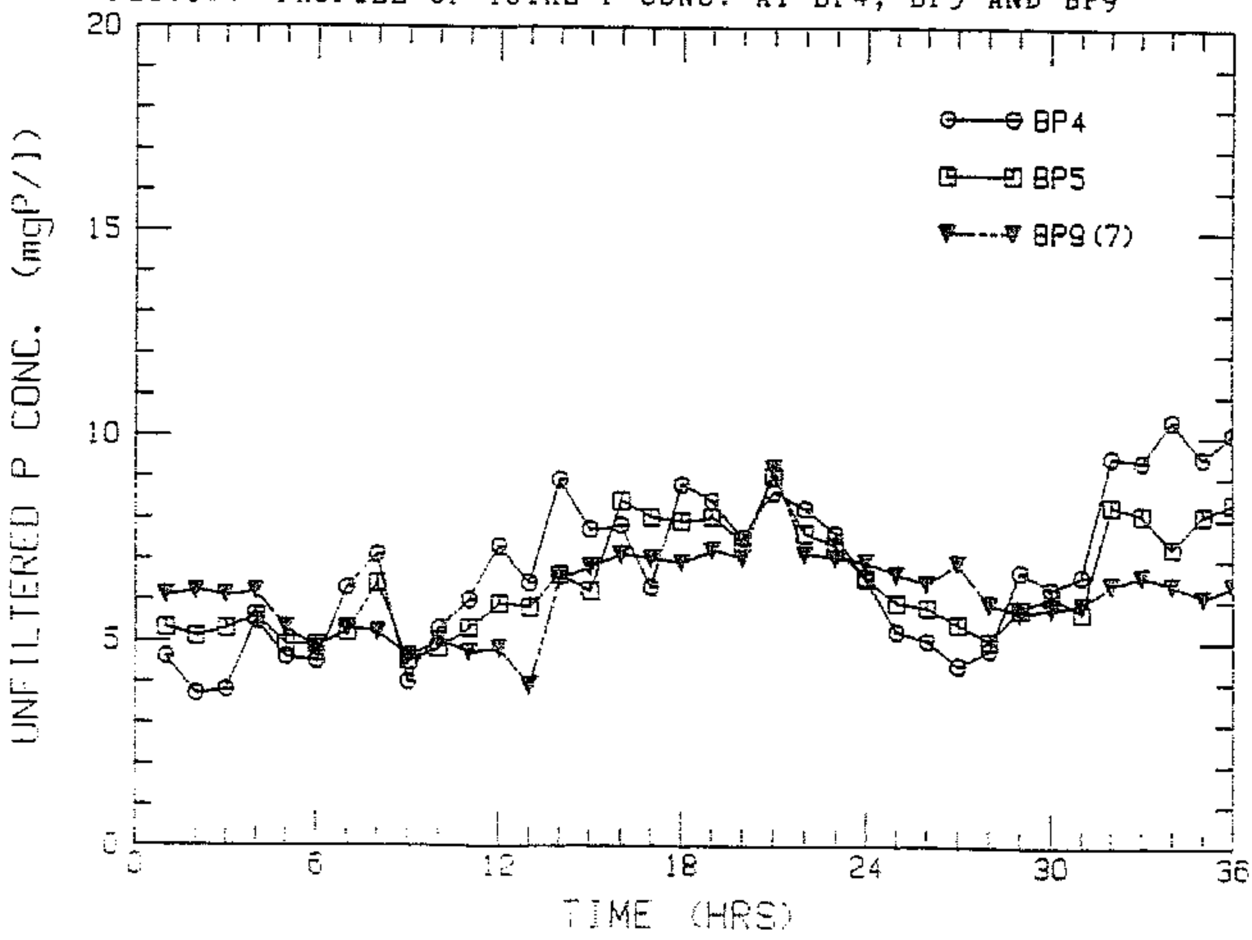


FIG.6.5 PROFILE OF TOTAL P CONC. AT BP5 AND BP6

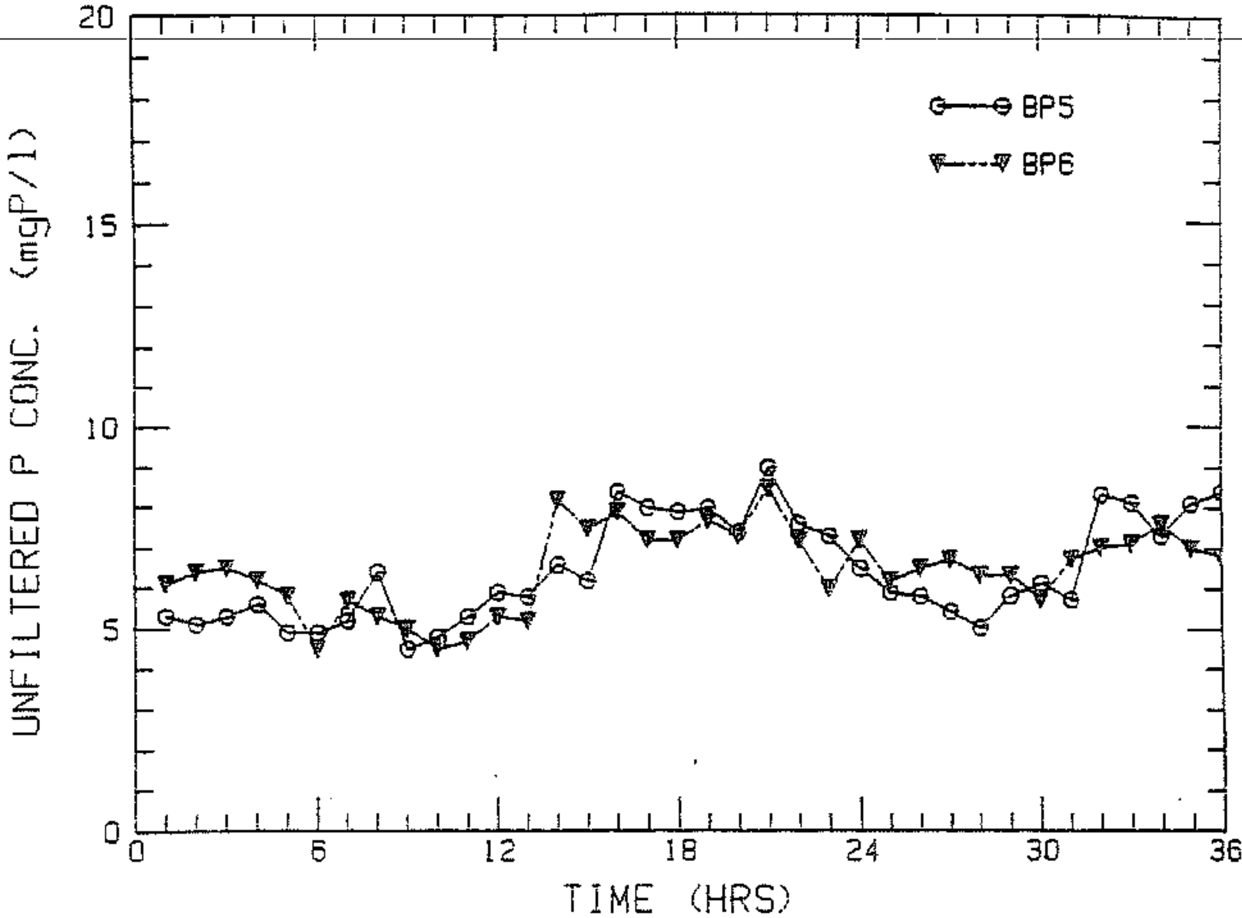


FIG.6.6 PROFILE OF TOTAL P CONC. AT CP1, CP6 AND CP7

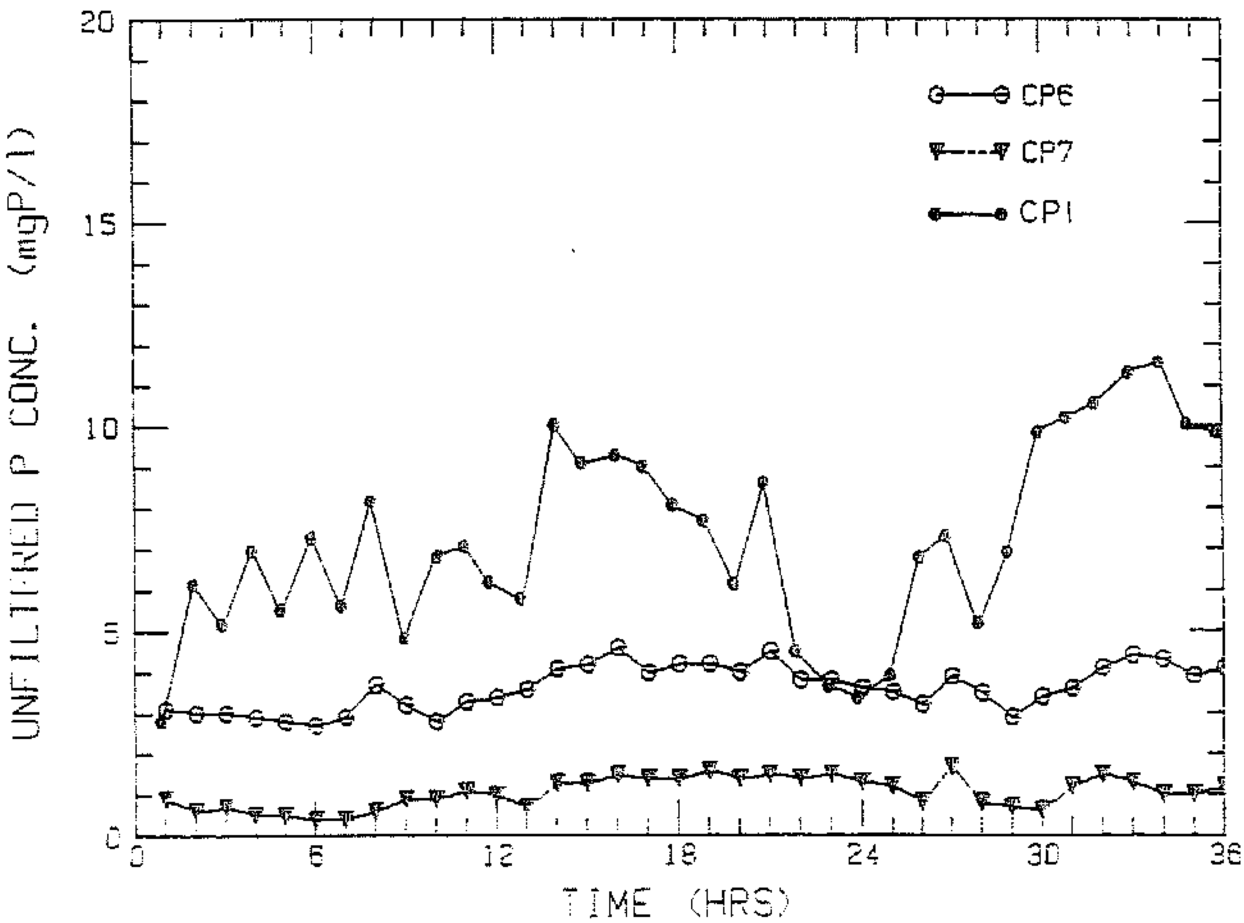


FIG.6.7 PROFILE OF TOTAL MASS AT CP1, CP6 AND CP7

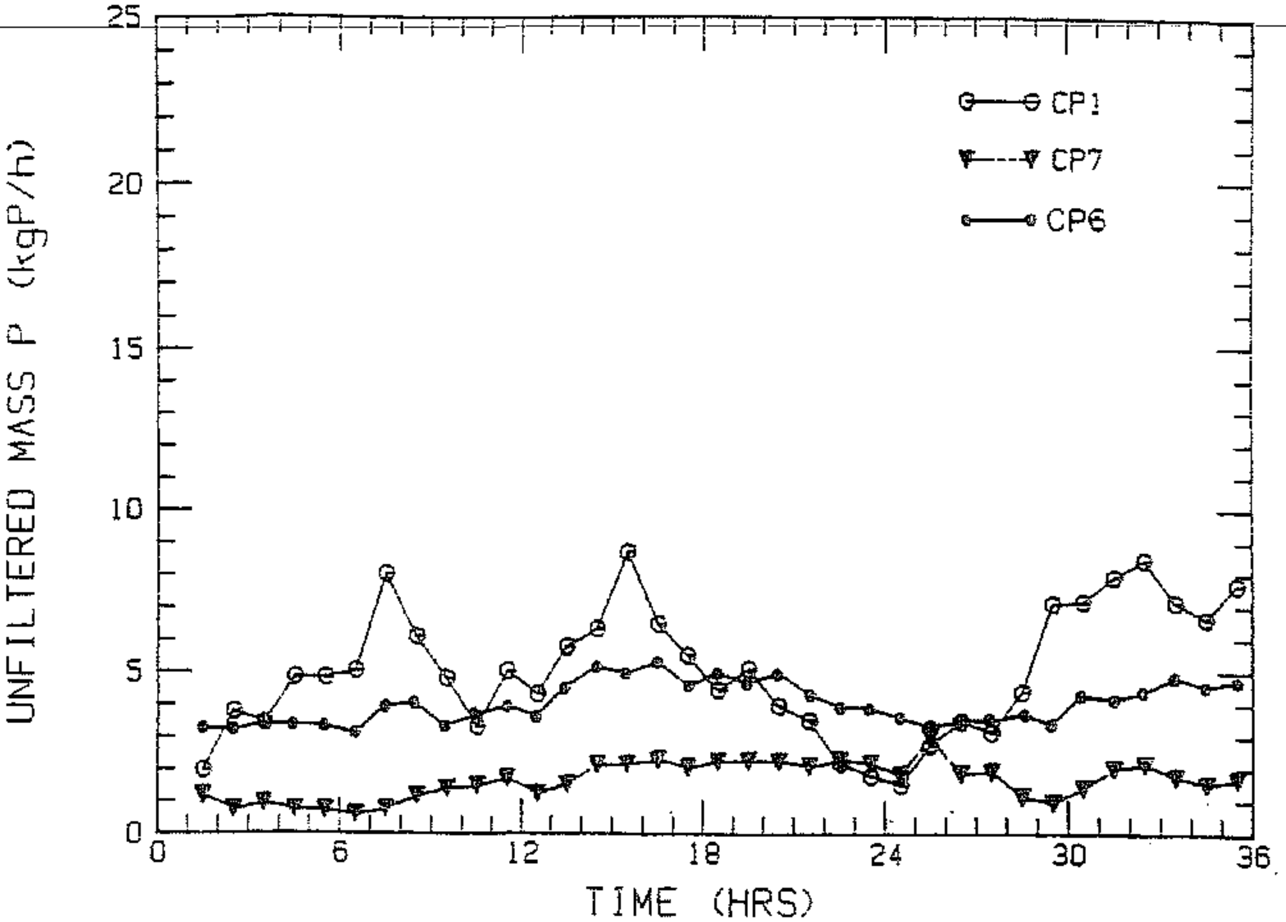


FIG.6.8 PROFILE OF TOTAL P CONC. AT CP4, CP5 AND CP7

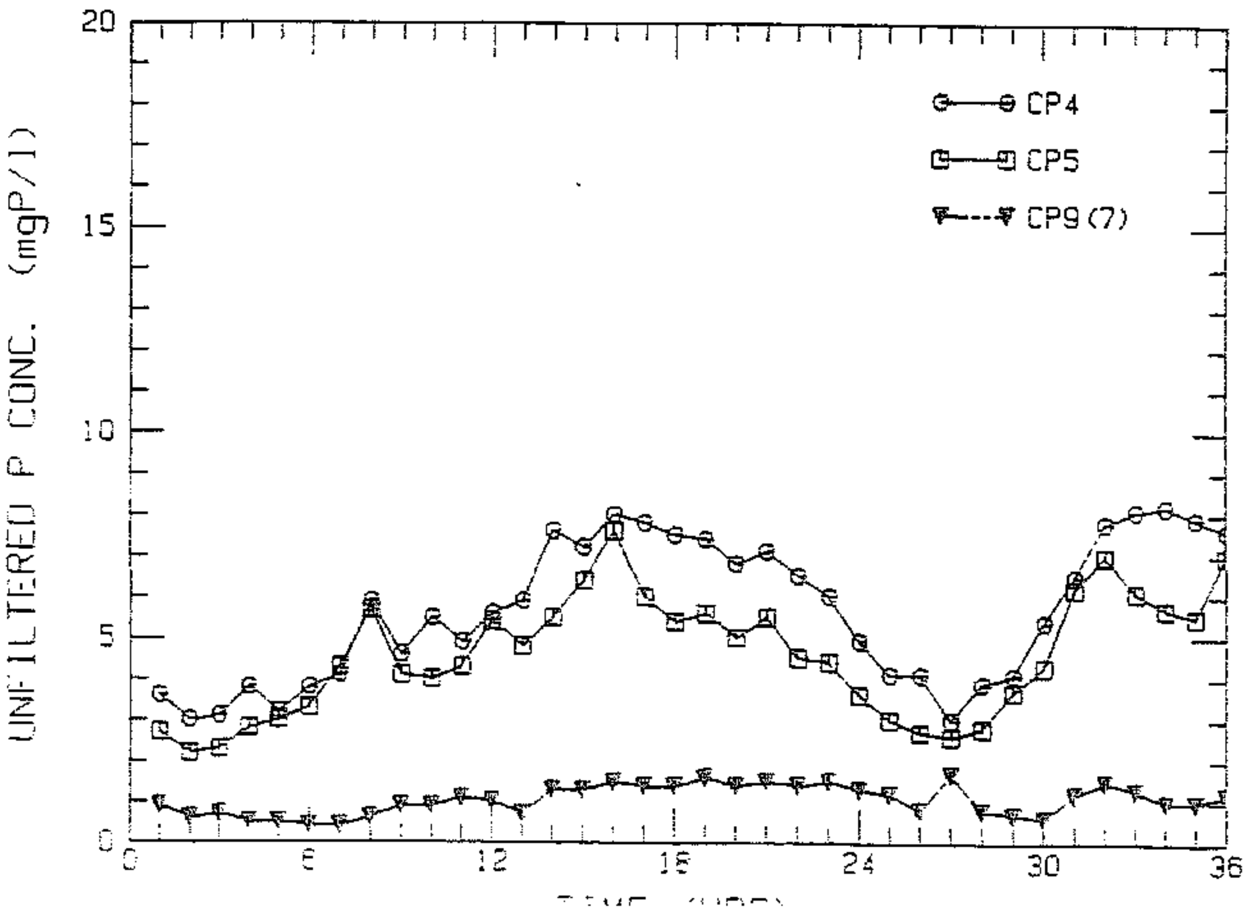


FIG.6.9 PROFILE OF TOTAL P CONC. AT CP3 AND CP4

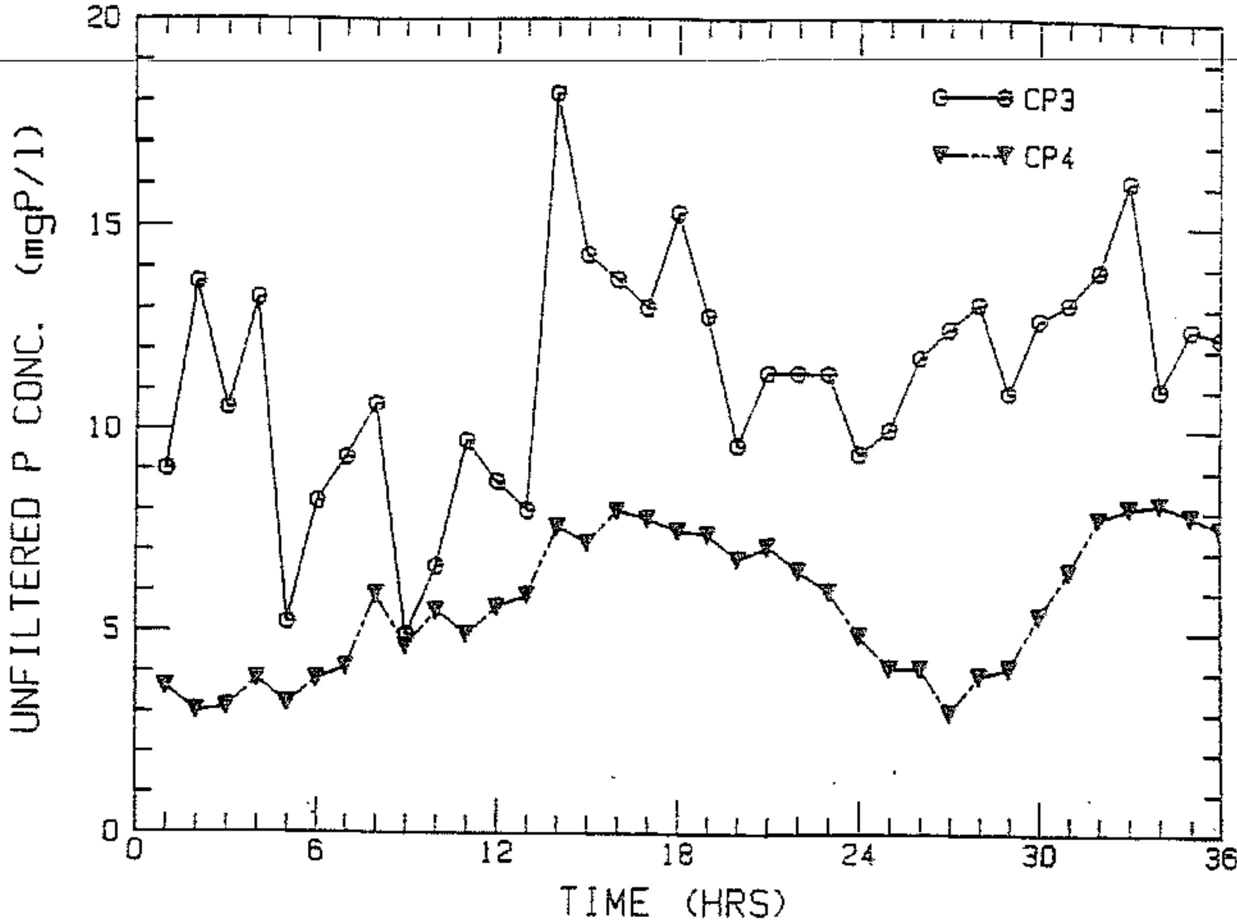
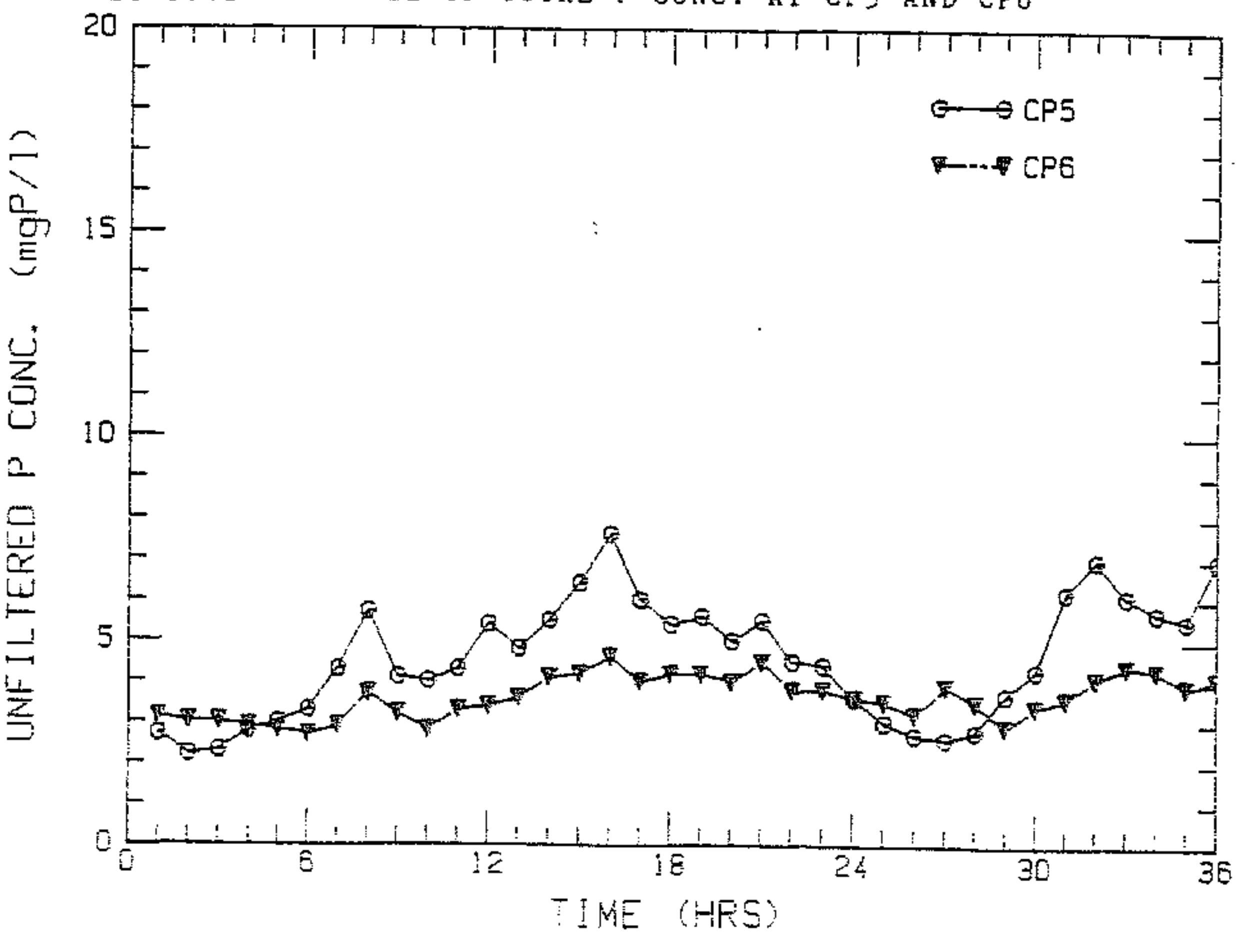


FIG.6.10 PROFILE OF TOTAL P CONC. AT CP5 AND CP6



ANNEXURE B

Tables

TABLE 1.1

Design and Operational Details of Unit B (Control) and Unit C (Ferric Chloride dosed) of the Vlakplaats Water Pollution control Works, Boksburg.

		Unit B (Control)	Unit C ($FeCl_3$ Dosed)
Average dry weather flow (ADWF):	Design (Ml/d)	18	18
Primary settlers	Type	Dortmund	Dortmund
	No.	6	6
	Diameter (m)	11	11
	Upflow velocity		
	- Design (at ADWF)(m/hr)	1,3	1,3
Biological filters (8x)	Type -	Single Filtration	Single Filtration
	Media	Stone	Stone
	Diameter (m)	37,8	37,8
	Ave Depth (m)	2,3	2,3
	Design Loading rate ($g\ PV/m^3/d$)	25	25
Humus tanks	Type	Dortmund	Mechanically Scraped
	No.	8	4
	Diameter (m)	11	22
	Upflow rate: Design (with 1:1 recirculation) m/hr	2,0	1
Maturation pond (17x)	Total retention time (days)	12	12

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FIG 7.1 ESCALATION OF CHEMICAL COST

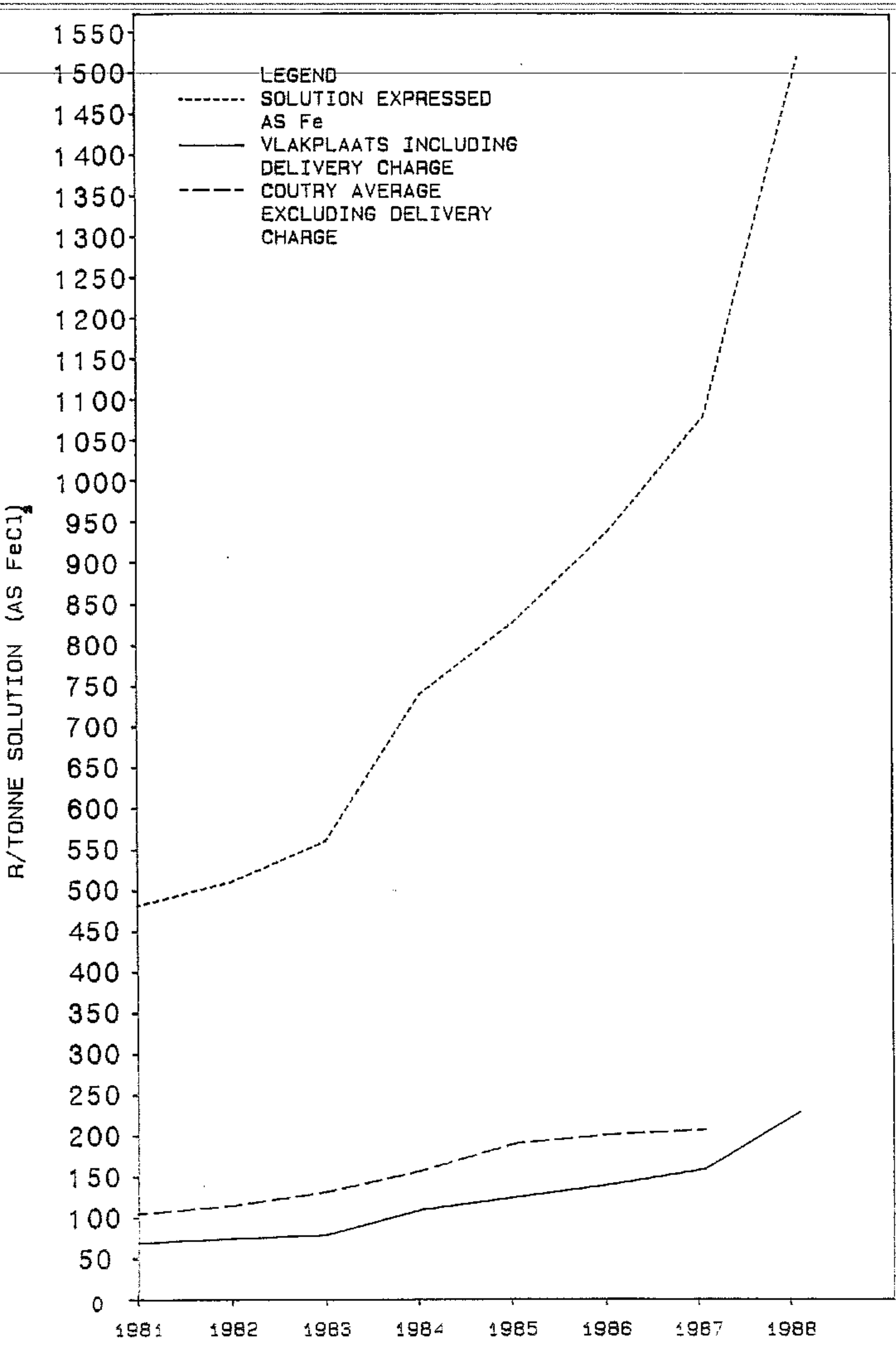

TABLE 2.1

FILTER PAPER TYPES INVESTIGATED

Commercial Brand Name and Abbreviation	Type	Diameter (cm)	Cost (Feb.'86 Rand/100)
Whatman No. 1 (W1)	Paper	12,5	R 5,81
Whatman GF/C microfibre (WGF/C)	Glassfibre	11,0	R86,20
MN80/90 Macherey Nagel Rund (MNGF)	Glassfibre	11,0	R28,75

TABLE 2.2

ANALYTICAL RESULTS FOR DISSOLVED ORTHO-PHOSPATE (mg/l as P) IN BIOLOGICAL FILTER EFFLUENT (WITH A TOTAL PHOSPATE CONTENT OF 3,2 mg/l as P) USING THREE TYPES OF FILTER PAPER AND TYPES OF FILTER PAPER PRETREATMENT.

SAMPLE NUMBER	W1		WGF/C		MNGF	
	UNWASHED	WASHED	UNWASHED	WASHED	UNWASHED	WASHED
1	2,2	2,5	2,4	2,3	2,3	2,2
2	2,3	2,5	2,3	2,2	2,4	2,3
3	2,4	2,6	2,0	2,3	2,4	2,2
4	2,4	2,4	2,3	2,1	2,2	2,3
5	2,4	2,5	2,2	2,1	2,3	2,3
6	2,1	2,5	2,1	2,4	2,3	2,3
7	2,4	2,2	2,4	2,4	2,4	2,4
8	2,4	2,5	2,3	2,2	2,3	2.3
9	2,3	2,5	2,3	2,4	2,3	2,2
10	2,2	2,3	2,2	2,3	2,4	2,3
$\bar{x}$	2,3	2,5	2,3	2,3	2,3	2,3
S.D.	0,1	0,1	0,1	0,1	0,1	0,1

Where : $\bar{x}$ = Arithmetic mean
S.D. = Standard deviation

TABLE 2.3

ANALYTICAL RESULTS FOR DISSOLVED ORTHO-PHOSPHATE (mg/l as P) IN HUMUS TANK EFFLUENT WITH A TOTAL PHOSPHATE CONTENT OF 0,9 mg/l (as P) USING THREE TYPES OF FILTER PAPER AND TWO TYPES OF FILTER PAPER PRETREATMENT

SAMPLE NUMBER	W1		WGF/C		MNGF	
	UNWASHED	WASHED	UNWASHED	WASHED	UNWASHED	WASHED
1	0,2	0,4	0,5	0,7	0,4	0,6
2	0,5	0,8	0,4	0,7	0,7	0,7
3	0,2	0,6	0,4	0,7	0,4	0,7
4	0,4	0,8	0,5	0,5	0,3	0,7
5	0,5	0,7	0,5	0,7	0,5	0,7
6	0,3	0,6	0,5	0,7	1,7*	0,6
7	0,5	0,7	0,2	0,4	0,5	0,6
8	0,5	0,7	0,5	0,7	0,5	0,6
9	0,5	0,4	0,2	0,7	0,4	0,5
10	0,4	0,7	1,2*	0,6	0,5	0,6
x	0,4	0,6	0,4	0,6	0,5	0,6
S.D.	0,1	0,1	0,1	0,1	0,1	0,1

* - outliers not included in calculation of average and standard deviation

x - Average

SD - Standard Deviation

TABLE 2.4.

ANALYTICAL RESULTS FOR DISSOLVED IRON (mg/l as Fe) IN THE FEED TO THE BIOLOGICAL FILTER (WITH A TOTAL IRON CONTENT OF 3,2 mg/l Fe)

SAMPLE NUMBER	W1		WGF/C		MNGF	
	UNWASHED	WASHED	UNWASHED	WASHED	UNWASHED	WASHED
1	0,6	0,6	0,1	0,2	0,0	0,0
2	0,6	0,6	0,1	0,2	0,0	0,0
3	0,4	0,6	0,1	0,2	0,2	0,6
4	0,4	0,6	0,2	0,2	0,2	0,6
5	0,4	0,6	0,2	0,2	0,2	1,8*
6	0,4	0,6	0,1	0,1	0,2	0,6
7	0,4	0,4	0,2	0,1	0,2	0,6
8	0,4	0,4	0,2	0,1	0,2	0,6
9	0,4	0,4	0,2	0,4*	0,2	0,2
10	0,6	0,6	1,2*	0,1	0,2	0,2
x	0,5	0,5	0,2	0,2	0,2	0,4
S.D.	0,1	0,2	0,1	0,1	0,1	0,3

* - Outliers not included in calculations for average and standard deviation

x - Average

S.D.- Standard Deviation

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TABLE 2.5

ANALYTICAL RESULTS FOR SUSPENDED SOLIDS (mg/l) ON HUMUS TANK EFFLUENT USING THREE TYPES OF FILTER PAPER AND PREWASHING.

SAMPLE NUMBER	W1		WGF/C		MNGF	
	UNWASHED	WASHED	UNWASHED	WASHED	UNWASHED	WASHED
1	-158	78	10	10	-55	24
2	-127	106	7	14	-49	12
3	-134	105	11	9	-45	12
4	-124	97	7	7	-44	6
5	-128	109	5	6	-47	10
6	-151	111	4	4	-40	13
x	-137	101	7	8	-47	13
S.D.	14	12	3	4	5	6
P	10	12	37	42	11	47

x - Arithmetic mean
S.D. - Standard deviation
P - Percentage standard deviation

TABLE 2.6

DETERMINATION OF SUSPENDED SOLIDS USING A STANDARD SUSPENSION OF FULLER'S EARTH (980 mg/l), ALL FILTER PAPERS WERE PREWASHED.

SAMPLE NUMBER	RUNDFILTER MN 58/90	WHATMAN NO.1	WHATMAN GF/C	WHATMAN GF/D	WHATMAN GF/F
1	937,0	905,9	944,1	941,3	937,2
2	920,8	908,2	938,7	936,2	932,2
3	927,2	892,3	940,9	939,9	931,3
x	928,3	902,1	940,9	939,9	931,3
R	95	92	96	96	95

x = Average
R = percentage recovery

5

TABLE 2.7

DETERMINATION OF SUSPENDED SOLIDS USING STANDARD SUSPENSION OF FULLER'S EARTH (980 mg/l); FILTER PAPERS WERE NOT PREWASHED.

SAMPLE NUMBER	RUNDFILTER MN 85/90	WHATMAN NO.1	WHATMAN GF/C	WHATMAN GF/D	WHATMAN GF/F
1	928,9	917,2	947,0	944,0	966,9
2	941,4	909,7	944,6	952,5	970,2
3	937,4	905,9	962,5	952,1	975,0
x	935,9	910,9	951,4	952,1	970,7
R	96	93	97	97	99

x - Average
R - Percentage Recovery

TABLE 2.8

DETERMINATION OF SUSPENDED SOLIDS USING A 20mg/l SODIUM BENTONITE SUSPENSION; ALL FILTER PAPERS WERE WASHED WITH DISTILLED WATER AND DRIED BEFORE USE.

SAMPLE NUMBER	RUNDFILTER MN 58/90	WHATMAN NO.1	WHATMAN GF/C	WHATMAN GF/D	WHATMAN GF/F
1	14,0	-5,9	15,1	8,9	12,7
2	6,5	-9,5	13,2	9,7	18,6
3	18,7	-9,5	11,9	10,8	8,9
x	13,1	-8,3	13,4	9,5	13,4
R	66	-4,2	66	48	67

x = Average
R = Percentage recovery

TABLE 2.9

DETERMINATION OF SUSPENDED SOLIDS USING A 20 mg/l SODIUM BENTONITE SUSPENSION; FILTER PAPERS WERE USED WITHOUT ANY PRE-WASH.

FILTER NUMBER	RUNDFILTER MN 58/90	WHATMAN NO.1	WHATMAN GF/C	WHATMAN GF/D	WHATMAN GF/F
1	8,7	-38,3	13,2	5,8	10,9
2	17,8	-41,3	13,1	8,4	11,0
3	13,2	-39,6	10,5	8,3	10,8
x	13,2	-39,7	12,3	7,5	10,9
R	66	-19,9	62	38	55

x = Average
R = Percentage recovery

V34AAA

TABLE 2.10

WEEKLY AVERAGE MASS BALANCE FOR CHLORIDES AT SAMPLING POINTS P_1, P_2 and P_3.

Week	P_1			P_2			$P_1 + P_2$ Mass	P_3			%
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Error
05.8-16.8	14,7	101	1 485	0,72	136	98	1 583	15,4	131	2 017	-22
12.8-16.8	12,7	128	1 613	0,75	179	134	1 747	13,3	121	1 609	+9
26.8-30.8	12,0	121	1 452	0,75	138	103	1 555	12,7	113	1 441	+8
09.9-13.9	12,2	152	1 854	0,92	194	178	2 033	13,1	145	1 899	+7
16.9-20.9	12,5	134	1 675	0,71	186	132	1 807	13,2	196	2 587	-30
AVERAGES			1 616			129	1 745			1 911	-9
STANDARD DEV.			161			32	193			422	

TABLE 2.11

WEEKLY AVERAGE MASS BALANCES FOR CHLORIDES AT SAMPLING POINTS P_4, P_9 and P_5

Week	P_4			P_9			$P_4 + P_9$ Mass	P_5			%
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Error
05.8-09.8	15,4	117	1 802	13,6	143	1 945	3 747	29,0	135	3 915	-4
12.8-16.8	13,4	121	1 621	18,0	179	3 222	4 843	31,4	167	5 243	-7
26.8-30.8	12,8	115	1 466	13,6	156	2 122	3 588	26,4	135	3 564	0
09.9-20.9	13,1	135	1 767	21,4	184	3 988	5 706	34,5	167	5 761	0
16.9-20.9	13,2	131	1 729	18,7	179	3 347	5 076	31,9	163	5 200	-2
AVERAGES			1 677			2 915	4 592			4 737	-3
STANDARD DEV.			136			851	903			945	

TABLE 2.12

AVERAGE WEEKLY MASS BALANCES FOR DISSOLVED ORTHO-PHOSPHATE AT MP1 SAMPLING POINTS P_1, P_2 and P_3.

Week in 1985	P_1			P_2			$P_1 + P_2$ Mass	P_3			%
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Error
29.7-02.8	14,6	9,0	131,4	0,82	1,6	1,3	132,7	15,4	6,5	100,1	+33
05.9-09.8	14,7	7,5	110,0	0,72	1,3	0,9	111,0	15,4	5,8	89,0	+24
12.8-16.8	12,6	8,7	110,0	0,75	1,1	0,8	110,0	13,3	8,0	106,0	+4
26.8-20.8	12,0	9,9	119,0	0,75	1,4	1,1	120,0	12,8	6,7	85,0	+40
09.9-13.0	12,2	11,0	134,0	0,92	2,7	2,5	137,0	13,1	6,1	80,0	+71
16.9-20.9	12,5	10,5	131,3	0,71	1,0	0,7	132,0	13,2	7,1	94,0	+14
AVERAGES			122,6		1,2	1,2	123,8			92,3	+34
STANDARD DEV.			11,0			0,7	11,7			9,7	

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TABLE 2.13

AVERAGE WEEKLY MASS BALANCES FOR DISSOLVED ORTHO-PHOSPHATE FOR POINT MP_2 SAMPLING POINTS P_4, P_9 AND P_5

Week	P_4			P_9			$P_4 + P_9$ Mass	P_5			% Error
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	
10.06-14.06	11,5	8,5	98,2	15,6	2,9	45,2	143,4	27,1	5,0	135,5	+6
17.06-21.06	12,0	6,6	79,6	15,5	1,1	17,1	96,7	27,5	5,0	137,5	-30
01.07-05.07	13,4	7,7	103,2	14,4	0,9	13,0	116,2	27,8	4,3	119,6	-3
08.07-12.07	12,6	6,7	84,4	15,0	1,0	15,0	99,4	27,6	4,4	121,4	-18
15.07-19.07	13,0	6,5	84,5	18,2	1,0	18,2	102,7	31,2	3,8	118,6	-13
29.07-02.08	15,4	7,7	118,6	14,0	1,2	16,8	135,4	29,4	4,8	141,1	-4
05.09-09.08	15,4	8,2	126,3	13,6	1,1	15,0	141,2	29,0	4,8	139,2	+1
12.08-16.08	13,4	5,6	75,0	18,0	1,2	21,6	96,6	31,4	3,4	106,8	-9
26.08-20.08	12,7	7,7	98,2	13,6	0,9	12,2	110,4	27,3	4,5	122,9	-10
09.09-13.09	13,1	5,0	65,5	21,4	0,7	15,0	80,5	34,5	2,7	93,2	-14
16.09-20.09	13,2	7,5	99,0	18,7	0,7	13,1	112,1	31,9	3,5	111,6	0
AVERAGES			93,0			18,4	112,2			122,5	-8
STANDARD DEV.			18,3			9,3	20,3			15,1	

TABLE 2.14

DAILY MASS BALANCES ON P_1, P_2 and P_3 - ORTHO PHOSPHATE

DAY	P_1			P_2			$P_1 + P_2$ Mass	P_3			% Error
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	
01.07.85	10,2	5,6	57,0	0,78	0,3	0,3	57,2	11,0	5,1	55,9	+2
02.07.85	12,6	6,0	75,4	0,79	2,2	2,2	77,6	13,4	7,9	105,5	-27
02.07.85	13,9	10,4	144,8	0,81	0,9	0,7	145,5	14,7	6,1	89,9	+61
04.07.85	12,7	9,7	123,3	0,72	1,5	1,1	124,4	13,4	10,4	139,4	-11
05.07.85	13,7	9,0	123,3	0,85	2,2	1,9	125,5	14,5	10,9	158,1	-21
08.07.85	10,8	9,1	97,8	0,75	0,9	0,7	98,5	11,5	5,4	58,6	+68
09.07.85	12,3	8,2	100,9	0,87	1,2	1,0	101,9	13,2	6,1	80,3	+26
10.07.85	12,3	8,2	100,6	0,97	1,0	1,0	101,6	13,2	5,5	72,8	+39
11.07.85	11,4	9,9	112,5	0,73	1,6	1,2	113,6	12,1	7,6	91,9	+23
12.07.85	12,3	11,4	140,6	0,91	1,2	1,1	141,6	13,2	6,8	90,0	+57
AVERAGES			107,6			1,1	108,7			94,2	+15
STANDARD DEV.			27,4			0,5	27,6			32,8	

TABLE 2.15

DAILY MASS BALANCES ON P_4, P_9 and P_6 - DISSOLVED ORTHO-PHOSPHATE (asP)

DAY	P_4 Flow Ml/d	P_4 Conc mg/l	P_4 Mass kg/d	P_9 Flow Ml/d	P_9 Conc mg/l	P_9 Mass kg/d	$P_4 + P_9$ Mass Kg/d	P_6 Flow Ml/d	P_6 Conc mg/l	P_6 Mass kg/d	% Error
01.07.85	11,0	6,0	65,8	16,7	0,5	8,4	74,2	27,8	2,6	72,1	+3
02.07.85	13,4	8,9	118,9	14,2	0,6	8,6	127,5	28,1	4,5	126,4	+1
02.07.85	14,7	8,6	126,7	14,8	0,8	11,9	138,6	29,8	4,8	142,0	-2
04.07.85	13,4	6,7	90,0	13,0	1,7	22,2	112,2	26,7	4,9	129,9	-14
05.07.85	14,5	8,3	120,6	13,1	1,1	14,5	135,1	27,6	4,8	132,8	+2
08.07.85	11,5	4,1	47,1	15,8	0,5	7,9	55,1	27,4	3,2	87,5	-37
09.07.85	13,1	8,2	108,0	14,3	1,2	17,2	125,2	27,6	4,5	123,9	+1
10.07.85	13,2	6,7	88,7	14,8	0,6	8,9	97,6	28,3	4,5	126,5	-23
11.07.85	12,1	9,1	110,1	15,1	1,5	22,8	132,9	28,7	4,4	126,3	+5
12.07.85	13,2	5,5	72,6	14,6	1,2	17,6	90,2	27,8	5,4	150,1	-40
AVERAGES			95,0			14,0	108,9			121,7	-11
STANDARD DEV.			26,5			5,7	28,6			23,8	

TABLE 2.16

AVERAGE WEEKLY MASS BALANCES FOR TOTAL PHOSPHATE FOR MP_1 (SAMPLING POINTS P_1, P_2 and P_3.)

Week	P_1 Flow Ml/d	P_1 Conc mg/l	P_1 Mass kg/d	P_2 Flow Ml/d	P_2 Conc mg/l	P_2 Mass kg/d	$P_1 + P_2$ Mass Kg/d	P_3 Flow Ml/d	P_3 Conc mg/l	P_3 Mass kg/d	% Error
29.7-02.8	14,6	14,3	208,8	0,82	52,0	42,6	251,4	15,4	21,7	334,2	-25
05.9-09.8	14,7	12,7	187,0	0,72	33,8	24,0	211,0	15,4	26,5	408,0	-48
12.8-16.8	12,6	14,1	177,7	0,75	35,2	26,4	204,0	13,3	27,4	364,0	-44
26.8-20.8	12.0	13,6	163,0	0,92	44,0	40,5	187,0	13,1	20,8	272,0	-24
09.9-13.9	12,2	14,5	177,0	0,92	44,0	40,5	217,5	13,1	20,8	272,0	-20
16.9-20.9	12,5	14,3	179,0	0,71	44,2	31,0	210,0	13,2	21,2	280,0	-25
AVERAGES			182,1			31,4	213,5			309,0	-31
STANDARD DEV.			15,2			8,3	21,3			76,0	

TABLE 2.17

AVERAGE WEEKLY MASS BALANCES FOR TOTAL PHOSPHATE FOR MP_2 SAMPLING POINTS P_4, P_9 and P_5

Week	P_4			P_9			$P_4 + P_9$ Mass	P_5			%
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Error
10.06-14.06	11,6	11,2	129,4	15,6	3,9	60,8	190,0	27,1	6,6	178,9	+6
17.06-21.06	12,1	8,9	98,9	15,5	2,0	31,0	129,9	27,5	6,4	176,0	-26
01.07-05.07	13,4	9,6	128,6	14,4	2,0	28,9	157,4	27,8	6,3	175,1	-10
08.07-12.07	12,6	9,1	114,7	15,0	1,7	25,5	140,2	27,7	5,5	152,4	-8
15.07-19.07	13,0	8,5	110,5	18,2	1,9	34,6	145,1	31,2	4,7	146,6	-1
22.07-26.06											
29.07-02.08	15,4	10,9	167,9	14,0	2,6	36,4	204,3	29,4	6,9	202,9	+1
05.08-09.08	15,4	13,1	201,7	13,6	2,4	32,6	234,4	29,0	8,4	243,6	-4
12.08-16.08	13,4	14,6	195,6	18,0	1,7	30,6	226,2	31,4	8,9	279,5	-19
26.08-13.09	12,8	10,8	137,7	13,6	1,9	25,8	163,5	27,3	6,2	169,3	-3
09.09-13.09	13,1	7,3	95,6	21,4	1,4	30,0	125,6	34,5	4,1	141,4	-11
16.09-20.09	13,2	9,7	128,0	18,7	1,5	28,1	156,1	31,9	4,8	153,1	+2
AVERAGES			137,1			33,1	170,2			183,5	-7
STANDARD DEV.			36,3			9,8	37,9			43,1	

TABLE 2.18

DAILY MASS BALANCES FOR TOTAL P AT MP_2 (SAMPLING POINTS P_4, P_9 and P_5).

Week	P_4			P_9			$P_4 + P_9$ Mass	P_5			%
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Error
01.07.85	11,0	7,5	82,5	16,7	1,1	18,4	100,9	27,8	4,1	113,7	-11
02.07.85	13,4	10,3	138,0	14,2	1,9	27,1	165,1	28,1	7,9	221,0	-25
02.07.85	14,7	10,2	150,0	14,8	1,7	25,3	175,2	29,8	6,0	177,5	-1
04.07.85	13,4	8,4	112,6	13,0	3,0	39,2	151,8	26,7	6,5	172,2	-12
05.07.85	14,5	11,1	161,0	13,1	2,2	28,9	189,9	27,6	6,9	190,9	0
08.07.85	11,5	5,5	63,0	15,8	1,1	17,4	80,4	27,4	3,8	103,9	-22
09.07.85	13,2	10,5	138,6	14,3	1,1	15,8	154,4	27,6	5,3	145,9	+6
10.07.85	13,2	9,4	124,1	14,8	1,8	26,8	150,8	28,3	6,1	171,4	-12
11.07.85	12,1	10,5	127,1	15,1	2,5	37,9	165,0	28,7	5,5	157,9	+5
12.07.85	13,2	9,6	126,7	14,6	2,2	32,1	158,8	27,8	6,6	183,5	-13
AVERAGES			122,4			26,9	149,2			163,8	-9
STANDARD DEV.			29,8			8,1	33,4			35,2	

TABLE 2.19

AVERAGE WEEKLY MASS BALANCES FOR COD AT MP_1 SAMPLING POINTS P_1, P_2 and P_3.

Week	P1			P2			$P_1 + P_2$ Mass	P3			%
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Error
29.7-02.8	14,6	958	13 986	0,82	3165	2 595	16 582	15,4	788	12 135	+37
05.9-09.8	14,7	841	12 363	0,72	4278	3 080	15 442	15,4	1146	17 648	-12
12.8-16.8	12,6	1303	16 418	0,75	5701	4 276	20 694	13,3	982	13 061	+58
26.8-20.8	12,0	764	9 168	0,75	2457	1 843	11 011	12,7	865	11 028	0
09.9-13.0	12,2	766	9 467	0,92	2925	2 691	12 158	13,1	785	10 283	+18
16.9-20.9	12,5	808	10 100	0,71	3152	2 238	12 338	13,2	889	11 735	+5
AVERAGES			11 917			2 788	14 704			12 648	+16
STANDARD DEV.			2 884			. 842	3 624			2 626	

TABLE 2.20

WEEKLY AVERAGE MASS BALANCES FOR COD BETWEEN SAMPLING POINTS P_4 P_9 and P_5.

Week	P_4			P_9			$P_4 + P_9$	P_5			%
	Flow Ml/d	Conc mg/l	Mass kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Mass Kg/d	Flow Ml/d	Conc mg/l	Mass kg/d	Error
10.06-14.06	11,6	427	4 932	15,6	43,0	670	5 602	26,2	118	3 204	+75
17.06-21.06	12,6	580	6 995	15,5	39,0	604	7 599	27,1	277	7 634	0
01.07-05.07	13,4	856	11 470	14,4	32,0	461	11 931	28,0	225	6 302	+89
08.07-12.07	12,6	407	5 128	15,0	26,0	370	5 518	28,2	253	7 135	-23
15.07-19.07	13,0	525	6 825	18,2	44,0	800	7 625	31,2	228	7 114	+7
22.07-26.07											
29.07-02.08	15,4	463	7 130	14,0	38,0	532	7 662	29,4	309	9 084	-16
05.09-09.08	15,4	471	7 253	13,6	63,0	857	8 110	29,0	369	10 701	-24
12.08-16.08	13,4	732	9 809	18,0	116	2 088	11 896	31,2	328	10 234	+16
26.08-20.08	12,8	408	5 202	13,6	51,0	694	5 896	26,7	207	5 527	+7
09.09-13.09	13,1	290	3 799	21,4	39,0	835	4 634	34,5	193	6 649	-30
16.09-20.09	13,2	392	5 174	18,7	40,0	748	5 922	32,5	176	5 720	+4
AVERAGES			6 702			787	7 490			7 209	+4
STANDARD DEV.			2 272			459	2 453			2 174	

TABEL 2.21 NON-CHEMICALLY DOSED,UNIT B
----- (UNFILTERED P MASS)

SAMPLE TIME	UNFILTERED P MASS (KgP/h)			
	SAMPLE POINT			MASS BALANCE (BP1+BP2)
	BP1	BP2	BP3	
6:30	3.25	.54	3.83	3.79
7:30	2.97	.73	3.63	3.70
8:30	5.64	1.02	7.64	6.66
9:30	15.48	1.19	22.51	16.67
10:30	6.52	1.29	8.47	7.81
11:30	9.74	.48	9.74	10.22
0:30	9.36	.44	8.92	9.80
1:30	8.68	.42	8.37	9.10
2:30	5.15	.43	5.04	5.58
3:30	6.27	.34	6.40	6.61
4:30	7.22	.38	8.35	7.60
5:30	5.57	.31	5.90	5.88
6:30	6.34	.45	7.18	6.79
7:30	8.60	.61	10.04	9.21
8:30	6.97	.59	8.12	7.56
9:30	7.15	.62	8.14	7.77
10:30	5.93	.62	6.69	6.55
11:30	4.03	.69	4.76	4.72
0:30	4.91	.69	5.33	5.60
1:30	3.83	.69	3.36	4.52
2:30	2.95	.64	2.63	3.59
3:30	2.11	51	2.59	2.62
4:30	1.70	.48	2.29	2.18
5:30	1.81	.50	2.15	2.31
6:30	3.34	.54	3.93	3.88
7:30	4.10	1.40	4.99	5.50
8:30	5.05	1.55	5.57	6.60
9:30	6.47	.95	7.21	7.42
10:30	6.60	.94	8.92	7.54
11:30	6.52	1.15	8.37	7.68
0:30	12.25	.99	14.28	13.24
1:30	9.95	.91	12.54	10.86
2:30	8.34	1.26	10.18	9.60
3:30	7.86	1.68	9.53	9.54
4:30	8.37	1.56	10.72	9.93

TABEL 2.22 NON-CHEMICALLY DOSED, UNIT B

(FILTERED P MASS)

SAMPLE TIME	FILTERED P MASS (KgP/h)			
	SAMPLE POINT			MASS BALANCE (BP1+BP2)
	BP1	BP2	BP3	
6:30	2.04	.23	2.15	2.27
7:30	1.83	.24	2.07	2.07
8:30	3.48	.28	3.92	3.76
9:30	10.04	.22	11.04	10.26
10:30	4.31	.27	4.72	4.58
11:30	6.77	.21	6.94	6.98
0:30	1.20	.23	6.86	1.43
1:30	3.97	.20	5.68	4.17
2:30	2.54	.19	3.18	2.73
3:30	4.63	.21	4.49	4.84
4:30	5.60	.27	6.12	5.87
5:30	3.56	.20	3.93	3.76
6:30	4.73	.22	4.36	4.95
7:30	6.49	.28	6.54	6.77
8:30	4.52	.28	5.11	4.80
9:30	4.54	.28	4.74	4.82
10:30	3.76	.26	4.07	4.02
11:30	2.62	.24	2.88	2.86
0:30	3.19	.23	3.44	3.42
1:30	2.03	.21	2.35	2.24
2:30	1.51	.21	1.92	1.72
3:30	1.40	.24	1.80	1.64
4:30	1.13	.26	1.43	1.39
5:30	1.19	.23	.96	1.42
6:30	2.26	.22	1.98	2.48
7:30	2.71	.27	2.96	[illegible]
8:30	2.76	.24	2.90	3.[illegible]0
9:30	3.68	.22	3.99	3.90
10:30	5.70	.22	6.21	5.92
11:30	4.59	.28	5.70	4.87
0:30	7.65	.25	8.25	7.90
1:30	7.80	.23	7.55	8.03
2:30	6.40	.47	7.47	6.87
3:30	5.89	.74	7.16	6.63
4:30	6.51	.65	7.68	7.16

TABEL 2.23 CHEMICALLY DOSED, UNIT C
(UNFILTERED P MASS)

SAMPLE TIME	UNFILTERED P MASS (KgP/h)			
	SAMPLE POINT			MASS BALANCE (CP1+CP2)
	CP1	CP2	CP3	
6:30	1.98	1.64	5.38	3.62
7:30	3.80	1.16	8.47	4.96
8:30	3.44	.93	7.06	4.37
9:30	4.85	.66	7.36	5.51
10:30	4.84	.65	5.27	5.49
11:30	5.04	.41	7.00	5.45
0:30	7.98	.41	11.67	8.39
1:30	6.07	.25	7.34	6.32
2:30	4.78	.24	4.86	5.02
3:30	3.31	.38	4.13	3.69
4:30	5.03	.43	7.27	5.46
5:30	4.32	.39	6.33	4.71
6:30	5.80	.68	10.07	6.48
7:30	6.34	1.17	11.47	7.51
8:30	8.69	1.60	13.72	10.29
9:30	6.48	2.16	9.88	8.64
10:30	5.50	2.04	9.61	7.54
11:30	4.45	2.00	8.40	6.45
0:30	5.11	2.14	8.61	7.25
1:30	3.97	1.88	5.94	5.85
2:30	3.52	2.02	6.50	5.54
3:30	2.21	1.89	6.58	4.10
4:30	1.81	2.18	5.75	3.99
5:30	1.52	1.85	4.33	3.37
6:30	2.78	3.00	6.21	5.78
7:30	3.50	.35	6.04	3.85
8:30	3.15	1.79	6.85	4.94
9:30	4.39	1.37	8.99	5.76
10:30	7.10	1.56	10.28	8.66
11:30	7.17	1.71	9.57	8.88
0:30	7.94	1.79	10.76	9.73
1:30	8.47	1.83	12.12	10.30
2:30	7.16	1.89	8.93	9.05
3:30	6.64	1.80	7.37	8.44
4:30	7.70	2.29	10.12	9.99

TABEL 2.24 CHEMICALLY DOSED, UNIT C
(FILTERED P MASS)

SAMPLE TIME	FILTERED P MASS (KgP/h)			
	SAMPLE POINT			MASS BALANCE (CP1+CP2)
	CP1	CP2	CP3	
6:30	1.16	.12	1.52	1.28
7:30	2.18	.09	2.36	2.27
8:30	2.04	.03	1.64	2.07
9:30	3.16	.02	2.72	3.18
10:30	3.08	.03	3.34	3.11
11:30	5.01	.02	4.24	5.03
0:30	8.15	.02	6.10	8.17
1:30	3.45	.01	3.46	3.46
2:30	2.43	.03	3.00	2.46
3:30	2.42	.06	2.41	2.48
4:30	3.90	.07	3.67	3.97
5:30	2.99	.04	2.69	3.03
6:30	4.34	.04	3.54	4.38
7:30	4.46	.04	3.95	4.50
8:30	5.73	.04	5.19	5.77
9:30	4.41	.04	4.11	4.45
10:30	3.71	.03	3.26	3.74
11:30	2.97	.02	2.51	2.99
0:30	3.32	.03	2.96	3.35
1:30	2.23	.03	2.01	2.26
2:30	1.99	.06	1.74	2.05
3:30	1.46	.06	1.27	1.52
4:30	1.10	.04	.88	1.14
5:30	.90	.03	1.18	.93
6:30	1.76	.04	2.17	1.80
7:30	2.33	.01	2.44	2.34
8:30	2.39	.04	2.43	2.43
9:30	3.02	.01	3.00	3.03
10:30	5.25	.01	4.96	5.26
11:30	6.04	.03	5.38	6.07
0:30	6.61	.05	5.90	6.66
1:30	6.74	.11	5.92	6.85
2:30	5.86	.12	4.58	5.98
3:30	5.09	.04	4.45	5.13
4:30	5.93	.03	5.67	5.96

TABEL 2.25 NON-CHEMICALLY DOSED, UNIT B.
(UNFILTERED P MASS)

SAMPLE TIME	UNFILTERED P MASS (KgP/h)			
	SAMPLE POINT			MASS BALANCE (BP4+BP9)
	BP4	BP9	BP5	
6:30	3.78	3.93	8.06	7.71
7:30	1.91	3.95	5.98	5.86
8:30	3.32	3.91	7.34	7.23
9:30	3.90	3.55	7.30	7.45
10:30	3.64	3.29	7.11	6.93
11:30	4.80	3.14	7.63	7.94
0:30	6.26	3.44	9.22	9.70
1:30	4.44	3.04	7.74	7.48
2:30	3.66	3.03	6.60	6.69
3:30	4.45	3.07	7.17	7.52
4:30	5.25	3.09	8.06	8.34
5:30	4.51	2.79	7.61	7.30
6:30	5.16	3.25	8.06	8.41
7:30	5.63	4.47	8.64	10.10
8:30	5.27	4.80	10.00	10.07
9:30	5.27	4.60	11.48	9.87
10:30	4.58	4.41	9.86	8.99
11:30	4.46	4.52	9.22	8.98
0:30	4.64	4.66	9.55	9.30
1:30	4.71	5.06	9.92	9.77
2:30	3.47	5.35	8.88	8.82
3:30	2.86	4.57	7.52	7.43
4:30	2.78	4.76	7.45	7.54
5:30	2.30	4.17	6.32	6.47
6:30	1.73	4.23	5.79	5.96
7:30	1.74	3.99	5.43	5.73
8:30	2.46	4.07	6.05	6.53
9:30	4.68	3.73	7.83	8.41
10:30	5.25	3.81	8.75	9.06
11:30	5.28	3.46	8.32	8.74
0:30	6.42	4.01	10.15	10.43
1:30	7.39	4.15	11.64	11.54
2:30	6.93	4.23	10.40	11.16
3:30	7.37	3.99	10.63	11.36
4:30	8.49	4.09	12.54	12.58

TABEL 2.26 NON-CHEMICALLY DOSED, UNIT B.
(FILTERED P MASS)

SAMPLE TIME	FILTERED P MASS (KgP/h)			
	SAMPLE POINT			MASS BALANCE (BP4+BP9)
	BP4	BP9	BP5	
6:30	2.32	2.97	6.74	5.29
7:30	1.47	3.60	5.40	5.07
8:30	2.50	3.63	6.35	6.13
9:30	3.05	3.24	6.40	6.29
10:30	3.24	3.12	6.45	6.36
11:30	3.91	2.89	6.95	6.80
0:30	4.96	3.18	8.11	8.14
1:30	3.64	2.64	6.82	6.28
2:30	2.60	2.43	5.68	5.03
3:30	3.19	2.75	5.96	5.94
4:30	4.18	3.16	7.20	7.34
5:30	3.16	3.27	6.76	6.43
6:30	3.78	3.38	7.74	7.16
7:30	5.29	4.17	8.78	9.46
8:30	5.10	4.55	8.22	9.65
9:30	5.12	4.34	8.99	9.46
10:30	4.15	4.18	8.06	8.33
11:30	3.45	4.23	7.37	7.68
0:30	3.50	4.36	7.87	7.86
1:30	3.69	4.06	7.87	7.75
2:30	2.83	4.24	7.22	7.07
3:30	2.35	4.28	6.06	6.63
4:30	2.27	4.45	6.10	6.72
5:30	1.89	3.96	5.66	5.85
6:30	1.37	3.97	5.20	5.34
7:30	1.33	3.36	4.90	4.69
8:30	1.95	3.31	5.50	5.26
9:30	3.63	3.31	6.60	6.94
10:30	4.04	3.54	7.28	7.58
11:30	4.66	3.11	7.68	7.77
0:30	5.63	3.59	8.99	9.22
1:30	6.14	3.96	9.94	10.10
2:30	5.92	4.06	9.32	9.98
3:30	6.04	3.77	9.18	9.81
4:30	6.58	3.76	10.41	10.34

TABEL 2.27 CHEMICALLY DOSED, UNIT C.
(UNFILTERED P MASS)

SAMPLE TIME	UNFILTERED P MASS (KgP/h)			
	SAMPLE POINT			MASS BALANCE (CP4+CP9)
	CP4	CP9	CP5	
6:30	1.58	.44	2.62	2.02
7:30	1.56	.36	2.39	1.92
8:30	2.14	.32	2.96	2.46
9:30	2.24	.27	3.42	2.51
10:30	2.45	.23	3.81	2.68
11:30	3.24	.11	4.18	3.35
0:30	4.75	.13	6.05	4.88
1:30	4.62	.23	5.78	4.85
2:30	3.69	.33	4.46	4.02
3:30	2.86	.68	9.25	3.54
4:30	4.46	.36	5.77	4.82
5:30	3.51	.36	5.25	3.87
6:30	4.25	.55	6.08	4.80
7:30	5.33	.70	7.50	6.03
8:30	6.16	.45	7.91	6.61
9:30	5.45	.80	8.43	6.25
10:30	4.28	.78	6.38	5.06
11:30	4.54	.87	6.55	5.41
0:30	3.98	.87	6.04	4.85
1:30	4.24	.83	6.20	5.07
2:30	3.20	.84	5.25	4.04
3:30	2.63	.90	4.63	3.53
4:30	2.56	.83	4.24	3.39
5:30	2.07	.71	3.40	2.78
6:30	1.72	.58	2.85	2.30
7:30	1.63	.66	2.62	2.29
8:30	1.35	.70	2.57	2.05
9:30	2.80	.35	3.80	3.15
10:30	3.28	.25	4.28	3.53
11:30	4.28	.46	6.46	4.74
0:30	5.58	.42	7.19	6.00
1:30	5.88	.42	6.81	6.30
2:30	4.56	.66	6.67	5.22
3:30	4.59	.55	6.27	5.14
4:30	5.74	.51	7.50	6.25

TABEL 2-28 CHEMICALLY DOSED, UNIT C.
(FILTERED P MASS)

SAMPLE TIME	FILTERED P MASS (KgP/h)			
	SAMPLE POINT			MASS BALANCE (CP4+CP9)
	CP4	CP9	CP5	
6:30	1.06	.27	1.87	1.33
7:30	1.07	.11	1.48	1.18
8:30	1.40	.08	1.86	1.48
9:30	1.47	.16	2.24	1.63
10:30	1.79	.23	2.96	2.02
11:30	2.67	.06	3.30	2.73
0:30	3.99	.03	4.72	4.02
1:30	3.83	.09	4.66	3.92
2:30	2.88	.24	3.41	3.12
3:30	2.42	.48	4.00	2.90
4:30	4.08	.15	4.58	4.23
5:30	2.93	.19	3.97	3.12
6:30	3.50	.30	4.54	3.80
7:30	4.25	.32	5.36	4.57
8:30	4.37	.24	5.42	4.61
9:30	3.97	.47	6.08	4.44
10:30	2.97	.45	4.87	3.42
11:30	3.05	.52	4.94	3.57
0:30	3.05	.49	4.50	3.54
1:30	3.23	.46	4.78	3.69
2:30	2.47	.52	4.04	2.99
3:30	2.10	.59	3.33	2.69
4:30	2.00	.50	3.02	2.50
5:30	1.45	.43	2.42	1.88
6:30	1.16	.35	1.90	1.51
7:30	1.33	.40	1.88	1.73
8:30	1.09	.50	1.76	1.59
9:30	2.07	.24	2.63	2.31
10:30	2.62	.06	3.37	2.68
11:30	3.71	.23	5.10	3.94
0:30	4.80	.34	6.00	5.14
1:30	4.85	.33	5.67	5.18
2:30	3.75	.43	5.03	4.18
3:30	3.39	.33	4.82	3.72
4:30	4.44	.28	6.78	4.72

TABLE 4.1

CONDITIONS REIGNING DURING THE TEST FOR THE EFFECT OF INCREASED SOLIDS LOAD AND INCREASED LINEAR UPFLOW RATES IN THE SECONDAY CLARIFIERS

CLARIFIER INFLUENT	PERIOD 1	PERIOD 2	PERIOD 3
Dates	5/5 - 20/5/86	4/7 - 21/7/86	22/7 - 31/7/86
Raw inflow to works/ clarifier (Ml/d)	2,77	3,87	5,93
Effluent Recycle rate clarifier (Ml/d)	4,86	6,3	9,33
Number of clarifiers in operation	4	3	2
Average influent feed rate/clarifier (Ml/d)	7,63	10,17	15,26
Average linear upflow rate (m/h)	0,84	1,12	1,67

TABLE 4.2

HUMUS TANK EFFLUENT QUALITY WITH AND WITHOUT POLY-ELECTROLYTE DOSING

	16/2 - 20/2/87		23/3 - 27/3/87		30/3/ - 3/4/87	
No. of Humus Clarifiers in use	3		2		2	
Poly Electrolyte Dosing (mg/l)	0,11		0,15		0,23	
Raw Inflow to Works Unit C, (Ml/d)	19,103		19,146		19,326	
Biofilter Effluent Volume CP_6 (Ml/d)	27,572		34,722		30,672	
Volume of Humus/Chem. Recycle CP_2 (Ml/d)	0,950		2,278		1,930	
Concentration of Humus/ Chemical Recycle (mg/l)	1,790		0,556		0,679	
Mass of Chemical/ Humus Sludge (t/d)	1,70		1,27		1,31	
Volume of Flow per Humus Tank (Ml/d)	9,191		17,361		15,336	
$FeCl_3$ dosing (mg/l)	42,12		40,66		43,82	
Upflow Rate (m/hr)	1,0		1,9		1,7	
	Without Poly	With Poly	Without Poly	With Poly	Without Poly	With Poly
	T D	T D	T D	T D	T D	T D
Ortho-P in Effluent CP_7 T = Total D = Dissolved	1,0 0,5	1,3 0,6	1,9 1,1	1,9 1,1	1,4 0,5	0,9 0,6
Fe in Effluent CP_7 T = Total D = Dissolved		2,7 2,2		2,5, 0,3		1,5 0,7

TABLE 4.3

DAILY ANALYSIS OF CHEMICALLY REMOVED ORTHO-P AT DOSING POINTS

WEEK DATES	DOSING RATE $mgFeCl_3/d$	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY		AVE	X STOICH
		CP_6	CP_7	CP_6	CP_7	CP_6	CP_7	CP_6	CP_7	CP_6	CP_7	CP_7	
01.07-05.07.85	32,3	2,9	0,5	5,1	0,6	4,9	0,8	5,3	1,7	4,7	1,1	0,9	1,7
08.07-12.07	32,3	3,2	0,5	4,1	1,2	4,1	0,6	5,5	1,5	4,0	1,2	1,0	1,6
15.07-19.07	31,4	3,3	0,9	3,1	1,0	3,9	0,9	4,1	1,0	3,8	1,1	1,0	1,7
22.07-26.07	31,4	2,8	0,6	3,6	0,8	2,9	0,4	4,1	1,3	5,3	1,2	0,9	1,8
29.07-02.08	32,0	3,7	0,8	4,6	1,0	3,9	0,4	4,0	0,9	6,3	2,7	1,2	1,4
05.08-09.08	38,9	2,8	0,3	3,0	0,6	6,7	2,0	6,3	2,4	5,2	0,4	1,1	1,8
12.08-16.08	51,9	3,6	0,5	3,3	0,8	5,2	0,7	2,1	0,2	4,7	3,6	1,2	2,6
26.08-30.08	33,7	3,1	0,5	3,7	1,0	4,0	1,4	2,5	1,0	4,5	0,8	0,9	1,8
09.09-13.09	43,0	3,4	0,6	1,1	1,0	0,2	0,3	2,6	1,2	2,1	0,3	0,7	2,6
16.09-20.09	43,0	2,7	0,7	2,4	0,3	3,5	1,0	3,6	0,9	3,3	0,7	0,7	2,2
23.09-27.09	41,3	3,1	0,5	3,0	0,5	4,1	1,5	3,5	1,0	4,1	1,4	1,0	1,8
30.09-04.10	41,3	2,6	0,6	2,1	0,0	3,2	0,6	3,6	0,6	4,4	1,7	0,7	2,0
07.10-11.10	33,9	3,8	0,7	3,4	0,4	3,7	1,0	2,3	0,4	11,4	4,4	0,6	1,9
DAILY AVERAGE		3,2	0,6	3,2	0,7	3,8	0,9	3,8	1,1	4,4	1,3	0,9	
NO. OF TIMES 1,0 mg/l WAS EXCEEDED			0		1		3		5		8		

* Data ignored because dosing pump was switched off.

TABLE 4.4

CALCULATED VOLUMETRIC $FeCl_3$ DOSING RATES BASED ON THE "DAILY-FOUR WEEK MOVING AVERAGE" DOSING STRATEGY.

	WEEK	SUN.	MON.	TUES.	WED.	THUR.	FRI.	SAT.
Ortho-P	1	3,0	4,7	4,6	4,6	5,9	5,7	3,8
Concentration	2	3,0	4,2	3,9	4,6	5,6	5,3	3,8
In Biofilter	3	3,0	3,1	3,9	4,1	5,0	4,5	3,8
Effluent	4	3,0	3,3	3,4	4,1	5,3	5,0	3,8
	AVE.	3,0	3,8	3,8	4,4	5,3	5,0	3,8
-0,8P (Target Eff. Conc.)		-0,8	-0,8	-0,8	-0,8	-0,8	-0,8	-0,8
Ortho-phosphate to be removed		2,2	3,0	3,0	3,6	4,5	4,2	3,0
mg/l x 10,48 = mg/l $FeCl_3$		23,05	31,44	31,44	37,7	47,16	44,10	31,44
ml/min. $FeCl_3$ at 288601/m (P6)		1065	1452	1452	1741	2178	2032	1452
Daily dose setting at P6 ml/min.		1040	1452	1452	1741	2178	2032	1452

Analysis on the plant indicated that twice the stoichiometric dose is required to achieve the phosphate standard. Therefore 2 x 5,24 = 10,48 mg$FeCl_3$ solution is required to remove lmg phosphate.

To calculate the dosing volume per minute:

mg/l P x 10,48 = mg/l $FeCl_3$ to remove phosphate

$$\text{ml/min.} = \frac{\text{mg/l P to be removed x 100\% flow at dosing point in l/m}}{\text{mg/l } FeCl_3 \text{ per litre}}$$

TABLE 4.5

COMPARISON OF THREE $FeCl_3$ DOSING STRATEGIES.

DOSING STRATEGY	MONTH	TIMES STOICHIOMETRIC	PERCENTAGE COMPLIANCE WITH SET ,g/; +0,OT			
			(1,0)	(1,5)	(2,0)	(4,0)
Constant with Incremental Adjustment	May 86	1,95	38	52	70	86
	June 86	2,44	47	65	70	94
Constant dose adjusted Thursdays and Fridays	July 86	1,82	42	72	84	100
	Aug. 86	1,63	10	38	71	100
Dosage 2,0 x Stoich. x previous 4 day moving average ortho-phosphate concentration	Sept.86	1,87	27	41	68	100
	Oct. 86	2,10	45	82	91	100
	Nov. 86	1,85	40	50	75	100
	Dec. 86	1,87	90	90	100	100
	Jan. 87	1,86	70	85	100	100
	Feb. 87	2,23	75	90	95	100

TABLE 5.1 : Weekly Averages of Daily Raw Sludge Production

Period	UNIT B					UNIT C				
	Volume (m3)	Conc (gm/l)	Inflow (Ml)	Mass (kg)	Mass/Ml (kg/Ml)	Volume (m3)	Conc (gm/l)	Inflow (Ml)	Mass (kg)	Mass/Ml (kg/Ml)
01/07/85-05/07	116	47.4	14.1	5498	391	131	51.0	12.6	6681	530
08/07 -- 12/07	120	36.5	13.1	4620	353	143	38.0	12.1	5434	449
15/07 -- 19/07	122	39.0	12.9	4758	369	122	39.0	12.2	4758	390
22/07 -- 26/07	126	42.0	13.3	5292	398	126	42.0	11.9	5292	445
29/07 -- 02/08	139	34.8	12.5	4837	387	143	47.6	15.2	6807	448
05/08 -- 09/08	139	54.8	12.8	7617	595	172	45.9	13.7	7895	576
12/08 -- 16/08	139	50.0	12.2	6950	570	155	43.2	12.7	6696	527
19/08 -- 23/08	139	41.2	12.7	5727	451	142	40.0	12.4	5680	458
26/08 -- 30/08	139	46.1	12.7	6408	505	143	40.2	12.5	5749	460
02/09 -- 06/09	139	41.1	12.7	5697	449	145	36.7	10.5	5749	505
09/09 -- 13/09	139	43.7	12.6	6057	482	143	44.5	12.3	6355	517
16/09 -- 20/09	143	55.0	12.3	7870	650	149	49.2	12.2	7321	602
23/09 -- 27/09	162	30.8	12.2	4999	410	180	32.6	11.9	5852	490
30/09 -- 06/10	169	42.6	12.1	7178	593	163	44.2	13.2	7200	498
07/10 -- 13/10	142	43.0	11.1	6083	548	172	45.5	11.7	7817	668
14/10 -- 20/10	139	37.2	12.6	5156	409	149	48.1	10.0	7157	722
21/10 -- 27/10	142	43.9	11.0	6211	565	171	41.5	11.0	7092	642
28/10 -- 03/11	145	72.6	19.9	10520	529	165	61.5	15.8	10141	640
04/11 -- 10/11	135	39.0	12.7	5248	412	137	46.9	12.1	6444	531
11/11 -- 15/11	142	46.5	10.1	6617	651	164	38.7	11.2	6355	568
18/11 -- 22/11	139	58.2	11.6	8136	699	172	45.1	11.6	7753	667
25/11 -- 29/11	139	43.4	14.9	6015	403	147	49.0	13.2	7198	546
02/12 -- 06/12	142	52.1	11.0	7414	623	171	48.6	11.8	8311	706
09/12 -- 13/12	138	51.8	10.9	7164	657	168	42.7	11.9	7157	601
17/12 -- 20/12	125	32.7	11.8	4078	345	133	44.0	10.8	5834	541
06/01/86-10/01	120	36.5	10.4	4668	448	122	48.4	10.3	5924	576
13/01 -- 17/01	131	48.4	11.1	6350	570	142	37.8	11.9	5383	452
20/01 -- 24/01	142	68.9	15.7	9804	624	143	47.0	16.1	6712	417
27/01 -- 31/01	120	42.1	12.7	5052	397	122	46.8	10.8	5728	528
02/06 -- 06/06	136	33.8	12.0	4685	361	143	51.7	13.4	7376	543
09/06 -- 13/06	130	36.6	12.0	4672	395	177	42.4	12.4	8224	652
16/06 -- 20/06	139	49.9	11.1	6919	678	180	43.9	10.6	7783	786
23/06 -- 27/06	132	25.5	11.9	3369	287	143	50.6	11.0	7226	669
30/06 -- 04/07	139	41.0	12.8	5687	443	145	41.7	12.6	5950	485
07/07 -- 11/07	139	30.1	12.3	4169	361	169	35.2	11.0	5745	482
14/07 -- 18/07	139	47.7	11.2	6619	616	143	41.1	11.4	5866	515
21/07 -- 27/07	152	42.4	11.8	6701	588	149	44.0	12.0	6289	543
28/07 -- 01/08	144	55.7	12.0	8150	679	188	41.5	11.7	8061	696
04/08 -- 08/08	182	28.1	12.2	5225	438	143	37.4	12.0	5335	440
11/08 -- 15/08	188	40.4	11.8	7846	667	148	40.4	12.3	6117	499
18/08 -- 22/08	139	51.4	12.2	7117	554	180	45.3	11.8	8094	667
25/08 -- 21/08	196	37.2	12.0	7291	641	143	43.4	12.1	6203	527
01/09 -- 07/09	139	33.0	12.2	4574	351	143	42.8	11.0	6112	519
08/09 -- 12/09	139	61.3	11.5	8493	762	177	43.4	11.1	7621	679
15/09 -- 19/09	168	34.0	12.3	6679	550	143	45.1	11.4	6443	570
22/09 -- 26/09	139	45.1	12.1	6254	503	143	47.8	11.9	6820	560
29/09 -- 30/09	139	46.2	9.2	6398	661	172	44.8	14.7	7311	538
06/10 -- 09/10	160	36.7	9.9	6626	669	143	46.3	12.4	6612	493
13/10 -- 17/10	139	44.9	11.6	6226	516	148	46.9	12.8	6700	549
20/10 -- 24/10	139	53.2	11.3	7379	659	177	46.6	14.0	8096	571
27/10 -- 31/10	139	37.2	13.9	5156	401	143	53.6	15.2	7660	507
03/11 -- 07/11	139	55.4	14.3	7678	608	160	46.7	14.2	8016	549
10/11 -- 14/11	139	54.8	14.1	7590	514	211	48.6	13.1	10809	769
17/11 -- 21/11	139	44.3	14.4	6143	430	154	49.8	12.7	8043	626
24/11 -- 28/11	139	48.9	16.4	6775	412	171	44.1	18.3	6300	465
01/12 -- 05/12	139	59.3	16.4	8222	480	183	46.8	16.3	8545	496
08/12 -- 12/12	139	32.8	15.0	4541	402	143	53.9	14.8	7700	507
15/12 -- 19/12	136	58.5	17.8	7971	439	163	54.6	16.5	8603	509
22/12 -- 24/12	139	51.7	15.9	7151	450	143	38.1	13.5	5436	401
28/12 -- 31/12	126	33.3	22.1	4202	203	143	35.3	18.3	5036	282
05/01/87-09/01	123	37.0	14.9	4690	307	143	39.1	11.4	5581	434
12/01 -- 16/01	142	54.3	18.7	7739	418	151	39.3	16.6	5811	350
19/01 -- 23/01	141	33.2	18.9	4659	245	143	46.7	14.5	6666	512
26/01 -- 30/01	139	54.6	15.6	7601	468	148	59.4	16.1	8477	511
02/02 -- 06/02	139	66.3	22.6	9186	383	177	50.8	22.2	9532	406
09/02 -- 13/02	144	36.0	16.6	5242	307	143	42.6	15.8	6078	370
16/02 -- 20/02	139	48.1	16.1	6664	414	143	48.2	17.4	6877	409
23/02 -- 27/02	139	57.1	14.5	7917	549	180	55.5	15.1	6991	672
02/03 -- 06/03	154	35.7	13.6	5391	401	143	49.0	22.3	6991	325
Average	141	44.9	13.4	6341	489	154	45.1	13.2	6893	533
Std Deviation	15	10.3	2.7	1449	129	18	5.5	2.5	1191	103

TABLE 5.2 : Weekly Averages of Daily Humus Sludge Production

Period	UNIT B Volume (Ml)	UNIT B Conc (mg/l)	UNIT B Inflow (Ml)	UNIT B Mass (kg)	UNIT B Mass/Ml (kg/Ml)	UNIT C Volume (Ml)	UNIT C Conc (mg/l)	UNIT C Inflow (Ml)	UNIT C Mass (kg)	UNIT C Mass/Ml (kg/Ml)
01/07/85-05/07	0.900	1108	14.1	995	71	0.790	2695	12.6	2219	169
08/07 -- 12/07	0.970	1534	13.1	1488	114	0.840	2271	12.1	1908	158
15/07 -- 19/07	1.070	513	12.9	549	43	0.840	2168	12.2	1821	149
22/07 -- 26/07	1.200	1692	13.3	2030	153	0.860	2421	11.9	2082	175
29/07 -- 02/08	1.200	1089	12.5	1307	105	0.810	3542	15.2	2869	189
05/08 -- 09/08	1.120	947	12.8	1079	84	0.720	4800	13.7	3456	252
12/08 -- 16/08	1.120	1746	12.2	1956	160	0.750	4861	12.7	3646	287
26/08 -- 30/08	1.120	1294	12.7	1449	114	0.750	2668	12.5	2001	160
09/09 -- 13/09	1.200	2071	12.7	2485	196	0.710	3184	12.3	2260	184
16/09 -- 20/09	1.250	712	10.7	890	83	0.710	3738	12.2	2654	218
23/09 -- 27/09	1.300	1152	12.2	1498	123	0.950	2844	12.3	2702	220
30/09-06/10/85	1.210	1310	12.1	1585	131	1.070	2462	12.8	2634	206
28/04/86-02/05	1.020	721	12.5	734	58	0.872	1936	12.1	1638	135
05/05 -- 10/05	0.182	2429	10.7	446	40	0.356	1495	11.1	565	48
12/05 -- 16/05	0.166	5676	11.7	795	66	0.211	1036	12.0	249	21
19/05 -- 23/05	1.021	607	11.2	616	56	0.892	2248	11.1	1549	161
26/05 -- 30/05	0.876	749	11.1	661	61	0.482	3327	11.6	1494	128
02/06 -- 06/06	1.000	733	12.9	730	57	0.497	2726	12.9	1156	97
09/06 -- 13/06	0.862	1701	12.0	440	36	0.387	3375	12.9	1189	94
16/06 -- 20/06	0.817	1385	10.4	944	124	1.192	942	10.0	1125	118
23/06 -- 27/06	0.881	480	13.3	425	32	1.503	703	12.6	991	79
30/06 -- 04/07	0.886	571	12.7	514	41	1.408	883	12.4	1246	100
07/07 -- 11/07	0.864	1682	11.7	1462	127	1.123	2689	12.0	3001	248
14/07 -- 18/07	0.883	1562	11.3	1375	124	1.383	1777	11.5	2542	215
21/07 -- 27/07	1.149	992	11.6	1145	97	1.447	1487	12.2	2270	190
28/07 -- 01/08	1.026	1189	11.9	1201	102	2.458	1606	11.6	4193	347
04/08 -- 08/08	0.993	1131	13.0	1125	86	1.933	1229	12.5	2404	191
11/08 -- 15/08	1.112	1612	12.1	1794	150	1.866	907	12.3	1677	136
18/08 -- 22/08	0.863	2554	12.8	2602	203	1.930	716	12.1	1387	114
25/08 -- 21/08	1.022	2095	12.0	2296	188	1.648	1386	12.1	2254	183
01/09 -- 07/09	1.104	1083	11.9	1201	102	1.639	1182	11.2	1921	174
08/09 -- 12/09	1.118	1117	11.4	1286	110	1.565	1380	11.2	2168	195
15/09 -- 19/09	1.074	2095	12.4	2241	187	1.674	1553	11.4	2588	230
22/09 -- 26/09	1.161	1852	12.5	2140	181	1.604	2058	11.6	3248	280
29/09 -- 30/09	0.993	1232	10.7	1230	125	1.398	2259	13.3	3147	244
06/10 -- 09/10	1.043	1290	10.1	1324	140	1.313	1912	13.5	2505	188
13/10 -- 17/10	1.163	1767	12.7	2020	167	1.234	2403	29.5	2936	179
20/10 -- 24/10	1.106	1456	11.4	1642	135	1.297	2320	15.2	3017	210
27/10 -- 31/10	1.411	1494	13.9	2052	156	1.514	2146	16.1	3246	221
03/11 -- 07/11	1.212	1114	13.6	1378	98	1.615	3909	14.2	7468	567
10/11 -- 14/11	1.157	944	14.7	1103	76	1.299	2167	13.6	2877	212
17/11 -- 21/11	1.849	1239	14.5	2210	159	1.206	2378	12.7	2887	234
24/11 -- 28/11	1.220	1697	16.7	2049	131	1.170	2102	13.6	2324	174
01/12 -- 05/12	1.242	995	17.2	1247	73	1.153	2155	17.2	2491	146
08/12 -- 12/12	0.911	1355	15.4	368	33	1.215	1907	15.2	2329	153
15/12 -- 19/12		1576	18.1			1.255	1869	17.8	2349	143
05/01/87-09/01	1.165	1443	14.8	1744	118	1.124	1091	13.5	1166	86
12/01 -- 16/01	1.163	958	18.7	1102	59	1.130	2803	16.6	2689	164
19/01 -- 23/01	1.343	1179	19.7	1562	78	1.242	1325	13.8	1692	121
26/01 -- 30/01	1.060	1916	16.3	1992	120	1.067	1498	16.6	1532	92
02/02 -- 06/02	1.137	908	24.2	1013	43	1.077	1659	23.9	1786	73
09/02 -- 13/02	1.297	881	17.2	1219	72	0.993	2039	16.1	2010	126
16/02 -- 30/02	1.056	830	16.2	862	54	0.950	1790	19.1	1638	99
23/02 -- 29/02	1.130	2552	14.5	2860	208	0.814	2569	15.1	2122	136
Average	1.064	1408	13.4	1367	107	1.147	2159	13.7	2284	174
Std Deviation	0.247	776	2.6	614	49	0.439	931	3.2	1062	83

TABLE 5.3

COMPARISON OF SLUDGE PRODUCTION RATES IN THE PRIMARY SETTLING TANKS FROM UNITS WITH (UNIT C) AND WITHOUT (UNIT B) $FeCl_3$ ADDITION.

Parameter	Unit B	Unit C	DIFFERENCE (%) (C-B)
Sludge Volume (m^3/d)	141 (±15)	154 (± 18)	+13 (9%)
Sludge Concentration (g/l)	44,9 (±10)	45,1 (± 5)	+ 0,2 (0,5%)
Raw Sewage Flow Rate (ML/d)	13,4 (±2,7)	13,2 (± 2,5)	- 0,2 (1,5%)
Volume Sludge/Volume of Raw Sewage (m^3/Ml)	10,5	11,7	+ 1,2 (11%)
Mass of Raw Sludge (t/d)	6,34 (±1,45)	6,89 (± 1,19)	+ 0,55 (8,7%)
Mass of Raw Sludge/Volume of Raw Sewage (kg/Ml)	489 (±124)	533 (±103)	+ 44 (9%)
Mass of Raw Sludge/Mass of EOD removed (+ sludge/t O_2)	1,81	1,55	0,26 (14%)

TABLE 5.4

COMPARISON OF HUMUS TANK SLUDGE PRODUCTION RATES FOR UNITS WITH (UNIT C) AND WITHOUT (UNIT B) $FeCl_3$ ADDITION.

PARAMETER	UNIT B	UNIT C	DIFFERENCE (%)
Sludge Volume (m^3/d)	1064 (± 247)	1147 (±4,39)	+ 83 (8%)
Concentration (g/l)	1,41 (± 0,76)	2,16(±0,93)	+ 0,75 (53%)
Sewage Flow Treated(Ml/d)	13,4 (± 2,6)	13,7 (±3,2)	+ 0,3 (2%)
Volume Sludge/Ml Sewage (m^3/Ml)	79,4	83,7	4,3 (5%)
Mass of Sludge (t/d)	1,37 (0,61)	2,28(±1,06)	+ 0,91 (66%)
Mass of Sludge/Volume of sewage treated (kg/Ml)	107 (± 49)	174(± 83)	+ 67 (63%)

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TABLE 6.1

RAW SEWAGE OVERALL AVERAGE QUALITY FOR UNITS B AND C
FOR PERIOD JUNE 1985 - MARCH 1987.

PARAMETER	UNIT B		UNIT C	
	AVE.*	STD. DEV*	AVE.	STD. DEV.
COD (mg/l)	768,0	121,0	807,0	168,0
Total-P (mgP/l)	12,0	1,9	11,8	2,2
Ortho-P (mgP/l)	8,7	1,7	8,4	1,7
NH_4-N (mgN/l)	29,2	9,6	28,7	8,3
Cl (mgCl/l)	113,0	49,0	126,0	33,0
Alkalinity ($mgCaCO_3/l$)	236,0	38,0	244,0	40,0
Ca-hardness ($mgCaCO_3/l$)	158,0	26,0	156,0	34,0
Conductivity (mS/m)	93,0	16,0	92,0	18,0
Total Fe (mg/l)	2,5	0,9	2,8	1,2
Dissolved Fe (mg/l)	1,1	0,5	1,2	0,6

* Averages and standard deviations based on weekly averages for all parameters.

TABLE 6.2

RAW SEWAGE OVERALL AVERAGE POLLUTANT LOADS ON UNITS B AND C
FOR THE PERIOD JUNE 1985 - MARCH 1987.

	UNIT B		UNIT C	
PARAMETERS	AVERAGE*	STANDARD DEV*	AVERAGE*	STANDARD DEV*
COD (kg/d)	10 266	2 755	10 682	3 021
Total P (kg/d)	160	37	153	38
Ortho-P (kg/d)	115	25	110	29
NH_4-N (kg/d)	388	186	378	115

* Overall average and standard deviation are based on weekly averages.

TABLE 6.3

EFFECT OF HUMUS SLUDGE RECYCLE ON OVERALL POLLUTANT REMOVAL FROM RAW SEWAGE TO THE PRIMARY SEDIMENTATION TANKS OVER PERIOD JUNE 1985 - MARCH 1987.

PARAMETER	UNIT B			UNIT C		
	Influent	Effluent	Removal	Influent	Effluent	Removal
COD (mg/l)	768	499	269 (35%)	807	447	360 (45%)
Total-P (mg/l)	12,0	10,9	1,1 (9%)	11,8	8,8	3,0 (25%)
Ortho-P (mg/l)	8,7	8,7	0,0 (0%)	8,4	6,5	1,9 (23%)
Total Fe(mg/l)	2,5	1,9	0,6 (24%)	2,8	3,5	-0,7(-25%)
Diss Fe (mg/l)	1,1	0,9	0,2 (18%)	1,2	1,3	-0,1 (-8%)

TABLE 6.4

REDUCTION IN OVERALL AVERAGE COD AND PHOSPHATE LOADS THROUGH PRIMARY SETTLERS FOR UNITS B AND C FOR PERIOD JUNE 1985 - MARCH 1987

PARAMETER	UNIT B			UNIT C		
	Influent	Effluent	Removal	Influent	Effluent	Removal
COD (kg/d)	10 266	6 770	3 496 (34%)	10 682	6 240	4 442 (42%)
Total P (kgP/d)	160	153	-7 (4%)	153	125	28 (18%)
Ortho-P (kgP/d)	115	121	-6 (-5%)	110	94	16 (14.5%)

TABLE 6.5

OVERALL AVERAGE EFFLUENT QUALITY IMPROVEMENT BROUGHT ABOUT BY BIOLOGICAL FILTERS FOR UNITS B AND C OVER THE PERIOD JUNE 1985 - MARCH 1987.

PARAMETER	UNIT B			UNIT C		
	Influent	Effluent	Removal	Influent	Effluent	Removal
COD (mg/l)	321	123	198 (62%)	275	101	174 (63%)
Total-P (mg/l)	10,3	10,3	0,0 (0%)	5,9	5,3	0,6 (10%)
Ortho-P (mg/l)	8,6	8,9	-0,3 (-3%)	4,4	3,9	0,5 (11%)
Alkalinity ($mgCaCO_3/l$)	222	153	69 (31%)	201	136	65 (32%)
Total Fe (mg/l)	1,3	1,1	0,2	2,4	2,0	0,4 (17%)
Diss. Fe (mg/l)	0,7	0,5	0,2	1,0	0,7	0,3 (30%)
NH_4-N (mg/l)	-	2,0	-	-	2,5	-
NO_3-N (mg/l)	-	4,4	-	-	3,7	-
Ca-H ($mgCaCO_3/l$)	-	157	-	-	159	-

TABLE 6.6

REDUCTION OF POLLUTANT LOADS IN BIOLOGICAL FILTERS OVER THE PERIOD JUNE 1985 - MARCH 1987

PARAMETER	UNIT B			UNIT C		
	Influent	Effluent	Removal	Influent	Effluent	Removal
COD (mkg/d)	8044	2927	5117 (64%)	7335	2628	4707 (64%)
Total-P (kg/d)	252	257	-5 (-2%)	161	141	20 (12%)
Ortho-P (kg/d)	211	226	-15 (-7%)	123	109	14 (11%)
Alkalinity ($kgCaCO_3/d$)	5451	3603	1848 (34%)	5036	3417	1619 (32%)
Hardness ($kgCaCO_3/d$)	3902	3946	44 (1%)	4168	4163	5 (0,1%)
Total Fe (kg/d)	34	26	8 (24%)	64	52	12 (19%)
NH_4-N (kg/d)	-	52	-	-	73	-
NO_3-N (kg/d)	-	112	-	-	98	-

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TABLE 6.7

AVERAGE EFFLUENT QUALITY IMPROVEMENT BROUGHT ABOUT BY CHEMICAL PHOSPHATE REMOVAL AND SECONDARY CLARIFICATION OVER THE PERIOD JUNE 1985 - MARCH 1987

PARAMETER	UNIT B			UNIT C		
	Influent	Effluent	Removal	Influent	Effluent	Removal
COD	123	61	62 (50%)	101	51	50 (50%)
Total-P	10,3	9,6	0,7 (7%)	5,3	2,0	3,3 (62%)
Ortho-P	8,9	8,8	0,1 (1%)	3,9	1,2	2,7 (69%)
NH_4-N	2,0	3,0	-1,0 (-50%)	2,5	4,6	-2,1 (-84%)
NO_3-N	4,4	4,2	0,2 (5%)	3,7	3,6	-0,1 (- 3%)
Cl	-	124	-	-	171	-
Alkalinity	153	146	7 (5%)	136	111	25 (18%)
Ca-Hardness	157	153	4 (3%)	159	157	2 (1%)
Conductivity	-	80	-	-	82	-
Total-Fe	1,1	0,7	0,4 (36%)	2,0	2,0	0,0 (0%)
Dissolved-Fe	0,5	0,3	0,2 (40%)	0,7	0,7	0,0 (0%)

TABLE 6.8

REDUCTION OF POLLUTANT LOADS IN UNITS B AND C OVER THE PERIOD JUNE 1985 - MARCH 1987.

PARAMETER	UNIT B			UNIT C		
	Raw Sewage	Maturat. Pond Eff.	Removal	Raw Sewage	Maturat. Pond Eff.	Removal
COD (kg/d)	10 266	742	9524 (93%)	10 682	701	9981 (93%)
Total-P	160	120	40 (25%)	153	32	121 (79%)
Ortho-P	115	108	7 (6%)	110	18	92 (84%)
NH_4 + NO_3-N	388	82	306 (79%)	378	98	280 (74%)

TABLE 7.1.

CAPITAL COSTS ASSOCIATED CHEMICAL DOSING EQUIPMENT (1987)

ITEM	COST
1 Dosing pump (Double headed system)	R 6 000
1 AC/DC motor plus panel	R 1 700
1 Baseplate for mounting	R 300
1 Pump for polyelectrolyte, plus motor, gearbox and baseplate	R 2 000
1 Inline mixer max. 7 bar pressure at 60° made of PVC	R 450
Stainless steel weir	R 400
PVC pipes, valves and filters	R 2 350
Ultrasonic flowmeter with chart recorder	R 5 000
Electronic instrument panel	R10 000
Polyelectrolyte tanks	R 2 000
Ferrichloride tank	R14 000
Mixer for polyelectrolyte	R 3 000
Loading valves	R 500
Chemical balancing tank plus float valve	R 700
Emergency showers and taps	R 1 300
Loading platform to off-load chemicals (Valves & Piping)	R 600
TOTAL	R50 300

TABLE 7.2

AVERAGE ELECTRICITY CONSUMPTION ON BIOLOGICAL FILTER SYSTEMS

Electricity power consumption kwh/d.

DATE	UNIT B (CONTROL)	UNIT C (CHEMICAL)	UNIT A
29/10/86 - 05/10	1513	1193	1534
06/10/86 - 12/10	1530	1184	1514
13/10/86 - 19/10	2218	1796	2305
20/10/86 - 26/10	1958	1454	1666
27/10/86 - 02/11	1395	1431	2164
03/11/86 - 09/11	1087	1142	1552
10/11/86 - 16/11	1212	1612	1624
17/11/86 - 23/11	1698	1391	1484
24/11/86 - 30/11	1127	1142	1411
01/12/86 - 07/12	1213	964	1403
08/12/86 - 14/12	1233	1010	1266
15/12/86 - 21/12	1200	984	1269
22/12/86 - 28/12	1158	995	1201
29/12/86 - 04/01/87	879	911	1137
05/01/87 - 11/01	1148	984	1147
12/01/87 - 18/01	1060	946	1117
19/01/87 - 25/01	1078	967	1009
26/01/87 - 01/02	1104	956	1106

TABLE 7.3

VLAKPLAATS WATER POLLUTION CONTROL WORKS	ACTUAL COSTS 1985/1986
	R
SALARIES, WAGES & ALLOWANCES:	469 666,00
MISCELLANEOUS EXPENSES:	
Admin. : Stores	2 887,00
Public Works	105 580,00
Contribution - Equalization Fund	50 000,00
Printing & Stationery	376,00
Electricity	199 205,00
Laboratory - Consum	3 919,00
Licences : Radios	360,00
Sample Analysis	4 457,00
Sample Analysis Ind.	4 172,00
Nutrient Removal	224 098,00
Sewerage	73 800,00
Consumable Assets	1 744,00
Regional Services Levy	-
Telephone	3 933,00
Stores Consumable	10 811,00
Insurance	7 346,00
Transport	96 360,00
Water	10 944,00
	799 992,00
REPAIRS & MAINTENANCE:	
Buildings	12 009,00
Meters	7 947,00
FURNITURE & EQUIPMENT	-
Sewerage Purification Works	108 438,00
	128 394,00
LOAN CHARGES:	
CLF Interest	706 991,00
CLF Redemption	343 594,00
CDF Interest	10 926,00
CDF Redemption	31 324,00
	1 092 835,00
Capital Outlay	22 866,00
Water Distiller	-
Clarifier	-
Laboratory	-
Carports	-
Lawnmower	-
Brush cutters	-
	22 866,00
TOTAL EXPENDITURE	R2 513 753,00
	============

ANNEXURE C

TABLES SHOWING WEEKLY AVERAGES OF DAILY RAW AND DIGESTED SLUDGE ANALYSIS

TABLE C1 : WEEKLY AVERAGES OF DAILY RAW SLUDGE ANALYSIS

ANNEXURE C

DATE	UNIT B C.O.D. mg/l	UNIT B DISSOLV O-P mg/l	UNIT B VOL. RAW SLUDGE m^3/d	UNIT B TOTAL SOLIDS g/l	UNIT B DISSOLV IRON mg/l	UNIT B FATTY ACIDS mg/l	UNIT B ALKALINITY mg/l	UNIT B pH	UNIT C C.O.D. mg/l	UNIT C DISSOLV O-P mg/l	UNIT C VOL. RAW SLUDGE m^3/d	UNIT C TOTAL SOLIDS g/l	UNIT C DISSOLV IRON mg/l	UNIT C FATTY ACIDS mg/l	UNIT C ALKALINITY mg/l	UNIT C pH
1986																
17/02 - 21/02	88226	40,8	161,5	44,5	28	1433	1170	5,8	54872	20,0	153,6	31,2	43	1309	1460	6,1
24/02 - 28/02	61341	46,9	153,7	30,5	34	1414	1350	5,7	41654	32,3	174,9	40,6	31	1212	1180	6,0
03/03 - 07/03	96783	29,8	173,0	62,2	35	3057	2250	5,7	76570	27,7	184,1	44,8	34	840	650	6,0
10/03 - 14/03	58393	34,5	145,1	44,4	24	1486	1320	5,9	51874	33,3	150,8	37,2	41	1853	1780	6,0
17/03 - 21/03	125979	44,0	140,0	62,9	23	1699	1650	5,9	81859	21,6	206,7	50,3	42	1735	1640	6,1
24/03 - 27/03	92642	28,8	167,4	56,3	45	2505	1980	5,8	69706	19,8	183,0	41,7	64	1992	1710	6,0
31/03 - 04/04	38645	41,6	115,0	30,2	23	1178	1020	6,0	87875	31,0	142,8	44,7	39	1500	1300	6,0
07/04 - 11/04	85556	56,6	138,6	54,7	42	2573	1640	5,7	73283	30,0	174,9	45,2	56	2592	1000	5,8
14/04 - 18/04	59594	47,3	150,0	54,4	35	2745	2150	5,7	50510	34,5	142,8	40,2	37	1853	1510	5,9
21/04 - 25/04	54818	29,0	150,2	35,1	35	1309	1150	5,8	69647	25,9	142,8	46,0	45	2175	1700	5,9
28/04 - 02/05	51178	41,4	142,3	32,8	20	1500	1350	5,7	45342	32,5	142,8	43,6	39	1722	1600	5,9
05/05 - 09/05	71459	40,0	153,9	33,9	31	1493	1620	5,7	48453	26,0	145,6	40,3	29	960	1120	6,1
12/05 - 16/05	41334	47,9	134,8	32,5	16	1050	1010	5,9	62806	40,7	130,5	40,5	24	1399	1230	5,9
19/05 - 23/05	81636	45,2	138,6	48,2	43	1320	1140	6,0	67108	24,1	142,8	44,9	60	1084	1400	6,2
26/05 - 30/05	67630	42,5	138,6	48,8	22	1437	1440	5,9	48969	25,1	154,8	36,6	35	919	1180	6,0
02/06 - 06/06	57922	44,3	138,6	33,4	12	1009	930	6,0	70 [illegible]	29,3	142,8	50,0	49	1294	1590	6,0
09/06 - 13/06	53887	27,6	125,9	36,6	19	1080	930	6,0	[illegible]	28,2	198,8	42,2	45	1305	1330	6,0
16/06 - 20/06	98524	47,6	138,6	49,9	33	2202	1708	5,8	76354	27,7	178,8	43,9	47	1197	1410	6,1
23/06 - 27/06	37745	42,3	134,8	26,4	26	1198	1108	6,0	40601	40,9	142,8	54,0	32	1399	1660	6,0
30/06 - 04/07	77613	47,5	138,6	43,2	24	1317	621	5,8	56435	40,5	142,8	36,3	32	1422	1540	6,0
07/07 - 11/07	35049	46,1	138,6	30,1	7	1609	1640	6,1	41108	25,5	163,2	35,2	25	916	1520	6,1
14/07 - 18/07	94391	42,2	138,6	47,7	19	1242	1500	5,9	69994	37,6	142,8	41,1	30	1969	1690	6,0
21/07 - 25/07	48254	40,2	157,6	42,4	13	1009	1390	5,8	52713	37,3	142,8	44,0	40	1358	1460	5,9
28/07 - 01/08	72282	37,5	146,2	55,7	27	1883	1710	5,8	60980	32,6	194,6	41,5	35	1583	1900	6,0
04/08 - 08/08	34806	38,7	184,6	28,1	9	1005	1110	6,0	49178	36,0	142,8	37,4	22	1058	1250	6,0
11/08 - 15/08	57802	46,0	192,7	40,4	14	1212	1620	6,0	65632	47,4	150,8	40,4	30	1305	1460	6,0
18/08 - 22/08	64567	43,5	138,6	41,1	20	1624	1620	5,9	91769	40,2	179,0	45,3	29	2228	2100	5,9
25/08 - 29/08	49718	34,5	184,6	37,2	17	1553	1300	6,0	65759	32,9	146,8	43,4	36	1800	1740	6,0
01/09 - 05/09	33592	41,2	138,6	30,8	26	1519	1470	5,8	57814	39,2	150,8	43,2	21	1564	1690	5,9
08/09 - 12/09	49485	38,0	138,6	61,3	34	2423	1910	5,9	39179	33,7	174,9	43,4	28	1519	1590	6,0
15/09 - 19/09	63926	53,5	196,2	34,0	12	1335	1350	6,0	74995	39,8	142,8	45,1	22	1587	1670	6,0
22/09 - 26/09	67720	26,0	138,6	45,1	14	1039	1208	5,9	62744	21,8	142,8	47,8	22	1501	1710	6,0
29/09 - 03/10	70886	30;5	138,6	44,2	22	1598	1470	5,8	63041	14,9	163,2	46,8	49	1924	1820	6,0
06/10 - 09/10	62232	36,9	177,0	36,7	13	893	150	6,0	80895	39,2	142,8	46,3	29	1542	1640	5,9
13/10 - 17/10	42086	35,4	138,6	44,9	10	1174	1360	5,8	40645	25,7	142,8	46,9	23	1399	1520	6,0
20/10 - 24/10	73642	35,8	138,6	33,2	18	1414	2059	5,7	74360	20,7	174,9	46,6	28	2025	1160	5,9
27/10 - 31/10	33664	38,2	138,6	37,2	12	1150	1340	5,9	45576	10,0	142,8	53,6	32	1495	1730	6,1
03/11 - 07/11	71931	43,2	138,6	55,4	21	1425	1360	5,9	80443	20,3	166,8	46,7	37	1647	1700	6,2
10/11 - 14/11	70563	42,4	138,6	54,8	22	3023	2390	5,8	52531	26,9	222,6	48,6	21	1305	1740	6,1
17/11 - 21/11	96687	31,2	138,6	44,1	15	1058	1140	5,9	114760	13,9	158,7	50,0	33	1755	2170	6,3
24/11 - 28/11	53601	49,3	138,6	48,9	23	1572	1650	5,9	44365	17,5	142,8	44,1	45	2048	2120	6,1
01/12 - 05/12		60,0	138,6	59,3	95	1658	1500	5,8		18,0	182,8	46,8	136	1860	1740	6,0
08/12 - 12/12		45,5	138,6	32,8	295	1238	1460	5,8		35,8	142,8	53,9	194	1860	2020	6,0
15/12 - 19/12		34,6	134,8	58,5	162	1553	1500	5,9		16,4	159,1	53,3	201	1178	1340	6,2
1987																
26/01 - 30/01	42751	12,3	138,6	56,8	72	1688	1650	5,8	47467	17,7	142,8	55,4	110	2247	2020	6,0
02/02 - 06/02	87290	34,1	138,6	66,1	134	2239	1840	5,8	82093	27,1	186,8	50,8	151	1253	1510	6,0
09/02 - 13/02	31031	42,7	146,2	36,0	63	1183	1470	5,7	37443	13,2	142,8	42,6	87	3089	2424	5,9
16/02 - 20/02	73804	37,5	138,6	48,1	310	1538	1220	5,8	52362	23,5	142,8	48,2	263	1988	1440	5,9
23/02 - 27/02	66421	34,1	138,6	57,1	174	2022	960	5,7	53040	20,8	182,6	55,5	319	1497	860	5,9
02/03 - 06/03	85057	27,9	150,1	35,7	161	1264	840	6,1	82019	24,6	142,8	49,0	126	1819	583	6,1

TABLE C2 : WEEKLY AVERAGES OF DAILY DIGESTED SLUDGE ANALYSIS

	UNIT B								UNIT C							
DATE	C.O.D mg/l	DISSOLV O-P mg/l	VOL. RAW SLUDGE m^3/d	TOTAL SOLIDS g/l	DISSOLV IRON mg/l	FATTY ACIDS mg/l	ALKA-LINITY mg/l	pH	C.O.D. mg/l	DISSOLV O-P mg/l	VOL. RAW SLUDGE m^3/d	TOTAL SOLIDS g/l	DISSOLV IRON mg/l	FATTY ACIDS mg/l	ALKA-LINITY mg/l	pH
17/02 - 21/02	18816	30,6	53,8	27,6	3	300	3120	7,2	37600	8	76,1	31,6	3	155	3040	7,2
24/02 - 28/02	18032	15,1	51,2	23,8	1	360	3580	7,0	16800	5	87,4	18,8	3	450	2660	7,0
03/03 - 07/03	88800	22,8	57,3	43,4	7	1155	2300	6,0	10525	27	92,7	20,6	23	278	2600	7,2
10/03 - 14/03	24800	51,9		43,2	3	180	3580	7,1	20800	8	75,4	29,2	1	115	2880	7,1
17/03 - 21/03	89510	30,2	44,9	48,4	8	1200	2280	6,5	29363	5	103,3	26,6	4	818	2740	7,1
24/03 - 27/03	33062	23,1	55,8	37,8	4	698	2820	7,0	20966	3	91,5	33,8	2	293	2660	7,0
01/04 - 04/04	66387	43,3	38,3	43,4	0	690	3380	7,1			71,4					
07/04 - 11/04	34538	50,7	46,2	23,0	1	758	3400	7,2	19600	7	87,4	24,0	3	165	2700	7,2
14/04 - 18/04	31619	56,9	30,0	44,8	6	870	2120	6,8	11856	9	71,4	19,8	4	135	2740	7,1
21/04 - 25/04	33712	43,1	53,9	25,4	4	175	3080	7,2	8870	10	71,4	16,2	3	110	2600	7,0
28/04 - 02/05	25600	17,6	47,4	34,4	2	308	3080	7,0	19600	10	71,4	27,8	3	115	2680	7,3
05/05 - 09/05	71344	56,8	51,3	44,8	6	1140	2040	6,6			72,1					
12/05 - 16/05	40789	43,1	44,9	36,0	1	285	3160	7,0	8466	17	65,2	19,8	3	75	2860	7,0
19/05 - 23/05	42460	23,0	46,2	31,2	4	145	2860	7,0	20238	13	71,4	25,2	4	160	2760	7,1
26/5 - 30/5	27440	63,3	46,2	33,6	4	608	2320	6,8	55664	7	75,4	36,6	4	1200	1820	7,0
2/6 - 6/6	26083	58,0	46,2	20,8	2	175	3340	7,1	15680	7	71,4	24,0	3	270	3020	7,1
09/06 - 13/06	36922	58,2	42,4	8,4	3	120	3120	7,1	10393	9	95,4	17,6	6	115	2720	7,1
16/06 - 20/06	54400	36 2	46,2	23,6	10	443	2980	7,0	4704	9	95,4	17,6	6	115	2720	7,1
23/06 - 27/06	[illegible]	56,9	44,9	19,6	3	360	3120	6,9	22140	10	89,4	16,2	5	308	2820	7,0
30/06 - 04/07	20779	54,0	46,2	15,8	4	435	3000	6,8	19200	10	71,4	22,2	5	323	3040	7,0
07/07 - 11/07	20800	39,9	46,2	17,2	2	293	3140	7,1	96970	16	71,4	16,6	2	155	2980	7,0
14/07 - 18/07	36000	33,5	46,2	20,8	3	360	3220	7,1	57323	14	81,6	19,4	2	150	2680	6,9
21/07 - 25/07	18400	55,7	56,4	15,0	3	855	2840	6,8	8160	22	71,4	19,2	3	390	2920	7,0
28/07 - 01/08	[illegible]	30,0	46,2	34,0	3	495	2640	6,6	48800	17	71,4	20,8	3	150	2800	7,1
04/08 - 08/08	32000	58,2	61,5	23,0	2	533	3760	6,9	26400	14	97,3	27,2	1	503	2840	7,0
11/08 - 15/08	45600	56,2	64,2	35,2	6	465	3340	7,3	14112	9	71,4	31,2	4	150	2800	6,9
18/08 - 22/08	48459	29,9	46,2	38,6	5	885	2240	7,0	4628	33	78,4	21,8	2	180	2760	6,9
25/08 - 29/08	33600	18,5	61,5	27,4	7	570	3540	7,0	16800	24	89,5	27,0	2	170	2780	7,0
01/09 - 05/09	18400	41,8	46,2	24,0	2	375	3320	7,1	9600	24	73,4	22,8	3	130	3000	7,0
08/09 - 12/09	35402	24,7	46,2	35,0	4	150	3200	7,0	11760	23	75,4	13,4	2	165	2860	7,0
15/09 - 19/09	25978	56,5	65,4	30,0	9	375	3740	7,1	20800	27	87,4	34,0	1	175	2040	7,0
22/09 - 26/09	46176	18,5	46,2	29,0	2	383	3540	7,0	32323	22	71,4	23,0	1	165	3080	7,0
29/09 - 03/10	40800	33,1	46,2	51,4	7	115	3960	7,2	55266	29	71,4	28,0	2	175	3060	7,0
06/10 - 09/10	18816	42,3	59,0	19,4	1	285	3220	7,1	80000	23	81,6	27,6	2	375	3060	6,9
13/10 - 17/10	28475	20,0	46,2	37,0	2	488	2980	7,0	13600	8	71,4	27,0	3	338	3020	7,0
20/10 - 24/10	38400	27,2	46,2	43,6	3	300	3360	7,2	10400	11	71,4	7,2	4	160	2860	7,1
27/10 - 31/10	23040	19,2	46,2	29,0	2	398	3580	7,2	20779	6	87,3	28,8	3	315	2540	6,9
03/11 - 07/11	53312	34,0	46,2	33,6	4	518	3260	7,2	35402	4	71,4	26,8	2	140	2840	7,2
10/11 - 14/11	24304	47,5	46,2	25,6	1	175	3440	7,1	31360	4	83,4	28,2	8	398	3160	7,1
17/11 - 21/11	52800	51,7	46,2	29,8	4	135	3500	7,2	12000	3	111,3	33,8	3	278	380	7,1
24/11 - 28/11	16464	12,3	46,2	21,8	3	170	3360	7,2		2	79,3	23,0	4	100	3000	7,2
01/12 - 05/12		80,7	46,2	35,0	5	668	2540	6,8		6	71,4	26,8	8	300	3300	7,3
08/12 - 12/12		48,3	50,8	29,0	9	533	3560	7,1		7	91,4	27,2	83			7,2
15/12 - 19/12			67,4							5	71,4	14,2	5			7,0
26/01 - 30/01	7872	15,0	69,3	26,4	8	125	3200	7,2	35954	4	79,5	26,4	156	100	3280	7,2
02/02 - 06/02	32323	39,0	69,3	32,4	4	145	3120	7,0	24230	4	71,4	32,2	5	765	3260	7,1
09/02 - 13/02	20010	47,4	73,1	27,2	3	338	3520	7,1	4704	4	93,4	30,0	6	623	3180	7,2
16/02 - 20/02	36800	31,2	69,3	21,6	5	100	3660	6,9	55664	4	71,4	28,2	4	773	3300	7,2
23/02 - 27/02	26765	59,6	69,3	21,8	1	473	1320	6,9	27200	6	71,4	26,2	1	150	1560	7,3
02/03 - 06/03	46320	35,1	75,0	25,6	1	160	1740	7,1	46176	4	91,3	41,6	148	175	1400	7,3

ANNEXURE D

Tables showing weekly averages of daily water analysis at various monitoring points

Table : 9B : Unit 9 : Sampling Point 9P

Raw Sewage

Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Ammonia	Chloride	Alkal	Hard	Conduct	Total Fe	Dissolved Fe
01/07/85-05/07	875	11.9	8.7							
08/07 -- 12/07	761	13.6	9.3							
15/07 -- 19/07	859	12.4	9.4							
22/07 -- 26/07	592	12.5	9.9							
29/07 -- 02/08	690	13.1	6.7							
05/08 -- 09/08	899	12.7	8.5							
12/08 -- 16/08	846	12.3	8.2							
26/08 -- 30/08	745	14.0	10.7							
09/09 -- 13/09	893	15.4	10.9							
16/09 -- 20/09	838	15.6	12.4							
23/09 -- 27/09	755	11.6	9.3							
30/09 -- 04/10	730	13.4	10.1							
20/01/86-24/01	649	12.1	9.2							
27/01 -- 30/01	1101	13.9	9.3							
17/02 -- 21/02	599	10.5	6.9			221	223		2.1	0.6
02/03 -- 07/03	773	12.2	6.7	25.0	162	287	173	120	1.8	0.6
31/03 -- 04/04	525	10.2	8.0			264	150		2.2	1.0
07/04 -- 11/04	933	12.1	9.2	39.0	115	260	149	100	1.5	0.7
14/04 -- 18/04	492	11.3	8.5		1	255	152		1.7	0.6
21/04 -- 25/04	988	10.0	6.8	31.0	85	258	179	73	2.6	0.9
28/04 -- 02/05	647	10.5	7.4	26.0	58	205	165	95	1.5	0.8
12/05 -- 16/05	655	13.9	9.2	28.0	114	201	174	94	2.1	0.7
19/05 -- 23/05	749	13.3	10.0	27.0	150	199	164	95	3.4	1.0
26/05 -- 30/05	674	10.4	9.6			241	147		1.9	0.8
02/06 -- 06/06	709	12.3	8.8	33.0	87	236	152	86	2.4	1.0
09/06 -- 13/06	801	10.9	7.9	28.0	99	237	148	80	3.6	1.4
16/06 -- 20/06	724	10.0	7.6	31.0	90	316	147	76	6.7	3.0
23/06 -- 27/06	732	8.6	6.6	33.0	95	321	171	88	2.8	1.3
30/06 -- 04/07	672	9.2	6.2	33.0	144	250	147	89	2.8	1.6
07/07 -- 11/07	836	11.5	8.8			332	135		3.4	1.5
14/07 -- 18/07	887	11.9	8.2	33.0	100	251	152	72	3.5	1.8
21/07 -- 27/07	836	11.4	7.4	38.0	97	238	139	66	1.9	0.8
28/07 -- 01/08	767	12.9	10.1	33.0	123	265	145	86	2.9	1.5
04/08 -- 08/08	734	9.6	9.7	29.0	144	266	146	86	1.8	0.6
11/08 -- 15/08	775	12.6	11.0	26.0	125	276	125	95	2.7	0.8
18/08 -- 22/08	884	13.2	10.3			275	154		2.5	1.1
25/08 -- 29/08	949	12.3	9.2	36.0	87	261	148	87	4.2	1.3
01/09 -- 07/09	973	16.3	10.7	24.0	142	265	137	97	2.9	1.1
08/09 -- 12/09	617	13.7	10.4	26.0	107	245	132	87	1.8	0.7
15/09 -- 19/09	856	13.0	9.8	31.0	149	272	139	99	1.4	0.4
22/09 -- 26/09	932	14.2	9.5	35.0	111	228	120	80	2.9	1.1
06/10 -- 09/10	748	14.5	11.8	42.0	89	224	132	95	1.4	0.8
13/10 -- 17/10	876	15.1	11.1	31.0	112	210	117	92	2.1	0.5
20/10 -- 24/10	741	12.7	10.2	28.0	13	200	115	109	2.2	0.9
27/10 -- 31/10	665	12.0	9.2	21.0	115	198	134	91	3.0	1.3
03/11 -- 07/11	695	11.5	9.6	44.0	151	238	149	99	2.2	0.8
10/11 -- 14/11	720	13.7	10.4	1.0		228	164		1.5	0.5
17/11 -- 21/11	814	15.5	9.0	53.0	140	227	168	136	2.9	0.9
24/11 -- 28/11	791	13.6	8.5	30.0	128	212	164	103	2.2	1.3
01/12 -- 05/12	680	10.8	9.2	19.0	123	197		109	2.3	1.3
08/12 -- 12/12		12.5	9.6			187			2.2	1.0
15/12 -- 19/12	785	9.8	6.5	14.0	71	184		66	2.9	1.8
22/12 -- 24/12		10.5	6.2		1					
28/12 -- 31/12		12.8	3.2							
05/01/87-09/01		9.5	6.4			192			3.2	2.0
12/01 -- 16/01	667	11.3	8.8	38.0	89	204	171	84	2.5	1.4
19/01 -- 23/01	561	9.4	5.9	20.0	73	176	187	70	1.9	1.0
26/01 -- 30/01	652	9.3	7.2	12.0	211	220	169	123	3.2	0.7
02/02 -- 06/02	630	7.7	5.6	40.0	166	150	214	86	2.6	0.8
09/02 -- 13/02	696	9.4	4.5	15.0	247	228	220	111	2.3	1.1
16/02 -- 20/02	670	9.3	6.3			227	193		3.1	2.2
23/02 -- 29/02	936	11.2	7.9	26.0	157	257	186	104	2.9	1.5
02/03 -- 06/03	637	12.0	8.6			238	200		2.0	1.1
Average	768	12.0	8.7	29.2	113	236	158	93	2.5	1.1
Std Deviation	121	1.9	1.7	9.6	49	38	26	16	0.9	0.5

Table : DB 2 Unit 8 : Sampling Point 8P1

Raw Sewage

Weekly Averages of Daily Loads (kg)

Period	COD	Total P	Ortho P	Ammonia
31/03 -- 04/04	6874	127.3	98.7	
07/04 -- 11/04	12022	172.6	131.5	578.0
14/04 -- 18/04	7204	159.8	120.3	
21/04 -- 25/04	13720	133.9	91.3	
28/04 -- 02/05	6559	113.2	81.9	35.0
12/05 -- 16/05	7904	165.7	110.0	327.0
19/05 -- 23/05	8902	158.7	118.7	352.0
26/05 -- 30/05	7895	121.8	111.7	
02/06 -- 06/06	9130	155.7	111.5	323.0
09/06 -- 13/06	11995	138.9	102.2	
23/06 -- 27/06	9312	108.6	84.6	421.0
30/06 -- 04/07	7433	140.7	96.5	
07/07 -- 11/07	8515	110.5	83.3	
14/07 -- 18/07	6616	90.3	62.6	328.0
21/07 -- 27/07	9772	135.1	87.5	373.0
28/07 -- 01/08	9636	137.0	98.3	
04/08 -- 08/08	8115	106.0	94.4	293.0
11/08 -- 15/08	9372	151.3	133.9	325.0
18/08 -- 22/08	10991	171.2	163.9	
25/08 -- 29/08	11471	149.8	110.1	310.0
01/09 -- 07/09	13560	187.9	145.6	
08/09 -- 12/09	8122	171.1	127.7	282.0
15/09 -- 19/09	10535	161.1	121.3	376.0
22/09 -- 26/09	11631	175.8	113.7	557.0
06/10 -- 09/10	7506	139.9	112.1	310.0
13/10 -- 17/10	11257	196.0	142.7	398.0
20/10 -- 24/10	8368	143.1	114.3	333.0
27/10 -- 31/10	8774	144.1	110.0	223.0
03/11 -- 07/11	9510	150.0	128.3	845.0
10/11 -- 14/11	10647	202.3	153.7	15.0
17/11 -- 21/11	7037	125.4	84.0	563.0
24/11 -- 28/11	13439	229.0	142.4	479.0
01/12 -- 05/12	11274	184.6	139.7	315.0
08/12 -- 12/12		211.0	168.7	
15/12 -- 19/12	19366	166.2	111.2	345.0
22/12 -- 24/12		181.5	145.3	
28/12 -- 31/12		301.8	70.6	
05/01/87-09/01		141.1	94.4	
12/01 -- 16/01	13352	213.5	166.9	655.0
19/01 -- 23/01	10788	182.0	111.5	378.0
26/01 -- 30/01	9969	165.7	123.1	425.0
02/02 -- 06/02	16824	182.4	137.8	888.0
09/02 -- 13/02	12088	165.4	77.2	253.0
16/02 -- 30/02	10853	149.2	101.0	
23/02 -- 29/02	14130	163.8	115.4	338.0
02/03 -- 06/03	8698	164.1	118.1	
Average	10266	159.7	114.6	388.1
Std Deviation	2755	36.6	25.3	186.4

Table : DB 3 Unit B : Sampling Point BP3
Feed to Primary Settlers
Weekly Averages of Daily Loads (kg)

Period	COD	Total P	Ortho P	Total Fe
31/03 -- 04/04	7874	175.9	121.5	41
07/04 -- 11/04	12974	200.0	144.8	31
14/04 -- 18/04	8434	186.7	128.4	36
21/04 -- 25/04	14513	150.9	101.2	47
28/04 -- 02/05	7501	135.5	87.9	27
12/05 -- 16/05	8871	174.6	115.9	36
19/05 -- 23/05	9378	174.5	128.7	52
26/05 -- 30/05	8381	135.8	118.6	27
02/06 -- 06/06	9591	167.3	117.8	38
09/06 -- 13/06	12683	152.9	110.9	53
23/06 -- 27/06	10368	138.2	102.0	50
30/06 -- 04/[illegible]	9786	204.6	124.8	67
07/07 -- 11/07	10002	163.0	99.2	43
14/07 -- 18/07	8338	116.4	75.1	42
21/07 -- 27/07	11484	171.0	105.7	37
28/07 -- 01/08	11364	166.4	115.5	43
04/08 -- 08/08	9417	133.5	109.3	34
11/08 -- 15/08	10965	192.4	160.5	49
18/08 -- 22/08	12424	217.6	175.8	50
25/08 -- 29/08	14215	189.3	137.1	58
01/09 -- 07/09	15096	227.8	165.1	45
08/09 -- 12/09	9918	200.5	144.6	41
15/09 -- 19/09	12902	211.3	140.7	34
22/09 -- 26/09	13325	230.3	138.8	50
06/10 -- 09/10	9300	177.3	122.7	24
13/10 -- 17/10	13363	231.8	157.1	46
20/10 -- 24/10	10316	185.5	132.9	44
27/10 -- 31/10	11330	202.1	138.9	52
03/11 -- 07/11	11068	186.1	145.1	44
10/11 -- 14/11	11793	239.2	167.7	34
17/11 -- 21/11	10123	160.3	89.9	44
24/11 -- 28/11	13710	274.9	152.4	88
01/12 -- 05/12		219.8	159.9	84
22/12 -- 24/12		247.6	156.8	
28/12 -- 31/12		374.9	90.5	
05/01/87-09/01		162.6	106.5	88
12/01 -- 16/01	14478	236.3	173.9	138
19/01 -- 23/01	12108	209.8	121.1	75
26/01 -- 30/01	11411	189.0	133.2	146
02/02 -- 06/02	17836	203.8	145.8	109
09/02 -- 13/02	13028	195.1	88.6	76
16/02 -- 30/02	12509	173.6	111.7	36
23/02 -- 29/02	15827	192.8	129.0	50
02/03 -- 06/03	9560	186.1	130.4	50
Average	11439	192.4	127.8	54
Std Deviation	2364	43.7	25.0	27

Table : DB 4 Unit B : Sampling Point SP4
Primary Settlers Effluent
Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Total Fe	Dissolved Fe
01/07/85-05/07	856	12.3	10.2	1.6	
08/07 -- 12/07	445	11.8	10.8	0.9	
15/07 -- 19/07	593	13.1	11.1	1.5	
22/07 -- 26/07	541	14.4	9.8	0.6	
29/07 -- 02/08	644	12.6	9.3		
05/08 -- 09/08	463	11.4	9.0	2.6	
12/08 -- 16/08	722	14.1	11.1	2.5	
26/08 -- 30/08.	523	10.0	8.7	1.9	
09/09 -- 13/09	725	13.3	10.9	2.2	
16/09 -- 20/09	541	12.1	10.3	1.4	
23/09 -- 27/09	494	13.1	11.1	1.4	
30/09 -- 04/10	437	11.9	9.0	1.6	
20/01/86-24/01	737	12.6	10.8	1.0	
27/01 -- 30/01	551	10.9	8.2		
17/02 -- 21/02	408	8.6	6.8	3.1	0.5
02/03 -- 07/03	479	9.5	6.6	1.2	0.5
10/03 -- 15/03	499	10.2	8.2	1.6	0.7
17/03 -- 22/03	394	7.7	6.5	1.1	0.4
24/03 -- 29/03	388	8.3	6.6	1.0	0.4
31/03 -- 04/04	210	9.6	6.3	1.5	0.8
07/04 -- 11/04	626	9.8	7.9	0.9	0.5
14/04 -- 18/04	457	10.2	8.5	1.1	0.6
21/04 -- 25/04	573	8.2	6.6	2.3	0.8
28/04 -- 02/05	362	10.5	7.9	1.9	0.5
12/05 -- 16/05	345	11.5	9.1	1.6	0.6
19/05 -- 23/05	440	11.7	10.1	1.7	0.5
26/05 -- 30/05	505	13.2	11.4	1.5	0.7
02/06 -- 06/06	363	10.6	8.3	1.8	0.8
09/06 -- 13/06	439	9.4	8.6	3.1	1.4
16/06 -- 20/06	497	10.9	9.1	3.5	2.3
23/06 -- 27/06	737	9.7	8.1	2.5	1.3
30/06 -- 04/07	452	10.9	7.7	2.4	1.5
07/07 -- 11/07	674	11.4	8.1	2.2	0.9
14/07 -- 18/07	689	12.1	8.6	2.1	1.1
21/07 -- 27/07	576	11.2	9.8	1.6	0.6
28/07 -- 01/08	528	12.4	10.2	1.8	0.5
04/08 -- 08/08	552	9.8	7.3	1.8	1.0
11/08 -- 15/08	530	15.6	11.5	1.6	0.5
18/08 -- 22/08	516	13.0	10.1	2.5	1.8
25/08 -- 29/08	503	12.5	9.8	4.4	0.8
01/09 -- 07/09	619	13.0	10.7	2.0	1.0
08/09 -- 12/09	776	13.2	10.6	1.8	0.5
15/09 -- 19/09	420	13.3	11.0	1.1	0.7
22/09 -- 26/09	480	11.8	9.1	1.4	0.4
06/10 -- 09/10	405	12.8	10.7	1.4	0.9
13/10 -- 17/10	466	13.5	11.0	1.3	0.6
20/10 -- 24/10	352	11.7	9.3	1.8	0.8
27/10 -- 31/10	458	12.4	10.6	2.4	1.0
03/11 -- 07/11	372	12.2	10.3	1.3	0.8
10/11 -- 14/11	366	11.9	9.2	1.0	0.2
17/11 -- 21/11	346	9.9	7.1	1.8	0.5
24/11 -- 28/11	385	10.5	8.4	2.6	0.7
01/12 -- 05/12		10.1	8.9	1.8	1.2
08/12 -- 12/12		10.3	8.0	1.8	1.0
15/12 -- 19/12		8.1	6.3	2.4	1.6
22/12 -- 24/12		9.3	7.8		
28/12 -- 31/12		6.7	4.5		
05/01/87-09/01		8.7	6.9	2.9	1.8
12/01 -- 16/01	435	8.8	6.5	3.0	1.5
19/01 -- 23/01	310	8.1	7.3	2.0	0.9
26/01 -- 30/01	470	10.1	7.1	1.5	1.0
02/02 -- 06/02	443	6.9	5.6	1.1	0.8
09/02 -- 13/02	320	7.7	5.7	1.5	1.1
16/02 -- 30/02	358	8.2	6.0	2.3	1.9
23/02 -- 29/02	504	9.5	6.2	2.3	1.7
02/03 -- 06/03	339	9.8	8.4	1.4	1.0
Average	499	10.9	8.7	1.9	0.9
Std Deviation	137	2.0	1.7	0.7	0.5

Table : DB 5 Unit B : Sampling Point BP4
Effluent from Primary Settlers
Weekly Averages of Daily Loads (kg)

Period	COD	Total P	Ortho P
10/03 -- 15/03	7009	148.0	119.4
17/03 -- 22/03	6697	130.9	110.6
24/03 -- 29/03	5642	122.0	97.0
31/03 -- 04/04	3197	136.3	88.7
07/04 -- 11/04	9856	152.0	121.1
14/04 -- 18/04	6933	153.7	127.2
21/04 -- 25/04	4728	111.9	89.0
28/04 -- 02/05	4395	127.9	98.4
12/05 -- 16/05	4354	141.4	111.1
19/05 -- 23/05	5932	148.7	127.4
26/05 -- 30/05	6170	159.0	137.6
02/06 -- 06/06	4783	138.8	108.0
09/06 -- 13/06	6533	135.4	126.8
23/06 -- 27/06	10382	137.4	114.9
30/06 -- 04/07	6223	153.8	115.8
07/07 -- 11/07	7481	123.2	84.1
14/07 -- 18/07	5378	109.7	78.4
21/07 -- 27/07	7460	146.1	128.0
28/07 -- 01/08	7124	167.5	138.5
04/08 -- 08/08	6513	115.7	87.2
11/08 -- 15/08	10255	206.3	150.7
18/08 -- 22/08	7198	173.5	149.1
25/08 -- 29/08	6871	167.6	130.5
01/09 -- 07/09	7418	175.6	150.8
08/09 -- 12/09	12205	179.0	144.0
15/09 -- 19/09	5667	176.7	146.5
22/09 -- 26/09	6629	157.2	121.1
06/10 -- 09/10	4377	132.2	110.7
13/10 -- 17/10	6667	186.0	152.0
20/10 -- 24/10	4160	136.5	109.6
27/10 -- 31/10	7036	181.9	154.7
03/11 -- 07/11	5408	177.5	149.3
10/11 -- 14/11	5864	189.3	145.5
17/11 -- 21/11	2545	101.8	61.6
24/11 -- 28/11	7125	189.9	150.2
01/12 -- 05/12		184.5	161.9
22/12 -- 24/12		175.4	145.8
28/12 -- 31/12		152.3	96.6
05/01/87-09/01		145.2	113.9
12/01 -- 16/01	7572	169.2	122.1
19/01 -- 23/01	6633	173.0	156.1
26/01 -- 30/01	8560	162.8	113.1
02/02 -- 06/02	11190	171.2	139.1
09/02 -- 13/02	5906	142.5	105.6
16/02 -- 30/02	6142	140.3	103.8
23/02 -- 29/02	8015	148.5	97.7
02/03 -- 06/03	5169	144.6	124.6
Average	6770	153.2	121.6
Std Deviation	1977	23.9	23.9

Table : 08 6 Unit 5 : Sampling Point BF5

Feed to Bio-filters

Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Alkal	Total Fe	Dissolved Fe
01/07/85-05/07	317	12.5	10.2	255		
08/07 -- 12/07	422	11.4	9.5	247		
15/07 -- 19/07	455	11.5	10.0	273		
22/07 -- 26/07	367	9.5	9.7	278		
29/07 -- 02/08	266	11.7	10.0	270		
05/08 -- 09/08	372	13.9	9.0	251		
12/08 -- 16/08	306	12.6	10.3	293		
26/08 -- 30/08	252	11.1	9.3	234		
09/09 -- 13/09	244	12.3	9.9	221		
16/09 -- 20/09	342	11.7	9.7	201		
23/09 -- 27/09	232	12.6	10.4	213		
30/09 -- 04/10	195	11.4	9.6	220		
20/01/86-24/01	130	10.1	9.5	164		
27/01 -- 30/01	305	6.3	8.1	143		
17/02 -- 21/02	178	6.3	6.8	202	0.8	0.2
02/03 -- 07/03	283	8.2	6.9	232	0.8	0.2
10/03 -- 15/03	206	6.5	7.1	244	1.0	0.5
17/03 -- 22/03	284	7.8	6.5	251	0.9	0.4
24/03 -- 29/03	357	8.8	7.2	261	0.8	0.2
31/03 -- 04/04	216	9.3	7.7	199	1.5	0.8
07/04 -- 11/04	361	9.3	8.1	244	0.7	0.3
14/04 -- 18/04	373	9.7	7.8	234	0.6	0.3
21/04 -- 25/04	222	9.1	7.5	220	1.2	0.9
28/04 -- 02/05	288	10.4	8.1	176	1.2	0.3
12/05 -- 16/05	271	10.8	9.5	183	0.9	0.6
19/05 -- 23/05	316	11.0	9.5	174	1.2	0.7
26/05 -- 30/05	361	12.1	11.2	228	1.2	0.6
02/06 -- 06/06	277	11.0	9.2	244	1.0	0.4
09/06 -- 13/06	346	7.2	7.7	242	1.9	0.9
16/06 -- 20/06	399	11.1	9.6	360	2.2	1.3
23/06 -- 27/06	467	10.5	9.7	360	2.3	1.5
30/06 -- 04/07	239	7.8	7.6	224	1.9	1.0
07/07 -- 11/07	360	12.1	10.0	285	1.2	0.6
14/07 -- 18/07	349	10.7	8.3	245	1.4	1.0
21/07 -- 27/07	369	10.8	8.1	240	1.2	0.5
28/07 -- 01/08	505	11.8	10.5	267	1.3	0.5
04/08 -- 08/08	484	10.0	8.8	253	1.1	0.5
11/08 -- 15/08	482	14.5	12.2	290	1.1	0.3
18/08 -- 22/08	439	12.5	9.2	236	2.0	1.0
25/08 -- 29/08	447	11.8	9.9	272	2.0	0.9
01/09 -- 07/09	443	12.0	9.2	264	1.5	0.8
08/09 -- 12/09	438	12.5	9.7	233	1.3	0.6
15/09 -- 19/09	425	12.8	10.2	241	0.6	0.5
22/09 -- 26/09	463	11.4	8.6	206	1.1	0.3
06/10 -- 09/10	343	11.8	10.2	203	1.1	0.6
13/10 -- 17/10	271	12.1	11.2	159	0.8	0.3
20/10 -- 24/10	215	11.2	10.5	144	1.3	0.3
27/10 -- 31/10	255	11.1	9.7	148	1.5	0.7
03/11 -- 07/11	364	12.7	10.1	211	1.0	0.3
10/11 -- 14/11	354	11.2	9.4	220	0.6	0.1
17/11 -- 21/11	280	10.0	8.3	176	0.7	0.5
24/11 -- 28/11	260	10.9	8.8	193	1.3	0.5
01/12 -- 05/12		10.0	8.5	192	1.9	1.3
08/12 -- 12/12		10.4	7.7	164	1.3	0.7
15/12 -- 19/12		6.7	5.4	146	2.3	1.7
22/12 -- 24/12		9.3	8.3			
28/12 -- 31/12		4.8	3.9			
05/01/87-09/01		7.6	5.1	147	2.3	1.5
12/01 -- 16/01	223	8.6	6.9	179	1.8	1.2
19/01 -- 23/01	213	7.0	6.6	167	1.3	0.4
26/01 -- 30/01	251	8.4	7.3	190	1.1	0.7
02/02 -- 06/02	197	7.5	5.5	161	1.2	0.8
09/02 -- 13/02	280	6.7	5.4	142	1.0	0.6
16/02 -- 20/02	288	7.8	6.4	186	1.0	0.7
23/02 -- 29/02	332	9.1	6.5	240	1.9	1.5
02/03 -- 06/03	244	9.7	8.2	261	1.4	1.0
Average	321	10.3	8.5	222	1.3	0.7
Std Deviation	89	2.0	1.6	48	0.5	0.4

Table : DB 7 Unit B : Sampling Point BPS
Feed to Bio-filters
Weekly Averages of Daily Loads (kg)

Period	COD	Total P	Ortho P	Alkal	Hard	Total Fe
10/03 -- 15/03	6609	277.5	234.6	7870.4	4414	32
17/03 -- 22/03	6839	185.7	157.4	6067.3	3575	21
24/03 -- 29/03	7124	173.6	142.1	5144.0	3080	15
31/03 -- 04/04	5276	219.8	182.4	4834.0	3720	37
07/04 -- 11/04	8887	227.8	198.2	5973.0	3699	17
14/04 -- 18/04	8421	219.0	176.9	5284.8	3337	13
21/04 -- 25/04	6511	257.4	218.1	6249.2	4634	30
28/04 -- 02/05	8712	314.0	243.8	5326.0	4963	36
12/05 -- 16/05	7052	277.9	243.6	4736.0	4041	23
19/05 -- 23/05	9162	313.4	272.0	5248.5	4712	41
26/05 -- 30/05	10587	351.5	327.8	6600.4	4086	35
02/06 -- 06/06	6749	262.8	219.3	6632.8	3863	27
09/06 -- 13/06	10382	167.1	200.3	6613.7	3623	62
23/06 -- 27/06	14243	320.9	295.4	10984	4941	71
30/06 -- 04/07	6981	216.9	223.6	6401.2	4163	54
07/07 -- 11/07	9443	299.7	244.5	7428.2	3370	29
14/07 -- 18/07	6344	217.5	164.9	4841.0	2705	26
21/07 -- 27/07	9130	268.6	200.2	5945.3	3482	30
28/07 -- 01/08	11796	274.1	245.3	6205.6	3371	30
04/08 -- 08/08	10523	216.8	192.2	5542.2	3349	25
11/08 - 15/08	11122	336.0	281.2	6695.2	2942	25
18/08 -- 22/08	8856	275.8	194.2	4632.0	3026	56
25/08 -- 29/08	11091	284.6	236.6	6596.0	3548	48
01/09 -- 07/09	8841	250.7	202.3	5478.5	2547	24
08/09 -- 12/09	7896	228.8	176.0	4182.6	2492	24
15/09 -- 19/09	8032	240.8	192.2	4535.8	2487	11
22/09 -- 26/09	8813	210.5	158.6	3849.0	2434	21
06/10 -- 09/10	6391	206.6	175.0	3470.7	2354	20
13/10 -- 17/10	10034	433.8	404.3	5721.8	4281	29
20/10 -- 24/10	7580	387.2	361.0	4949.0	4229	46
27/10 -- 31/10	6658	327.5	287.9	4232.4	3651	40
03/11 -- 07/11	7227	250.2	198.8	4173.8	2839	19
10/11 -- 14/11	7005	223.3	187.4	4372.4	3197	12
17/11 -- 21/11	4207	266.8	194.9	5711.0	[illegible]088	0
24/11 -- 28/11	7191	299.0	242.4	5284.2	4401	35
01/12 -- 05/12		276.9	236.2	5333.6		51
08/12 -- 12/12		292.6	213.1	4758.5		36
15/12 -- 19/12		157.7	131.0	4697.5		85
22/12 -- 24/12		284.2	253.6			
28/12 -- 31/12		139.2	112.3			
05/01/87-09/01		201.4	125.7	3643.0		64
12/01 -- 16/01	6710	234.4	180.0	5089.8	4706	53
19/01 -- 23/01	6092	200.4	188.5	4707.2	4823	39
26/01 -- 30/01	6166	205.8	190.0	4398.0	4440	25
02/02 -- 06/02	6040	230.0	167.3	4967.6	6483	38
09/02 -- 13/02	7529	181.2	145.4	3855.2	5722	28
16/02 -- 30/02	7562	204.6	168.5	4885.0	4970	27
23/02 -- 29/02	8308	224.7	160.7	5925.2	4409	47
02/03 -- 06/03	5759	229.4	193.8	6152.0	4583	33
Average	8044	252.0	211.1	5451.6	3902	34
Std Deviation	1970	58.8	57.8	1285.4	980	17

Table : DB B Unit B 1 Sampling Point BP6

Bio-filters Effluent

Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Ammonia	NO3	Alkal	Hard	Total Fe	Dissolved Fe
01/07/85-05/07	138	12.5	9.8			169		1.1	
08/07 -- 12/07	93	11.4	9.4			168		0.7	
15/07 -- 19/07	126	11.5	10.3			175		0.9	
22/07 -- 26/07	76	9.5	8.4			226		1.3	
29/07 -- 02/08	150	11.7	10.6			212			
05/08 -- 09/08	182	13.9	10.5			175		3.0	
12/08 -- 16/08	208	12.6	9.9			200		2.5	
26/08 -- 30/08	147	11.1	8.7			152		1.6	
09/09 -- 13/09	161	12.3	9.2			142		0.5	
16/09 -- 20/09	114	11.7	9.9			138		1.4	
23/09 -- 27/09	119	12.6	10.4			163		0.6	
30/09 -- 04/10	127	11.9	9.7			149		1.0	
20/01/86-24/01	90	10.1	9.5			124		0.5	
27/01 -- 30/01	125	5.1	8.4			132		0.6	
17/02 -- 21/02	109	7.7	6.4			140	231	0.4	0.1
02/03 -- 07/03	112	8.7	7.6	2.0	4.5	170	206	0.5	0.0
10/03 -- 15/03	69	8.7	8.5	0.0	3.6	180	135	0.8	0.2
17/03 -- 22/03	67	7.8	7.1	0.0	2.9	164	149	0.7	0.1
24/03 -- 29/03	162	7.9	6.2	1.0	3.0	134	160	0.6	0.1
31/03 -- 04/04	62	8.3	7.3			103	155	1.2	1.0
07/04 -- 11/04	98	9.4	8.3	6.0	7.4	171	157	0.3	0.1
14/04 -- 18/04	106	8.7	8.0			158	150	0.5	0.0
21/04 -- 25/04	64	8.6	7.6	0.0	8.1	150	169	0.9	0.4
28/04 -- 02/05	86	8.5	7.8	0.0	5.2	123	165	0.5	0.2
12/05 -- 16/05	54	10.2	9.5	1.0	4.2	103	159	0.6	0.1
19/05 -- 23/05	91	11.0	10.2	1.0	7.8	112	163	1.1	0.4
26/05 -- 30/05	89	11.9	10.8			141	147	0.8	0.3
02/06 -- 06/06	146	9.3	8.5	2.0	1.5	131	150	0.5	0.0
09/06 -- 13/06	150	9.1	6.5	2.0	2.3	393	132	2.6	0.6
16/06 -- 20/06	127	10.3	9.2	2.0	4.7	205	156	1.5	0.8
23/06 -- 27/06	127	10.2	9.5	8.0	3.5	271	164	2.2	1.2
30/06 -- 04/07	116	11.0	9.5	6.0	2.9	175	146	1.4	0.9
07/07 -- 11/07	175	11.5	9.7			231	144	1.1	0.6
14/07 -- 18/07	170	11.0	8.9	6.0	2.5	173	143	0.9	0.4
21/07 -- 27/07	189	11.2	9.9	5.0	3.7	181	157	0.9	0.4
28/07 -- 01/08	190	11.9	10.6	5.0	2.4	192	146	0.8	0.2
04/08 -- 08/08	159	10.9	9.2	5.0	2.2	185	145	0.4	0.2
11/08 -- 15/08	202	13.8	12.4	4.0	2.4	204	129	1.0	0.1
18/08 -- 22/08	198	13.1	11.1			183	151	1.0	0.2
25/08 -- 29/08	144	12.2	10.0	6.0	5.0	181	147	1.8	0.4
01/09 -- 07/09	123	11.9	10.7		3.3	158	144	1.1	0.3
08/09 -- 12/09	88	11.8	9.7	0.0	2.4	151	137	0.8	0.2
15/09 -- 19/09	195	11.3	9.0	5.0	6.9	144	140	0.7	0.4
22/09 -- 26/09	151	11.9	9.0	3.0	4.0	119	131	1.0	0.2
06/10 -- 09/10	160	11.4	9.1	1.0	9.7	122	139	1.0	0.2
13/10 -- 17/10	149	12.4	10.9	0.0	5.2	117	119	0.5	0.1
20/10 -- 24/10	79	13.0	11.5	0.0	4.8	106	124	0.5	0.1
27/10 -- 31/10	114	11.5	10.1	2.0	9.5	106	133	1.1	0.5
03/11 -- 07/11	66	13.4	10.9	2.0	4.9	125	144	0.8	0.4
10/11 -- 14/11	92	11.4	9.8			145	156	0.2	0.0
17/11 -- 21/11	109	10.6	9.1	0.0	6.4	118	161	0.5	0.2
24/11 -- 28/11	90	10.1	9.7	0.0	2.8	121	165	0.8	0.4
01/12 -- 05/12		10.1	8.5	0.0	4.4	122		1.7	1.1
08/12 -- 12/12		9.4	8.6			100		0.6	0.4
15/12 -- 19/12		8.1	7.1	2.0	3.2	97		2.6	1.7
22/12 -- 24/12		9.2	8.3						
28/12 -- 31/12		7.8	5.9						
05/01/87-09/01		8.7	7.4			76		2.1	1.5
12/01 -- 16/01	92	8.8	7.9	0.0	5.7	99	161	1.8	1.1
19/01 -- 23/01	98	8.4	7.6	0.0	2.1	98	166	0.8	0.4
26/01 -- 30/01	87	8.9	8.4	0.0	4.4	129	165	0.7	0.5
02/02 -- 06/02	130	6.5	6.0	0.0	3.7	96	202	1.5	0.7
09/02 -- 13/02	100	7.4	6.6	0.0	5.2	103	213	0.7	0.5
16/02 -- 20/02	112	8.1	7.0			115	188	2.0	1.6
23/02 -- 29/02	93	9.2	8.0	0.0	1.5	144	174	1.6	1.1
02/03 -- 06/03	90	9.0	8.1			193	188	1.2	0.7
Average	123	10.3	8.9	2.0	4.4	153	157	1.1	0.5
Std Deviation	35	1.9	1.4	2.4	2.1	49	23	0.6	0.4

Table : DB 9 Unit B : Sampling Point BP6
Effluent from Bio-filters
~~Weekly Averages of Daily Loads (kgs)~~

Period	COD	Total P	Ortho P	Ammonia	NO3	Alkal	Hard	Total Fe
10/03 -- 15/03	2206	283.5	277.1	0.0	133	5923.4	4405	27
17/03 -- 22/03	2080	191.2	173.5	0.0	71	3984.0	3650	18
24/03 -- 29/03	3205	155.4	134.7	21.0	63	2630.2	3147	12
31/03 -- 04/04	1497	195.5	172.6			2491.5	3743	30
07/04 -- 11/04	2395	228.4	202.0	150.0	184	4189.2	3815	7
14/04 -- 18/04	2409	197.1	180.8			3566.0	3405	11
21/04 -- 25/04	1491	244.4	217.9			4248.2	4864	27
28/04 -- 02/05	2627	257.6	236.9	0.0	157	3718.4	5008	15
12/05 -- 16/05	1383	261.3	245.4	27.0	112	2662.2	4114	15
19/05 -- 23/05	2840	330.0	302.4	29.0	228	3454.2	4831	37
26/05 -- 30/05	2590	344.5	313.9			4070.2	4228	23
02/06 -- 06/06	3903	226.9	206.2	62.0	46	3581.5	4094	14
09/06 -- 13/06	2083	221.7	188.5			3843.3	3783	27
23/06 -- 27/06	3896	312.7	291.4	242.0	106	8283.7	4994	66
30/06 -- 04/07	2982	294.0	274.0	169.0	82	4898.5	4113	35
07/07 -- 11/07	4800	290.6	243.9			5928.0	3612	28
14/07 -- 18/07	3469	226.7	175.9	186.0	78	3392.2	2827	22
21/07 -- 27/07	4809	278.9	245.4	130.0	96	4486.4	3896	22
28/07 -- 01/08	4384	275.4	246.7	116.0	56	4448.8	3392	18
04/08 -- 08/08	3496	237.5	200.2	112.0	49	4022.8	3201	9
11/08 -- 15/08	4683	319.6	286.4	91.0	55	4712.2	2972	23
18/08 -- 22/08	3669	273.4	239.9			3980.5	3168	25
25/08 -- 29/08	3866	293.5	240.4	95.0	79	4307.8	3552	41
01/09 -- 07/09	1664	249.9	215.4			2873.5	2568	14
08/09 -- 12/09	1638	214.2	176.3	0.0	43	2709.4	2466	15
15/09 -- 19/09	3669	213.3	170.6	93.0	128	2707.0	2642	12
22/09 -- 26/09	2809	217.6	165.6	65.0	87	2236.8	2466	19
06/10 -- 09/10	3147	199.0	156.4	16.0	160	2099.0	2393	17
13/10 -- 17/10	5254	443.7	393.1	0.0	186	4200.8	4247	18
20/10 -- 24/10	2716	448.2	397.7	0.0	169	3662.2	4274	18
27/10 -- 31/10	3438	345.4	305.3	38.0	179	3110.2	3719	32
03/11 -- 07/11	1749	270.7	216.4	49.0	121	2525.0	2872	14
10/11 -- 14/11	1839	225.8	195.1			2880.2	3109	4
17/11 -- 21/11	2907	270.2	239.4	0.0	219	3865.0	6156	0
24/11 -- 28/11	2483	275.9	264.7	0.0	74	3331.6	4512	23
01/12 -- 05/12		279.1	239.8	0.0	122	3381.0		46
08/12 -- 12/12		261.9	238.5			2721.8		16
15/12 -- 19/12		225.9	200.4	65.0	104	2544.0		74
22/12 -- 24/12		267.6	246.8					
28/12 -- 31/12		228.1	166.9					
05/01/87-09/01		230.6	194.7			1927.2		53
12/01 -- 16/01	2750	240.4	210.7	0.0	159	2906.0	4540	49
19/01 -- 23/01	2738	237.8	215.5	0.0	63	2747.2	4676	24
26/01 -- 30/01	2102	233.2	219.9	0.0	121	3203.2	4574	18
02/02 -- 06/02	4063	208.3	184.2	0.0	108	2918.8	6204	47
09/02 -- 13/02	2740	200.8	179.1	0.0	139	2792.0	5776	20
16/02 -- 30/02	2978	214.2	184.4			3017.4	4940	53
23/02 -- 29/02	2300	228.8	198.7	0.0	34	3563.8	4347	41
02/03 -- 06/03	2118	212.9	191.1			4577.7	4403	27
Average	2927	256.8	225.8	51.6	112	3602.6	3946	26
Std Deviation	988	57.0	54.9	65.3	52	1137.3	952	16

Table : 8B.10 Unit B : Sampling Point 877

Humus Tank Effluent

Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Ammonia	NO3	Chloride	Alkal	Hard	Conduct	Total Fe	Dissolved Fe
01/07/85-05/07	59	10.0	10.0			126	153			0.4	
08/07 -- 12/07	33	10.5	9.7			105	166			0.6	
15/07 -- 19/07	37	10.9	10.7			114	173			0.7	
22/07 -- 26/07	50	10.9	10.1			114	191			0.3	
29/07 -- 02/08	51	11.1	10.8			115	202				
05/08 -- 09/08	115	10.7	10.2			109	184			1.3	
12/08 -- 16/08	126	11.0	10.1			136	186			1.1	
26/08 -- 30/08	57	10.0	9.8			108	149			0.9	
09/09 -- 13/09	59	10.2	9.6			129	141			0.3	
16/09 -- 20/09	41	11.2	10.7			130	140			0.3	
23/09 -- 27/09	79	10.9	10.2			115	152			0.6	
30/09 -- 04/10	67	10.1	8.7			116	142			0.6	
20/01/86-24/01	35	10.1	9.8			127	105			0.4	
27/01 -- 30/01	136	5.7	9.0			105	127			0.2	
17/02 -- 21/02	56	6.9	5.9				145	219		0.3	0.1
03/03 -- 07/03	92	8.4	8.0	5.0	3.1	148	160	180	112	0.3	0.0
10/03 -- 15/03	47	9.3	7.6	1.0	5.5	132	169	139	121	0.4	0.1
17/03 -- 22/03	57	7.5	6.6	0.0	3.4	92	158	139	74	0.2	0.0
24/03 -- 29/03	81	8.3	6.5	0.0	7.9	137	140	163	91	0.1	0.0
31/03 -- 04/04	28	8.3	7.7				98	146		0.5	0.0
07/04 -- 11/04	62	9.0	8.7	2.0	4.3	147	145	145	99	0.0	0.0
14/04 -- 18/04	44	8.6	8.1				162	134		0.2	0.0
21/04 -- 25/04	46	7.0	6.8	0.0	9.5	85	146	165	74	0.8	0.2
28/04 -- 02/05	32	8.2	7.4	0.0	9.7	112	107	168	83	0.2	0.0
12/05 -- 16/05	29	9.7	9.1	0.0	2.3	121	98	154	80	0.1	0.0
19/05 -- 23/05	49	10.8	10.3	3.0	7.8	136	109	156	84	0.6	0.4
26/05 -- 30/05	67	11.6	11.4				135	140		0.3	0.1
02/06 -- 06/06	52	9.6	8.9	2.0	1.4		134	156		0.0	0.0
09/06 -- 13/06	49	8.3	7.0				149	137		0.9	0.2
16/06 -- 20/06	41	10.1	9.4	4.0	5.4		218	148		1.5	0.5
23/06 -- 27/06	84	10.0	9.7	8.0	3.7	129	302	164	81	2.5	1.7
30/06 -- 04/07	58	10.1	9.0	8.0	1.7	134	176	147	80	1.2	0.6
07/07 -- 11/07	78	11.8	9.8				223	135		0.6	0.4
14/07 -- 18/07	67	9.3	8.8	6.0	3.6	104	180	137	74	1.1	0.4
21/07 -- 27/07	76	10.3	8.3	4.0	4.3	96	187	148	69	0.4	0.1
28/07 -- 01/08	88	11.6	9.9	2.0	2.2	142	159	138	86	0.2	0.1
04/08 -- 08/08	55	9.4	8.0	7.0	1.3	155	198	137	86	0.0	0.0
11/08 -- 15/08	87	12.2	11.0	6.0	2.8	123	209	129	87	0.1	0.0
18/08 -- 22/08	77	10.3	9.8				186	147		0.1	0.1
25/08 -- 29/08	68	10.1	9.5	5.0	4.8	95	162	138	80	0.7	0.3
01/09 -- 07/09	64	11.6	9.7	3.0	6.0	110	168	133	85	0.5	0.0
08/09 -- 12/09	79	11.7	10.1	0.0	1.9	106	142	141	80	0.6	0.2
15/09 -- 19/09	70	10.9	9.9	7.0	7.2	202	141	135	92	0.4	0.1
22/09 -- 26/09	67	12.1	9.4	8.0	3.9	142	115	128	76	0.4	0.0
06/10 -- 09/10	53	10.1	9.5	3.0	9.2	127	111	131	98	0.4	0.2
13/10 -- 17/10	69	11.6	10.6	4.0	6.7	91	116	116	75	0.2	0.0
20/10 -- 24/10	50	12.0	11.5	0.0	4.7	115	95	121	84	0.1	0.0
27/10 -- 31/10	63	10.6	9.5	0.0	1.0	89	91	126	71	0.5	0.4
03/11 -- 07/11	55	12.0	11.6	2.0	5.8	126	123	140	84	0.1	0.0
10/11 -- 14/11	50	10.4	10.2				140	158		0.0	0.0
17/11 -- 21/11	57	9.9	8.5	1.0	7.3	120	136	163	100	0.4	0.0
24/11 -- 28/11	70	11.0	9.4	2.0	4.4	108	120	159	86	0.3	0.3
01/12 -- 05/12	63	9.0	8.3	3.0		125	125		96	2.1	1.5
08/12 -- 12/12		9.2	8.2				94			1.2	0.6
15/12 -- 19/12	46	8.3	6.9	4.0	4.3	85	86		69	2.6	1.9
22/12 -- 24/12		8.1	7.7								
28/12 -- 31/12		5.1	4.8								
05/01/87-09/01		7.5	7.3				73			1.5	1.1
12/01 -- 16/01	80	8.0	7.5	0.0	0.6	88	94	157	75	1.4	1.0
19/01 -- 23/01	66	8.2	7.0	0.0	0.8	75	99	165	73	0.7	0.4
26/01 -- 30/01	49	8.4	7.9				126	136		0.3	0.4
02/02 -- 06/02	58	6.5	6.0	0.0	0.2	190	119	211	97	2.0	0.6
09/02 -- 13/02	67	7.0	6.2	0.0	3.9	247	99	217	11	0.9	0.5
16/02 -- 20/02	55	7.5	5.7				111	159		2.0	1.4
23/02 -- 29/02	50	9.1	7.5	10.0	0.0	195	134	178	0	1.9	1.2
02/03 -- 06/03	50	8.3	8.2			135	216	187		1.0	0.7
Average	61	9.6	8.8	3.0	4.2	124	146	153	80	0.7	0.3
Std Deviation	21	1.6	1.5	2.9	2.7	32	41	24	22	0.6	0.5

Table : DB 11 Unit 9 : Sampling Point 9P7

Effluent from Humus Tanks

Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P	Ammonia	NO3	Chloride	Alkal	Hard	Total Fe
10/03 -- 15/03	1427	255.3	234.0	36.0	196	4710	5307.4	4352	12
17/03 -- 22/03	1234	169.8	149.8	0.0	79	2140	3606.1	3163	5
24/03 -- 29/03	1477	148.8	117.1	0.0	138	2432	2513.0	2924	2
31/03 -- 04/04	626	178.6	166.3				2179.5	3260	12
07/04 -- 11/04	1441	209.0	201.6	47.0	102	3467	3364.6	3365	0
14/04 -- 18/04	953	184.4	173.9				3501.4	2898	4
21/04 -- 25/04	798	184.4	189.5				4035.0	4588	15
28/04 -- 02/05	951	239.2	214.7	0.0	299	3457	3121.6	4930	6
12/05 -- 16/05	743	248.5	233.3	0.0	60	3184	2506.0	3954	2
19/05 -- 23/05	1508	315.7	298.5	87.0	226	3946	3287.5	4444	22
26/05 -- 30/05	1932	328.8	325.0				3835.6	3972	8
02/06 -- 06/06	1264	232.3	214.8	61.0	43		3575.5	4233	0
09/06 -- 13/06	1261	214.4	188.6				3809.7	3457	15
16/06 -- 20/06		323.8	318.0						
23/06 -- 27/06	2447	291.7	281.9	236.0	109	3805	8768.7	4775	72
30/06 -- 04/07	1402	281.8	271.8	216.0	46	3620	4821.8	3913	33
07/07 -- 11/07	2019	284.6	216.2				5450.0	3238	12
14/07 -- 18/07	1182	175.5	164.0	180.0	108	3111	3407.4	2548	30
21/07 -- 27/07	1809	242.4	194.9	97.0	105	2338	4383.9	3494	10
28/07 -- 01/08	1957	256.5	219.0	45.0	49	3140	3506.8	3053	4
04/08 -- 08/08	1175	194.7	165.1	148.0	28	3293	4138.2	2880	0
11/08 -- 15/08	1913	269.1	242.2	129.0	60	2657	4603.6	2844	2
18/08 -- 22/08	1404	213.1	201.6				3763.5	2840	0
25/08 -- 29/08	1490	230.4	212.6	75.0	72	1419	4094.0	3100	15
01/09 -- 07/09	1029	254.1	209.8				3295.8	2546	4
08/09 -- 12/09	493	197.6	172.5	0.0	32	1799	2397.4	2360	10
15/09 -- 19/09	1249	192.9	176.9	123.0	126	3547	2509.6	2390	7
22/09 -- 26/09	1171	214.5	161.7	165.0	80	2915	2035.4	2258	8
06/10 -- 09/10	920	162.4	154.9	46.0	142	1964	1814.7	2148	3
13/10 -- 17/10	2398	403.0	367.0	139.0	233	3161	4021.0	4033	6
20/10 -- 24/10	1666	400.1	381.8	0.0	160	3923	3176.2	4026	5
27/10 -- 31/10	1761	305.4	274.3	0.0	17	1542	2592.0	3318	14
03/11 -- 07/11	1035	223.4	215.7	46.0	135	2934	2294.4	2636	2
10/11 -- 14/11	939	195.7	191.5				2618.8	2964	0
17/11 -- 21/11	2045	254.0	204.5	33.0	241	3959	3464.0	5806	66
24/11 -- 28/11	1855	286.9	246.5	51.0	112	2758	3150.2	4147	9
01/12 -- 05/12	1671	239.1	219.9	79.0		3316	3325.2		56
22/12 -- 24/12		227.8	215.9						
28/12 -- 31/12		144.6	137.0						
05/01/87-09/01		186.7	179.2				1753.2		39
12/01 -- 16/01	2057	208.1	191.4	0.0	0	2360	2575.2	4289	37
19/01 -- 23/01	1766	222.0	189.1	0.0	22	2113	2643.2	4446	18
26/01 -- 30/01	1066	204.5	199.1				2823.3	4080	14
02/02 -- 06/02	1718	188.4	173.8	0.0	6	5364	3521.6	6261	60
09/02 -- 13/02	1747	180.2	159.5	0.0	100	6343	2571.4	5596	24
16/02 -- 30/02	1379	188.9	144.9				2799.0	4763	50
23/02 -- 29/02	1194	214.9	177.9	216.0	0	4207	3176.2	4191	46
02/03 -- 06/03	1139	187.1	184.1			2859	4874.7	4296	23
Average	1425	232.4	210.9	70.5	101	3181	3444.7	3693	17
Std Deviation	457	57.7	56.5	73.8	77	1060	1196.2	979	19

Table : OB 12 Unit B : Sampling Point BP7
Humus Tank Effluent Recycle
Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P	Ammonia	NO3	Chloride	Alkal	Hard	Total Fe
10/03 -- 15/03	956	174.2	159.2	27.0	146	3512	3663.6	2997	8
17/03 -- 22/03	1036	119.4	92.0	0.0	27	736.0	2407.1	2269	6
24/03 -- 29/03	2067	118.3	101.6	0.0	35	619.0	1998.8	2405	1
31/03 -- 04/04	282	83.6	77.6				985.0	1514	4
07/04 -- 11/04	599	87.0	83.8	18.0	39	1339	1400.0	1408	0
14/04 -- 18/04	348	67.2	63.7				1272.2	1057	2
21/04 -- 25/04	531	121.8	124.0				2601.2	2967	9
28/04 -- 02/05	519	135.0	123.2	0.0	171	1977	1741.8	2730	3
12/05 -- 16/05	416	140.6	131.2	0.0	38	2007	1451.6	2245	2
19/05 -- 23/05	859	191.3	181.9	55.0	142	2478	1919.0	2739	11
26/05 -- 30/05	1081	181.9	180.1				2135.0	2209	4
02/06 -- 06/06	889	165.8	154.2	42.0	30		2275.5	2618	0
09/06 -- 13/06	916	155.0	135.7				2739.7	2496	11
16/06 -- 20/06		211.0	207.2						
23/06 -- 27/06	1583	187.9	181.7	150.0	69	2416	5650.3	3076	47
30/06 -- 04/07	913	183.2	176.7	143.0	30	2403	3134.5	2543	21
07/07 -- 11/07	1304	187.2	143.7				3541.0	2132	8
14/07 -- 18/07	722	112.1	105.5	134.0	80	2322	2159.8	1610	22
21/07 -- 27/07	932	121.7	98.5	61.0	66	1470	2206.0	1752	5
28/07 -- 01/08	930	122.7	104.7	21.0	23	1488	1692.4	1461	2
04/08 -- 08/08	597	94.1	79.7	78.0	14	1733	2013.2	1413	0
11/08 -- 15/08	844	117.8	106.5	53.0	25	1092	2012.0	1251	1
18/08 -- 22/08	420	63.7	60.3				1126.0	851	0
25/08 -- 29/08	736	115.4	106.2	31.0	30	584.0	2038.8	1545	7
01/09 -- 07/09	261	57.7	44.7				777.3	609	2
08/09 -- 12/09	137	55.1	47.9	0.0	10	547.0	667.6	659	3
15/09 -- 19/09	329	50.9	46.0	32.0	33	934.0	662.2	635	2
22/09 -- 26/09	298	53.4	42.8	29.0	14	516.0	513.2	570	1
06/10 -- 09/10	366	60.7	58.0	23.0	71	978.0	705.0	821	1
13/10 -- 17/10	1566	261.9	238.8	90.0	152	2058	2613.6	2632	5
20/10 -- 24/10	1103	264.4	252.5	0.0	104	2543	2102.6	2657	2
27/10 -- 31/10	857	162.4	145.9	0.0	6	552.0	1340.2	1619	6
03/11 -- 07/11	241	52.2	50.6	5.0	16	336.0	532.0	599	0
10/11 -- 14/11	181	38.2	37.4				511.8	575	0
17/11 -- 21/11	1449	180.0	144.9	23.0	171	2805	2454.0	4113	47
24/11 -- 28/11	679	114.5	98.2	21.0	47	1159	1229.8	1644	3
01/12 -- 05/12	644	88.7	81.5	31.0		1276	1232.0		21
08/12 -- 12/12		78.9	71.8				860.2		9
05/01/87-09/01		88.0	84.6				832.0		18
12/01 -- 16/01	741	70.3	64.9	0.0	0	902.0	864.0	1473	13
19/01 -- 23/01	570	68.8	57.7	0.0	7	630.0	834.2	1392	5
26/01 -- 30/01	465	87.4	82.9				1221.3	1723	6
02/02 -- 06/02	370	36.2	33.9	0.0	1	1319	700.2	1268	10
09/02 -- 13/02	682	70.2	62.0	0.0	39	2495	1002.8	2186	10
16/02 -- 30/02	541	74.9	57.1				1103.0	1878	19
23/02 -- 29/02	479	85.9	71.3	93.0	0	1815	1272.8	1683	18
02/03 -- 06/03	443	68.1	66.7			1284	1662.0	1993	13
Average	725	115.5	104.7	36.2	53	1510	1692.6	1814	8
Std Deviation	414	56.9	53.8	43.9	52	813.9	1004.2	822	10

Table : DB 13 Unit B : Sampling Point BP7

Effluent to Maturation Ponds

Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P	Ammonia	NO3	Chloride	Alkal	Hard	Total Fe
10/03 -- 15/03	471	81.1	74.8	9.0	50	1198	1643.8	1355	4
17/03 -- 22/03	751	110.1	101.3	0.0	52	1404	2379.2	2030	2
24/03 -- 29/03	770	109.8	82.3	0.0	103	1813	1855.0	2123	2
31/03 -- 04/04	343	95.0	88.6				1194.5	1746	7
07/04 -- 11/04	842	122.1	117.8	29.0	62	2128	1964.6	1957	0
14/04 -- 18/04	605	117.3	110.2				2229.2	1841	3
21/04 -- 25/04	268	62.6	65.5				1433.8	1621	6
28/04 -- 02/05	432	104.2	91.5	0.0	128	1480	1379.8	2200	3
12/05 -- 16/05	326	107.9	102.1	0.0	22	1177	1054.4	1709	1
19/05 -- 23/05	588	123.9	117.2	32.0	84	1468	1183.8	1736	9
26/05 -- 30/05	851	146.9	144.9				1700.6	1763	4
02/06 -- 06/06	518	91.5	83.9	19.0	13		1300.0	1614	0
09/06 -- 13/06	345	59.4	52.8				1070.0	961	4
16/06 -- 20/06		112.8	110.8						
23/06 -- 27/06	864	103.7	100.2	86.0	40	1389	3118.3	1699	25
30/06 -- 04/07	489	98.6	95.1	73.0	15	1217	1687.2	1370	12
07/07 -- 11/07	716	97.4	72.5				1909.0	1106	4
14/07 -- 18/07	460	63.4	58.5	46.0	27	789.0	1247.6	938	8
21/07 -- 27/07	877	120.7	96.4	36.0	39	868.0	2177.9	1742	5
28/07 -- 01/08	1028	133.8	114.3	24.0	26	1652	1814.4	1592	2
04/08 -- 08/08	578	100.7	85.4	70.0	13	1560	2125.0	1467	0
11/08 -- 15/08	1069	151.3	135.6	76.0	36	1565	2591.6	1593	1
18/08 -- 22/08	984	149.4	141.3				2637.5	1990	0
25/08 -- 29/08	754	115.0	106.5	44.0	42	835.0	2055.2	1555	8
01/09 -- 07/09	702	154.8	123.0				2087.7	1656	4
08/09 -- 12/09	357	142.6	124.6	0.0	22	1252	1729.8	1701	7
15/09 -- 19/09	920	142.0	130.9	91.0	93	2613	1847.4	1755	5
22/09 -- 26/09	874	161.1	118.9	136.0	66	2399	1522.2	1687	7
06/10 -- 09/10	554	101.7	96.9	23.0	72	986.0	1109.7	1326	2
13/10 -- 17/10	833	141.1	128.1	49.0	81	1103	1407.4	1401	2
20/10 -- 24/10	563	135.7	129.3	0.0	56	1380	1073.6	1368	1
27/10 -- 31/10	904	143.0	128.4	0.0	11	990.0	1251.8	1699	8
03/11 -- 07/11	794	171.2	165.2	41.0	120	2598	1762.4	2037	1
10/11 -- 14/11	758	157.5	154.1				2107.0	2388	0
17/11 -- 21/11	596	74.0	59.6	10.0	70	1154	1010.0	1693	19
24/11 -- 28/11	1176	172.4	148.3	30.0	65	1599	1920.4	2503	6
01/12 -- 05/12	1027	150.5	138.4	48.0		2038	2093.2		35
05/01/87-09/01		98.7	94.6				921.2		21
12/01 -- 16/01	1316	137.8	126.5	0.0	0	1458	1711.2	2816	25
19/01 -- 23/01	1196	153.2	131.3	0.0	16	1483	1809.0	3053	12
26/01 -- 30/01	601	117.1	116.2				1602.0	2357	8
02/02 -- 06/02	1348	152.1	140.0	0.0	4	4045	2821.4	4993	50
09/02 -- 13/02	1065	110.0	97.5	0.0	61	3848	1568.6	3410	15
16/02 -- 30/02	838	114.1	87.9				1696.0	2885	31
23/02 -- 29/02	715	129.0	106.6	123.0	0	2392	1903.4	2508	28
02/03 -- 06/03	592	89.6	87.8			1575	2172.0	2774	16
Average	742	120.2	106.3	34.2	48	1670	1755.1	1947	9
Std Deviation	269	28.9	26.6	37.7	35	771.7	500.2	723	11

Table : OC-1 Unit C-1 Sampling Point SP1

Raw Sewage

Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Ammonia	Chloride	Alkal	Hard	Conduct	Total Fe	Dissolved Fe
01/07/85-05/07	1032	11.4	8.1							
08/07 -- 12/07	895	14.8	9.4							
15/07 -- 19/07	1035	14.0	10.3							
22/07 -- 26/07	1009	10.5	8.1							
29/07 -- 02/08	958	14.3	9.0							
05/08 -- 09/08	841	12.7	7.5							
12/08 -- 16/08	1303	14.1	8.7							
26/08 -- 30/08	764	13.6	9.9							
09/09 -- 13/09	776	14.5	11.0							
16/09 -- 20/09	806	14.3	10.5							
23/09 -- 27/09	880	15.5	11.7							
30/09 -- 04/10	1004	14.6	10.3							
20/01/86-24/01	574	13.9	10.7							
27/01 -- 30/01	728	12.2	6.9							
17/02 -- 21/02	557	12.5	7.5			220	225		2.3	0.7
02/03 -- 07/03	847	10.1	5.9	27.0	141	254	193	117	2.3	1.0
10/03 -- 15/03	727	10.6	8.3	26.0	138	311	135	116	3.8	0.5
17/03 -- 22/03	712	10.6	7.9	21.0	125	274	144	102	2.4	0.7
24/03 -- 29/03	1026	7.9	6.3	29.0	137	260	163	96	2.2	0.9
31/03 -- 04/04	726	12.2	9.6			244	153		9.0	1.5
07/04 -- 11/04	721	10.5	7.9	36.0	104	250	153	94	1.8	0.8
14/04 -- 18/04	594	10.4	7.5			265	154		1.5	0.5
21/04 -- 25/04	742	11.3	7.3	32.0	96	283	168	89	2.5	0.8
28/04 -- 02/05	662	13.1	8.6	24.0	110	225	174	95	1.2	0.5
12/05 -- 16/05	652	11.5	8.6	30.0	177	199	167	101	2.6	0.8
19/05 -- 23/05	917	12.4	9.5	27.0	159	201	165	100	2.4	1.1
26/05 -- 30/05	782	13.4	9.5			267	152		3.3	0.9
02/06 -- 06/06	732	12.9	6.1			311	142		2.2	0.8
09/06 -- 13/06	656	8.3	6.3	34.0	93	255	187	84	4.2	1.4
16/06 -- 20/06	902	10.7	6.8	32.0	86	366	164	76	4.7	1.7
23/06 -- 27/06	645	8.0	5.5	33.0	103	300	175	92	4.0	1.7
30/06 -- 04/07	598	7.3	4.7	27.0	137	245	151	84	2.5	1.5
07/07 -- 11/07	826	11.5	6.8			284	146		3.3	1.1
14/07 -- 18/07	957	11.5	7.1	28.0	77	250	131	65	3.1	1.4
21/07 -- 27/07	840	14.0	7.6	35.0	147	274	158	42	3.2	1.0
28/07 -- 01/08	1165	13.6	10.0	25.0	144	282	140	91	1.9	0.6
04/08 -- 08/08	886	10.3	7.6	30.0	152	298	137	85	1.9	1.5
11/08 -- 15/08	1018	14.8	11.0	32.0	123	269	132	98	1.6	0.5
18/08 -- 22/08	833	12.9	9.7			269	140		2.9	1.5
25/08 -- 29/08	865	14.6	10.4	39.0	93	311	152	95	5.0	1.8
01/09 -- 07/09	932	15.5	10.9	26.0	134	246	142	98	3.1	1.3
08/09 -- 12/09	731	13.0	9.1	18.0	102	246	134	90	2.5	1.1
15/09 -- 19/09	777	12.3	9.1	26.0	157	261	142	98	2.2	1.0
22/09 -- 26/09	931	14.0	8.8		112	222	121	81	2.1	0.8
06/10 -- 09/10	842	15.3	12.6	64.0	104	248	140	101	1.9	1.0
13/10 -- 17/10	941	13.9	10.8	34.0	120	208	145	93	1.9	0.5
20/10 -- 24/10	725	13.3	9.6	27.0	165	210	125	116	4.2	1.4
27/10 -- 31/10	931	11.6	9.8		109	196	119	85	2.1	0.9
03/11 -- 07/11	719	11.7	9.4	23.0	110	224	146	81	2.6	1.0
10/11 -- 14/11	814	14.6	10.4			233	170		2.0	1.0
17/11 -- 21/11	823	10.1	8.3	38.0	120	217	172	110	2.5	0.9
24/11 -- 28/11	667	11.6	8.3	29.0	127	205	173	95	2.3	1.0
01/12 -- 05/12	696	11.7	9.9	23.0	121	204		36	2.6	1.5
08/12 -- 12/12		9.8	7.6			200			2.5	1.2
15/12 -- 19/12	416	8.6	6.5	27.0	68	178		84	2.9	2.3
22/12 -- 24/12		12.3	9.2				1			
28/12 -- 31/12		7.6	5.9							
05/01/87-09/01		12.6	7.3			210			3.2	1.8
12/01 -- 16/01	577	8.7	7.0	22.0	96	197	171	79	2.9	2.2
19/01 -- 23/01	512	7.8	5.9	21.0	73	194	178		1.4	1.2
26/01 -- 30/01	773	9.9	6.4	26.0	192	211	160	113	1.6	1.0
02/02 -- 06/02	905	9.2	6.6	22.0	225	220	223	125	3.8	1.4
09/02 -- 13/02	592	8.0	5.0	12.0	138	185	215		2.9	1.5
16/02 -- 30/02	1190	8.7	5.8			203	167		3.3	3.1
23/02 -- 29/02	740	10.4	7.6	26.0	169	249	190	104	3.5	2.8
02/03 -- 06/03	689	12.0	6.7			275	187		2.1	1.3
Average	807	11.3	8.4	28.7	126	244	156	92	2.8	1.2
Std Deviation	168	2.2	1.7	8.3	33	40	34	18	1.2	0.6

Table : DC 2 Unit C : Sampling Point CP1
Raw Sewage
Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P	Ammonia
10/03 -- 15/03	9480	135.2	106.3	364.0
17/03 -- 22/03	10343	151.9	113.0	314.0
24/03 -- 29/03	13538	104.3	83.7	387.0
31/03 -- 04/04	9682	160.1	125.8	
07/04 -- 11/04	9386	136.0	102.8	499.0
14/04 -- 18/04	7403	129.5	95.4	
21/04 -- 25/04	10087	147.7	92.8	
28/04 -- 02/05	5921	124.9	81.3	297.0
12/05 -- 16/05	7788	136.7	101.9	376.0
19/05 -- 23/05	10477	143.4	110.2	365.0
26/05 -- 30/05	8845	150.4	106.3	
02/06 -- 06/06	9052	153.9	101.9	
09/06 -- 13/06	9265	92.8	61.2	
23/06 -- 27/06	8611	106.2	72.1	444.0
30/06 -- 04/07	7644	103.0	71.0	361.0
07/07 -- 11/07	8395	109.8	63.8	
14/07 -- 18/07	10135	131.1	75.5	274.0
21/07 -- 27/07	10180	169.2	90.2	328.0
28/07 -- 01/08	13465	156.7	114.7	288.0
04/08 -- 08/08	10289	118.8	87.4	349.0
11/08 -- 15/08	12732	182.3	134.9	405.0
18/08 -- 22/08	11424	157.4	144.3	
25/08 -- 29/08	10223	177.0	127.0	357.0
01/09 -- 07/09	9706	176.8	137.9	
08/09 -- 12/09	8290	147.2	103.2	215.0
15/09 -- 19/09	9220	146.2	109.1	272.0
22/09 -- 26/09	11772	174.0	107.1	
06/10 -- 09/10	11376	207.5	170.5	751.0
13/10 -- 17/10	11816	172.0	133.8	453.0
20/10 -- 24/10	11016	200.8	145.0	322.0
27/10 -- 31/10	15604	179.9	162.1	
03/11 -- 07/11	8185	154.1	125.4	332.0
10/11 -- 14/11	11383	208.6	150.8	
17/11 -- 21/11	7703	66.4	42.4	413.0
24/11 -- 28/11	9196	161.9	115.4	394.0
01/12 -- 05/12	11929	201.3	171.3	394.0
08/12 -- 12/12	.	148.7	114.7	
15/12 -- 19/12	10367	147.2	112.7	673.0
22/12 -- 24/12		169.4	126.7	
28/12 -- 31/12		141.4	107.9	
05/01/87-09/01		201.0	107.9	
12/01 -- 16/01	9482	147.6	114.1	
19/01 -- 23/01	7928	117.5	[illegible].5	293.0
26/01 -- 30/01	11995	153.1	[illegible].3	433.0
02/02 -- 06/02	20405	207.4	[illegible]3.0	466.0
09/02 -- 13/02	9536	112.0	70.8	191.0
16/02 -- 30/02	20739	139.2	98.1	
23/02 -- 29/02	11446	161.3	117.6	334.0
02/03 -- 06/03	17226	294.5	158.4	
Average	10682	153.4	110.4	378.1
Std Deviation	3021	37.6	28.7	115.3

Table : DC 3 Unit C : Sampling Point CP3

Feed to Primary Settlers

Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P	Total Fe
10/03 -- 15/03	8296	142.7	98.5	162
17/03 -- 22/03	11150	179.0	113.8	85
24/03 -- 29/03	14681	126.8	84.2	146
31/03 -- 04/04	10382	184.0	127.1	264
07/04 -- 11/04	10546	176.0	103.9	99
14/04 -- 18/04	8659	172.1	96.1	80
21/04 -- 25/04	11474	190.0	95.3	126
28/04 -- 02/05	6941	165.5	82.7	92
12/05 -- 16/05	8018	141.1	102.0	33
19/05 -- 23/05	12153	186.9	113.2	118
26/05 -- 30/05	10726	200.7	110.9	238
02/06 -- 06/06	12750	195.5	103.9	110
09/06 -- 13/06	12768	137.0	65.3	193
23/06 -- 27/06	9324	141.1	73.0	79
30/06 -- 04/07	8809	129.3	72.4	76
07/07 -- 11/07	9358	145.6	64.6	89
14/07 -- 18/07	11416	169.9	76.5	83
21/07 -- 27/07	11512	211.2	91.4	130
28/07 -- 01/08	15706	221.7	122.7	112
04/08 -- 08/08	13298	183.1	91.5	117
11/08 -- 15/08	14370	239.6	139.5	96
18/08 -- 22/08	12555	226.4	147.4	138
25/08 -- 29/08	11557	221.9	129.8	128
01/09 -- 07/09	11265	237.0	140.1	128
08/09 -- 12/09	9761	191.4	105.5	125
15/09 -- 19/09	11198	203.4	111.7	136
22/09 -- 26/09	14252	240.1	108.8	131
06/10 -- 09/10	13575	270.0	173.2	110
13/10 -- 17/10	14072	217.5	135.4	79
20/10 -- 24/10	13057	255.0	147.1	147
27/10 -- 31/10	18145	263.3	165.7	68
03/11 -- 07/11	10516	207.1	128.8	206
10/11 -- 14/11	13556	254.4	153.2	137
17/11 -- 21/11	10490	74.8	43.9	161
24/11 -- 28/11	11246	211.7	117.1	93
01/12 -- 05/12		234.6	175.1	139
08/12 -- 12/12		201.1	116.1	169
15/12 -- 19/12		192.7	114.2	439
22/12 -- 24/12		214.2	130.7	
28/12 -- 31/12		171.3	109.2	
05/01/87-09/01		225.3	109.6	576
12/01 -- 16/01	10647	183.4	117.0	837
19/01 -- 23/01	8934	145.6	95.4	123
26/01 -- 30/01	13012	179.9	104.7	95
02/02 -- 06/02	21331	246.8	149.7	532
09/02 -- 13/02	10674	151.1	71.4	429
16/02 -- 30/02	21754	168.1	98.5	401
23/02 -- 29/02	12402	188.2	118.5	326
02/03 -- 06/03	17936	333.1	161.2	264
Average	12192	194.9	112.4	184
Std Deviation	3173	45.3	29.3	156

Table : DC 4 Unit 2 : Sampling Point CP4

Primary Settlers Effluent

Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Total Fe	Dissolved Fe
01/07/85-05/07	471	9.6	7.7	4.3	
08/07 -- 12/07	407	9.1	6.7	3.0	
15/07 -- 19/07	525	8.5	6.5	1.8	
22/07 -- 26/07	540	8.9	7.0	2.2	
29/07 -- 02/08	463	10.9	7.7		
05/08 -- 09/08	471	13.7	8.2	4.0	
12/08 -- 16/08	732	14.6	5.6	10.5	
26/08 -- 30/08	408	10.5	7.7	3.7	
09/09 -- 13/09	290	7.3	5.0	3.0	
16/09 -- 20/09	392	9.7	7.5	3.6	
23/09 -- 27/09	423	9.9	7.5	2.3	
30/09 -- 04/10	595	9.2	7.1	3.1	
20/01/86-24/01	241	9.1	7.1	1.5	
27/01 -- 30/01	703	7.3	5.3		
17/02 -- 21/02	412	7.3	5.4	3.4	0.6
02/03 -- 07/03	450	8.0	5.8	2.7	0.5
10/03 -- 15/03	422	7.7	5.5	4.1	0.6
17/03 -- 22/03	343	6.9	5.3	3.2	0.7
24/03 -- 29/03	497	5.5	4.3	2.1	0.9
31/03 -- 04/04	331	9.4	6.6	5.0	1.2
07/04 -- 11/04	416	8.1	6.2	2.6	0.7
14/04 -- 18/04	371	8.1	5.4	2.9	0.6
21/04 -- 25/04	651	8.0	5.5	3.4	0.9
28/04 -- 02/05	293	7.3	5.4	2.6	0.7
12/05 -- 16/05	343	11.2	8.7	3.2	0.7
19/05 -- 23/05	450	10.1	7.9	5.0	1.2
26/05 -- 30/05	428	11.5	9.1	5.0	1.3
02/06 -- 06/06	491	9.4	7.2	2.9	1.0
09/06 -- 13/06	423	8.5	6.2	9.1	2.0
16/06 -- 20/06	577	7.8	6.6	4.7	1.8
23/06 -- 27/06	679	8.7	5.8	4.0	2.0
30/06 -- 04/07	392	7.6	5.2	4.0	1.5
07/07 -- 11/07	536	8.1	5.4	3.6	2.1
14/07 -- 18/07	447	9.1	7.0	4.1	1.1
21/07 -- 27/07	354	7.9	5.3	3.6	1.0
28/07 -- 01/08	563	12.7	9.8	3.1	0.9
04/08 -- 08/08	517	9.5	6.6	4.1	1.9
11/08 -- 15/08	678	12.6	9.2	3.4	0.8
18/08 -- 22/08	489	10.0	7.5	3.4	1.1
25/08 -- 29/08	615	8.9	7.6	3.4	1.2
01/09 -- 07/09	484	10.9	9.3	3.1	1.1
08/09 -- 12/09	306	10.1	7.5	3.5	1.3
15/09 -- 19/09	496	8.0	6.4	3.2	0.9
22/09 -- 26/09	406	12.1	9.6	4.8	1.5
06/10 -- 09/10	394	11.5	9.3	3.9	1.8
13/10 -- 17/10	402	12.1	9.0	3.4	1.3
20/10 -- 24/10	616	9.8	6.9	3.5	0.7
27/10 -- 31/10	352	8.2	6.5	2.9	1.4
03/11 -- 07/11	556	9.5	8.0	2.6	0.8
10/11 -- 14/11	431	11.8	9.6	4.0	1.6
17/11 -- 21/11	475	8.2	6.0	3.8	1.0
24/11 -- 28/11	320	7.1	5.6	3.1	0.8
01/12 -- 05/12		7.6	6.2	5.1	2.5
08/12 -- 12/12		8.0	5.9	3.1	1.3
15/12 -- 19/12		6.2	4.4	3.2	2.3
22/12 -- 24/12		6.9	5.1		
28/12 -- 31/12		4.5	3.3		
05/01/87-09/01		5.7	4.3	3.3	2.5
12/01 -- 16/01	265	6.3	4.3	3.1	1.5
19/01 -- 23/01	358	7.3	5.5	2.1	1.7
26/01 -- 30/01	401	8.5	5.6	1.9	1.0
02/02 -- 06/02	201	5.4	3.3	2.6	1.1
09/02 -- 13/02	329	5.2	3.6	1.9	0.9
16/02 -- 30/02	344	6.5	4.0	3.0	2.4
23/02 -- 29/02	362	6.7	5.3	3.1	1.8
02/03 -- 06/03	473	8.5	6.6	1.9	1.0
Average	447	8.8	6.5	3.5	1.3
Std Deviation	116	2.1	1.6	1.4	0.5

Table : DC 5 Unit C : Sampling Point CP4

Effluent from Primary Settlers

Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P
10/03 -- 15/03	5765	104.7	75.6
17/03 -- 22/03	5217	103.4	80.3
24/03 -- 29/03	6994	78.5	60.0
31/03 -- 04/04	4728	131.3	91.9
07/04 -- 11/04	5743	112.3	85.0
14/04 -- 18/04	4908	110.5	74.6
21/04 -- 25/04	11047	118.9	80.9
28/04 -- 02/05	3087	73.6	53.4
12/05 -- 16/05	4127	132.8	102.9
19/05 -- 23/05	5471	128.2	100.3
26/05 -- 30/05	5072	135.2	106.3
02/06 -- 06/06	6822	124.1	95.8
09/06 -- 13/06	6869	124.2	93.0
23/06 -- 27/06	9706	124.7	83.0
30/06 -- 04/07	5606	115.3	71.2
07/07 -- 11/07	4926	84.6	57.2
14/07 -- 18/07	5826	116.3	86.6
21/07 -- 27/07	4534	95.6	60.4
28/07 -- 01/08	7802	174.5	134.4
04/08 -- 08/08	7031	129.7	89.4
11/08 -- 15/08	9575	178.8	131.5
18/08 -- 22/08	7278	150.2	114.0
25/08 -- 29/08	8336	117.0	100.8
01/09 -- 07/09	6024	158.9	128.0
08/09 -- 12/09	3971	128.6	96.8
15/09 -- 19/09	6526	109.0	67.5
22/09 -- 26/09	5613	165.4	131.6
06/10 -- 09/10	5874	171.8	139.7
13/10 -- 17/10	5554	165.7	122.8
20/10 -- 24/10	9647	162.0	115.5
27/10 -- 31/10	5989	131.6	105.9
03/11 -- 07/11	8854	152.4	119.7
10/11 -- 14/11	5459	185.2	149.8
17/11 -- 21/11	2823	70.9	50.1
24/11 -- 28/11	4776	105.2	81.7
01/12 -- 05/12		140.0	114.1
08/12 -- 12/12		130.3	96.4
15/12 -- 19/12		113.6	80.5
22/12 -- 24/12		122.9	92.8
28/12 -- 31/12		86.4	62.2
05/01/87-09/01		94.4	70.8
12/01 -- 16/01	4693	111.3	77.7
19/01 -- 23/01	3839	121.6	91.4
26/01 -- 30/01	6662	120.8	86.7
02/02 -- 06/02	4941	131.8	82.8
09/02 -- 13/02	5628	89.2	61.3
16/02 -- 30/02	6442	100.6	70.8
23/02 -- 29/02	5779	108.5	86.3
02/03 -- 06/03	12753	213.8	170.2
Average	6240	125.6	93.9
Std Deviation	2044	30.3	26.2

Table : DC-5 Unit 2 : Sampling Point CPS
Feed to Bio-filters
Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Alkal	Total Fe	Dissolved Fe
01/07/85-05/07	225	5.1	4.3	225		
08/07 -- 12/07	253	5.6	4.4	248		
15/07 -- 19/07	228	6.4	3.8	210		
22/07 -- 26/07	366	4.9	3.5	232		
29/07 -- 02/08	309	5.7	4.8	262		
05/08 -- 09/08	369	7.8	5.6	255		
12/08 -- 16/08	328	8.4	3.4	244		
26/08 -- 30/08	207	6.4	4.5	225		
09/09 -- 13/09	193	4.3	2.7	170		
16/09 -- 20/09	176	4.5	3.7	193		
23/09 -- 27/09	205	5.7	4.1	212		
30/09 -- 04/10	181	5.9	3.8	222		
20/01/86-24/01	224	5.3	3.4	174		
27/01 -- 30/01	238	3.0	3.1	135		
17/02 -- 21/02	222	4.2	3.3	171	1.2	0.3
03/03 -- 07/03	280	5.6	4.3	221	1.4	0.5
10/03 -- 15/03	317	6.2	4.3	229	1.5	0.4
17/03 -- 22/03	256	4.5	3.4	213	1.4	0.3
24/03 -- 29/03	256	3.9	2.9	204	1.2	0.4
31/03 -- 04/04	208	5.2	3.7	176	2.2	0.5
07/04 -- 11/04	259	5.7	4.1	208	1.5	0.6
14/04 -- 18/04	157	3.6	2.6	181	1.2	0.3
21/04 -- 25/04	167	3.7	2.8	163	1.7	0.7
28/04 -- 02/05	238	4.5	3.3	155	1.8	0.5
12/05 -- 16/05	265	7.4	5.5	145	1.7	0.6
19/05 -- 23/05	238	6.1	4.8	167	2.2	0.8
26/05 -- 30/05	265	8.3	7.4	213	1.8	0.6
02/06 -- 06/06	259	5.7	4.2	184	1.6	0.5
09/06 -- 13/06	292	4.6	2.9	184	4.2	1.1
16/06 -- 20/06	272	5.6	4.3	329	4.3	1.7
23/06 -- 27/06	324	6.6	4.8	312	5.0	2.0
30/06 -- 04/07	326	6.7	9.9	256	3.4	1.2
07/07 -- 11/07	309	5.0	2.9	257	3.7	1.3
14/07 -- 18/07	300	5.3	3.4	183	3.7	1.4
21/07 -- 27/07	373	8.1	4.9	252	4.0	1.1
28/07 -- 01/08	408	6.2	6.7	255	2.6	0.9
04/08 -- 08/08	426	7.9	5.4	267	2.6	1.0
11/08 -- 15/08	429	8.9	7.2	259	2.1	0.4
18/08 -- 22/08	344	7.6	5.5	224	2.4	1.1
25/08 -- 29/08	379	7.9	5.7	259	2.5	0.9
01/09 -- 07/09	332	7.7	6.0	226	2.6	0.7
08/09 -- 12/09	320	7.0	4.9	198	2.8	0.7
15/09 -- 19/09	342	6.1	4.8	203	2.1	0.7
22/09 -- 26/09	331	8.9	6.9	194	3.2	1.2
06/10 -- 09/10	338	8.1	6.4	184	3.4	1.8
13/10 -- 17/10	263	6.7	9.0	137	3.4	0.9
20/10 -- 24/10	215	5.5	3.2	131	1.9	0.6
27/10 -- 31/10	243	6.6	4.8	154	2.4	1.0
03/11 -- 07/11	299	5.7	4.5	170	1.8	0.6
10/11 -- 14/11	228	7.1	5.3	182	2.2	0.6
17/11 -- 21/11	206	4.7	2.7	143	1.7	0.3
24/11 -- 28/11	281	5.6	4.4	171	2.1	0.7
01/12 -- 05/12		6.9	5.9	176	2.9	2.2
08/12 -- 12/12		6.5	4.6	166	2.5	0.9
15/12 -- 19/12		4.6	3.2	148	3.0	1.6
22/12 -- 24/12		4.8	3.7			
28/12 -- 31/12		3.8	3.0			
05/01/87-09/01		6.6	4.4	178	2.5	1.9
12/01 -- 16/01	206	5.4	3.7	152	2.4	1.5
19/01 -- 23/01	186	5.6	4.4	154	1.6	1.0
26/01 -- 30/01	235	5.7	3.4	198	1.9	0.8
02/02 -- 06/02	181	5.8	3.4	161	1.6	1.1
09/02 -- 13/02	291	4.2	2.9	177	1.6	0.8
16/02 -- 30/02	405	3.9	2.2	139	2.7	2.2
23/02 -- 29/02	304	5.6	4.2	230	2.5	2.0
02/03 -- 06/03	217	5.9	4.7	201	1.8	1.3
Average	275	5.9	4.4	201	2.4	1.0
Std Deviation	68	1.4	1.5	43	0.9	0.5

Table : DC 7 Unit C : Sampling Point CP5
Feed to Bio-filters
Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P	Alkal	Hard	Total Fe
17/03 -- 22/03	5064	82.4	64.2	2918.0	1968	14
24/03 -- 2[illegible]03	3452	52.6	38.5	2739.2	2174	17
31/03 -- 04/04	5342	130.3	93.2	4516.0	4037	58
07/04 -- 11/04	6587	145.0	104.7	5299.2	3918	38
14/04 -- 18/04	4058	93.5	69.1	4506.8	3712	26
21/04 -- 25/04	4567	100.0	76.0	4151.5	4506	44
28/04 -- 02/05	5920	100.6	74.9	3658.0	4261	46
12/05 -- 16/05	5738	158.0	118.0	3053.6	3537	36
19/05 -- 23/05	4847	127.4	98.9	3387.8	3406	44
26/05 -- 30/05	5038	157.4	140.2	4030.0	2771	34
02/06 -- 06/06	5338	115.4	85.3	3802.8	2984	34
09/06 -- 13/06	6717	88.0	58.8	3382.3	3637	90
23/06 -- 27/06	6486	132.1	96.1	6246.0	4384	100
30/06 -- 04/07	9068	166.9	254.4	6819.5	4165	91
07/07 -- 11/07	6702	105.7	62.0	5426.2	2981	76
14/07 -- 18/07	7896	139.9	88.3	4810.0	2862	96
21/07 -- 27/07	11073	195.9	115.3	5972.7	3631	92
28/07 -- 01/08	9726	196.4	161.0	6334.8	3892	67
04/08 -- 08/08	10844	202.9	138.0	6841.6	4013	66
11/08 -- 15/08	10577	219.1	178.6	6338.2	3158	52
18/08 -- 22/08	10532	256.4	186.1	6382.5	4452	90
25/08 -- 29/08	7524	158.5	114.0	5229.4	2981	50
01/09 -- 07/09	9236	225.2	179.1	5913.5	3555	67
08/09 -- 12/09	8511	185.2	130.0	5246.0	3447	74
15/09 -- 19/09	8886	158.9	125.4	5285.8	3530	54
22/09 -- 26/09	8452	225.3	174.2	4917.8	3396	81
06/10 -- 09/10	9205	220.7	174.2	5000.2	3824	92
13/10 -- 17/10	8639	219.7	282.0	4463.6	3818	109
20/10 -- 24/10	7148	183.9	107.1	4364.2	4062	63
27/10 -- 31/10	8218	219.4	158.6	5173.8	4438	82
03/11 -- 07/11	10158	182.3	131.0	6084.5	5615	73
10/11 -- 14/11	7309	227.6	171.1	5850.8	5102	70
17/11 -- 21/11	5489	105.7	73.2	5448.0	7847	61
24/11 -- 28/11	7584	150.9	120.0	4630.2	4297	57
01/12 -- 05/12		196.1	168.6	4983.8		81
08/12 -- 12/12		187.2	132.0	4750.6		72
15/12 -- 19/12		129.0	90.4	4228.0		84
22/12 -- 24/12		156.4	129.7			
28/12 -- 31/12		106.4	84.2			
05/01/87-09/01		156.9	106.7	4278.6		68
12/01 -- 16/01	5808	152.9	105.5	4286.6	4567	67
19/01 -- 23/01	5744	182.7	141.9	4580.0	4838	39
26/01 -- 30/01	6105	147.3	90.5	5258.2	4183	54
02/02 -- 06/02	4749	177.8	105.6	5582.0	6524	50
09/02 -- 13/02	8023	116.8	81.3	4917.2	6030	44
16/02 -- 30/02	9211	108.1	60.7	3840.0	5591	76
23/02 -- 29/02	9504	171.5	130.4	7114.6	5622	79
02/03 -- 06/03	6989	313.9	248.5	9642.0	7341	72
Average	7335	161.1	123.3	5036.7	4168	64
Std Deviation	2029	51.3	51.8	1268.3	1234	22

Table : DC 3   Unit C : Sampling Point CP6

Bio-filters Effluent

Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Ammonia	NO3	Alkal	Hard	Total Fe	Dissolved Fe
01/07/85-05/07	94	5.1	4.6			153		1.4	
08/07 -- 12/07	107	5.6	4.2			164		1.5	
15/07 -- 19/07	79	6.4	3.6			160		1.0	
22/07 -- 26/07	85	4.9	3.7			197		2.8	
29/07 -- 02/08	88	5.7	4.5			210			
05/08 -- 09/08	232	7.8	4.8			193		6.0	
12/08 -- 16/08	256	8.4	3.8			206		4.8	
26/08 -- 30/08	103	6.4	3.8			130		3.0	
09/09 -- 13/09	78	4.3	2.7			94		2.1	
16/09 -- 20/09	93	4.5	3.1			122		1.6	
23/09 -- 27/09	152	5.7	3.6			116		2.1	
30/09 -- 04/10	105	5.9	3.2			119		2.4	
20/01/86-24/01	66	5.3	4.9			109		1.2	
27/01 -- 30/01	79	2.7	2.8			112		0.9	
17/02 -- 21/02	43	3.3	2.4			104	236	0.7	0.0
02/03 -- 07/03	65	4.6	3.6	0.0	0.8	149	196	0.6	0.2
10/03 -- 15/03	89	4.3	3.6	0.0	4.3	153	141	0.6	0.1
17/03 -- 22/03	81	3.7	3.9	0.0	1.1	151	138	0.6	0.1
24/03 -- 29/03	74	3.0	2.6	2.0	3.4	132	162	0.8	0.1
31/03 -- 04/04	81	3.9	3.5			108	146	1.8	0.2
07/04 -- 11/04	78	4.4	3.7	2.0	3.5	138	153	1.1	0.3
14/04 -- 18/04	63	4.4	3.7			150	146	0.7	0.1
21/04 -- 25/04	48	3.3	2.8	0.0	8.5	135	173	0.9	0.2
28/04 -- 02/05	73	4.1	3.7	4.0	5.0	113	178	0.8	0.1
12/05 -- 16/05	89	5.6	4.7	0.0	3.3	89	156	1.2	0.1
19/05 -- 23/05	73	5.7	4.3	1.0	3.6	112	174	1.1	0.3
26/05 -- 30/05	80	7.9	6.5			139	148	1.6	0.4
02/06 -- 06/06	83	4.8	4.0	5.0	5.1	118	162	1.4	0.5
09/06 -- 13/06	96	3.8	3.2	1.0	0.5	151	147	1.7	0.8
16/06 -- 20/06	100	3.6	3.1	2.0	5.1	186	172	3.2	1.5
23/06 -- 27/06	148	3.7	2.9	6.0	1.4	268	184	3.0	0.8
30/06 -- 04/07	100	5.8	3.7	8.0	0.8	156	155	1.9	0.9
07/07 -- 11/07	95	4.4	3.0			192	147	1.9	0.7
14/07 -- 18/07	131	5.5	4.5	5.0	3.5	156	140	3.2	1.0
21/07 -- 27/07	222	6.9	3.8	5.0	3.3	188	159	3.8	0.6
28/07 -- 01/08	179	7.1	4.8	3.0	1.4	200	147	1.8	0.7
04/08 -- 08/08	166	5.1	3.6	7.0	1.4	202	150	2.8	1.1
11/08 -- 15/08	137	7.7	6.1	3.0	1.1	204	128	1.2	0.2
18/08 -- 22/08	135	6.8	4.4			174	153	2.1	0.9
25/08 -- 29/08	111	5.4	3.8	4.0	5.2	182	142	2.0	0.7
01/09 -- 07/09	68	7.6	4.8		4.0	152	147	1.6	0.6
08/09 -- 12/09	49	6.1	4.6	4.0	2.4	134	131	2.5	0.7
15/09 -- 19/09	140	4.7	3.4	5.0	4.8	130	145	2.3	0.3
22/09 -- 26/09	117	6.1	4.2	5.0	3.1	117	133	2.6	0.4
06/10 -- 09/10	105	7.2	5.4	5.0	6.6	126	143	3.4	1.2
13/10 -- 17/10	82	5.9	4.0	4.0	4.0	94	127	2.4	0.6
20/10 -- 24/10	132	4.8	3.5	0.0	3.6	87	125	1.4	0.2
27/10 -- 31/10	93	5.6	4.1	4.0	4.5	98	132	2.2	0.9
03/11 -- 07/11	126	5.1	4.1	2.0	1.8	99	140	2.0	0.5
10/11 -- 14/11	97	6.6	4.6			114	161	1.9	0.3
17/11 -- 21/11	103	5.6	3.0			76	168	1.9	0.2
24/11 -- 28/11	98	5.2	3.6	0.0	3.5	88	159	2.3	0.5
01/12 -- 05/12		5.2	4.7	0.0	6.9	102		3.1	1.7
08/12 -- 12/12		5.2	3.8			83		3.0	0.7
15/12 -- 19/12		4.7	3.0	2.0	6.8	71		2.9	1.8
22/12 -- 24/12		3.9	3.2						
28/12 -- 31/12		3.6	2.7						
05/01/87-09/01		4.2	3.3			90		2.9	2.0
12/01 -- 16/01	79	4.7	3.9	0.0	3.0	77	159	1.7	1.1
19/01 -- 23/01	68	5.5	4.9	0.0	1.8	78	165	1.2	1.0
26/01 -- 30/01	65	6.5	5.2	0.0	3.1	120	154	1.0	0.6
02/02 -- 06/02	54	6.1	3.6	0.0	5.5	94	211	1.9	0.8
09/02 -- 13/02	81	4.2	3.7	0.0	3.6	96	218	1.2	0.8
16/02 -- 20/02	93	4.5	3.5			104	193	2.4	2.2
23/02 -- 29/02	71	5.8	4.8	2.0	6.6	131	154	2.2	1.4
02/03 -- 06/03	87	7.2	6.4			208	169	1.5	1.0
Average	101	5.3	3.9	2.5	3.7	136	159	2.0	0.7
Std Deviation	42	1.3	0.9	2.4	2.1	42	24	1.0	0.5

Table : DC 9 Unit C : Sampling Point CB6

Effluent from Bio-filters

Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P	Ammonia	NO3	Alkal	Hard	Total Fe
17/03 -- 22/03	940	58.7	48.8			1895.0	1968	10
24/03 -- 29/03	992	40.8	35.4	28.0	47	1780.8	2184	10
31/03 -- 04/04	2086	97.6	87.1			2754.5	3758	45
07/04 -- 11/04	1995	113.5	95.2	53.0	92	3522.8	3902	28
14/04 -- 18/04	1601	122.9	101.8			3783.0	3834	19
21/04 -- 25/04	1308	85.1	74.3			3580.8	4488	25
28/04 -- 02/05	1773	101.1	91.2	97.0	121	2782.8	4351	19
12/05 -- 16/05	1977	119.1	100.4	0.0	69	1880.6	3293	26
19/05 -- 23/05	1481	117.4	89.7	22.0	79	2257.6	3516	22
26/05 -- 30/05	1525	148.3	122.7			2614.8	2791	31
02/06 -- 06/06	1713	98.3	81.0	97.0	99	2443.0	3365	28
09/06 -- 13/06	1608	77.1	50.6			3277.7	3092	32
23/06 -- 27/06	3009	75.7	58.0	124.0	29	5455.0	3744	61
30/06 -- 04/07	2961	141.1	120.3	237.0	24	4795.8	4518	48
07/07 -- 11/07	1972	98.3	65.5			4065.0	2931	38
14/07 -- 18/07	3412	145.9	117.7	119.0	83	4098.8	3678	84
21/07 -- 27/07	5014	166.2	89.5	105.0	69	4426.8	3763	84
28/07 -- 01/08	4478	171.0	129.8	78.0	36	4965.8	3790	45
04/08 -- 08/08	4216	129.7	91.4	181.0	36	5152.6	3820	72
11/08 -- 15/08	3321	187.2	149.2	71.0	26	4987.6	3128	29
18/08 -- 22/08	4053	201.2	143.4			5210.5	4480	83
25/08 -- 29/08	2294	110.2	77.4	95.0	124	3719.8	2883	40
01/09 -- 07/09	1739	184.6	163.2			3919.5	3814	27
08/09 -- 12/09	1294	163.1	121.5	108.0	65	3554.0	3460	66
15/09 -- 19/09	3608	121.5	88.9	127.0	122	3397.2	3791	59
22/09 -- 26/09	3000	155.3	105.5	131.0	81	2975.0	3367	67
06/10 -- 09/10	2846	195.0	145.6	133.0	176	3480.2	3889	92
13/10 -- 17/10	2680	190.8	130.2	131.0	131	3067.4	4126	77
20/10 -- 24/10	4409	161	116.6	0.0	120	2904.0	4180	47
27/10 -- 31/10	3160	187	137.2	138.0	156	3303.6	4454	75
03/11 -- 07/11	4673	185.0	151.4	70.0	63	3537.0	5157	78
10/11 -- 14/11	3104	212.0	146.9			3653.2	5185	61
17/11 -- 21/11	4676	117.9	85.4			3415.0	8010	61
24/11 -- 28/11	2665	139.4	97.8	0.0	94	2370.6	4290	62
01/12 -- 05/12		146.2	135.6	0.0	196	2906.2		88
08/12 -- 12/12		148.4	109.2			2364.4		86
15/12 -- 19/12		135.2	81.5	64.0	217	1975.0		81
22/12 -- 24/12		115.7	105.7					
28/12 -- 31/12		100.9	75.5					
05/01/87-09/01		110.2	86.7			2386.0		80
12/01 -- 16/01	2225	132.6	111.3	0.0	85	2180.6	4501	48
19/01 -- 23/01	2712	172.6	147.8	0.0	48	2263.8	4903	27
26/01 -- 30/01	1766	169.2	140.3	0.0	58	3207.0	4063	28
02/02 -- 06/02	1663	191.0	111.7	0.0	161	2887.4	6498	59
09/02 -- 13/02	2233	115.2	103.5	0.0	98	2656.8	6054	35
16/02 -- 30/02	2566	122.6	94.9			2860.2	5323	67
23/02 -- 29/02	2205	181.3	148.3	53.0	226	4074.0	5682	69
02/03 -- 06/03	3527	290.6	260.4			8383.3	6807	72
Average	2628	140.7	108.8	73.0	98	3416.8	4163	52
Std Deviation	1095	45.5	37.5	62.8	55	1212.7	1190	24

Table : SC 10 Unit C : Sampling Point CP7
Humus Tank Effluent
Weekly Averages of Daily Concentrations

Period	COD	Total P	Ortho P	Ammonia	NO3	Chloride	Alkal	Hard	Conduct	Total Fe	Dissolved Fe
01/07/85-05/07	32	2.0	0.9			149	122			1.4	
08/07 -- 12/07	26	1.7	1.0			140	156			1.5	
15/07 -- 19/07	44	1.9	1.0			159	138			1.8	
22/07 -- 26/07	38	1.8	0.9			159	159			2.5	
29/07 -- 02/08	38	2.6	1.2			147	180				
05/08 -- 09/08	63	2.4	1.1			143	119			4.2	
12/08 -- 16/08	116	1.7	1.2			179	168			3.6	
26/08 -- 30/08	51	1.9	0.9			156	106			1.9	
09/09 -- 13/09	39	1.4	0.7			184	76			2.0	
16/09 -- 20/09	40	1.5	0.7			179	120			2.7	
23/09 -- 27/09	39	1.7	1.0			163	103			1.2	
30/09 -- 04/10	45	1.1	0.7			174	99			0.9	
20/01/86-24/01	36	1.5	1.4			197	93			0.6	
27/01 -- 30/01	132	0.1	0.8			93	96			1.1	
17/02 -- 21/02	21	0.6	0.4				86	223		0.2	0.0
02/03 -- 07/03	43	2.1	1.4	0.0	2.5	183	124	187	106	0.3	0.1
10/03 -- 15/03	44	2.1	1.3	0.0	4.7	158	139	143	99	0.4	0.0
17/03 -- 22/03	43	1.4	0.7	4.0	2.5	123	120	134	76	0.8	1.0
24/03 -- 29/03	41	0.7	0.2	1.0	2.4	180	94	166	92	1.0	0.0
31/03 -- 04/04	26	1.3	0.6				68	151		1.8	0.8
07/04 -- 11/04	42	1.4	0.8	3.0	4.4	185	99	161	94	1.8	0.5
14/04 -- 18/04	35	1.4	0.9				126	147	0	0.5	0.1
21/04 -- 25/04	26	1.2	0.5	0.0	7.2	144	111	172	80	0.5	0.0
28/04 -- 02/05	33	1.7	1.0	4.0	5.0	137	97	171	84	1.2	0.3
12/05 -- 16/05	50	2.2	1.4	0.0	3.5	164	72	156	81	1.1	0.2
19/05 -- 23/05	51	2.5	1.9	3.0	3.8	180	89	168	88	2.1	0.4
26/05 -- 30/05	70	5.2	3.8				114	134		2.5	0.6
02/06 -- 06/06	44	1.6	0.5	4.0	6.3		95	153		2.4	0.6
09/06 -- 13/06	46	1.5	0.7	0.0	2.0		121	156		2.8	1.1
16/06 -- 20/06	41	1.9	1.2	69.0	2.0		156	177		4.3	1.2
23/06 -- 27/06	84	7.6	7.1	7.0	4.1		302	164		2.5	1.2
30/06 -- 04/07	46	2.3	1.5	10.0	1.9	192	146	156	82	3.2	0.7
07/07 -- 11/07	39	1.5	0.5				156	148		3.0	0.8
14/07 -- 18/07	81	2.6	1.0	2.0	3.7	170	133	141	75	3.6	1.0
21/07 -- 27/07	104	3.1	1.3	5.0	2.6	150	167	158	74	3.9	0.5
28/07 -- 01/08	93	3.6	1.7	4.0	1.9	193	179	152	89	2.5	1.0
04/08 -- 08/08	54	2.1	1.0	9.0	2.0	216	164	137	87	3.0	1.2
11/08 -- 15/08	64	3.4	2.2	5.0	1.7	164	182	129	89	0.6	0.1
18/08 -- 22/08	66	3.0	2.1				146	152		2.2	0.4
25/08 -- 29/08	54	2.8	1.7	3.0	2.5	141	159	141	86	1.7	0.3
01/09 -- 07/09	60	2.9	1.9	6.0	2.9	162	139	142	87	0.9	0.4
08/09 -- 12/09	29	2.8	2.0	2.0	2.7	140	114	137	80	2.7	1.0
15/09 -- 19/09	63	1.6	0.8	4.0	4.3	202	103	140	92	2.2	0.4
22/09 -- 26/09	43	2.4	1.2	7.0	2.8	192	98	136	79	2.3	0.4
06/10 -- 09/10	56	2.2	1.2	6.0	5.2	158	99	135	98	3.6	1.4
13/10 -- 17/10	48	1.9	0.9	4.0	4.3	153	77	121	89	1.6	0.3
20/10 -- 24/10	48	1.8	0.9	0.0	3.3	177	52	131	91	1.0	0.2
27/10 -- 31/10	66	2.5	1.7	7.0	4.5	125	70	133	73	2.2	0.8
03/11 -- 07/11	63	2.3	1.3	1.0	4.3	165	74	142	79	2.6	0.5
10/11 -- 14/11	50	2.9	2.2				95	161		1.4	0.3
17/11 -- 21/11	67	1.8	1.2		8.0	193	45	174	111	1.3	0.0
24/11 -- 28/11	63	1.8	1.0	0.0	2.7	167	49	160	92	2.0	0.5
01/12 -- 05/12	51	1.5	0.6	0.0	5.3	157	67		94	2.8	1.5
08/12 -- 12/12		1.2	0.9				50		1	2.0	0.6
15/12 -- 19/12	23	0.5	0.2	3.0	5.9	124	36		68	3.3	1.7
22/12 -- 24/12		2.3	0.2								
28/12 -- 31/12		1.1	0.9								
05/01/87-09/01		1.1	0.6				55			2.8	1.8
12/01 -- 16/01	46	1.9	0.8	0.0	1.8	131	55	160	78	2.6	1.1
19/01 -- 23/01	74	2.4	0.9	0.0	3.5	98	47	160	71	1.3	0.7
26/01 -- 30/01	43	1.5	0.8	0.0	3.5	300	69	156	108	1.4	0.6
02/02 -- 06/02	36	1.3	0.9	0.0	5.0	226	61	202	93	2.3	2.7
09/02 -- 13/02	45	0.6	0.3	0.0	2.5	333	58	219		2.0	0.6
16/02 -- 20/02	48	1.0	0.3				72	199		2.8	0.4
23/02 -- 29/02	50	1.2	2.0	0.0	8.5	294	88	184		2.9	1.4
02/03 -- 06/03	48	5.4	5.1				201	170		1.5	0.9
Average	51	2.0	1.2	4.6	3.6	171	111	157	82	2.0	0.7
Std Deviation	21	1.2	1.1	11.1	1.7	45	47	27	23	1.0	0.5

Table : DC 11 Unit C : Sampling Point CP7

Effluent from Humus Tanks

Weekly Averages od Daily Loads (kgs)

Period	COD	Total P	Ortho P	Ammonia	NO3	Chloride	Alkal	Hard	Total Fe
17/03 -- 22/03	600	20.4	10.9				1771.0	2002	27
24/03 -- 29/03	519	9.2	3.1	13.0	31	2318	1189.5	2089	13
31/03 -- 04/04	643	31.5	13.9				1693.0	3732	43
07/04 -- 11/04	1037	34.3	19.8	76.0	112	4718	2453.4	3978	45
14/04 -- 18/04	934	43.4	28.5				3059.0	3789	16
21/04 -- 25/04	694	31.5	12.7				2850.2	4236	15
28/04 -- 02/05	776	39.1	23.1	93.0	116	3187	2292.2	4012	28
12/05 -- 16/05	1019	46.8	29.6	0.0	72	3374	1507.2	3292	25
19/05 -- 23/05	984	50.0	36.6	62.0	79	3751	1701.6	3232	41
26/05 -- 30/05	1257	93.7	68.9				2082.6	2434	46
02/06 -- 06/06	883	30.4	15.3	74.0	116		1877.0	3016	48
09/06 -- 13/06	813	26.7	8.8				2450.3	3168	51
23/06 -- 27/06	1649	146.1	137.6	137.0	80		5878.0	3186	49
30/06 -- 04/07	1206	56.2	32.0	288.0	55	5540	3966.0	4409	100
07/07 -- 11/07	824	30.2	9.8				3067.0	2876	58
14/07 -- 18/07	2006	69.6	27.1	46.0	85	3911	3207.5	3479	99
21/07 -- 27/07	2182	66.0	29.5	101.0	52	3017	3723.8	3490	77
28/07 -- 01/08	1802	78.4	38.6	94.0	45	4551	4136.0	3612	50
04/08 -- 08/08	1256	48.3	24.4	219.0	49	5259	3837.8	3202	70
11/08 -- 15/08	1445	76.4	50.2	110.0	37	3616	4100.6	2885	14
18/08 -- 22/08	1804	79.4	46.1				3967.5	4134	96
25/08 -- 29/08	1004	54.1	32.1	66.0	55	3109	3048.4	2680	33
01/09 -- 07/09	1028	75.8	58.3				3377.5	3503	25
08/09 -- 12/09	726	192.8	48.9	51.0	69	3564	2840.6	3408	68
15/09 -- 19/09	1522	39.0	18.6	94.0	101	4758	2507.4	3408	53
22/09 -- 26/09	1021	57.8	29.4	174.0	69	4756	2334.6	3228	55
06/10 -- 09/10	1432	58.4	30.5	152.0	132	3994	2554.2	3500	94
13/10 -- 17/10	1507	59.4	27.3	126.0	135	4817	2412.4	3792	50
20/10 -- 24/10	1553	56.3	28.1	0.0	106	5675	1679.4	4209	32
27/10 -- 31/10	2142	78.2	52.7	231.0	149	4138	2287.4	4296	72
03/11 -- 07/11	2215	76.9	55.5	34.0	144	5515	2616.2	5034	95
10/11 -- 14/11	1748	85.1	61.3				2761.5	5022	23
17/11 -- 21/11	3028	0.0	0.0		315	7588	1454.0	7628	79
24/11 -- 28/11	1634	46.2	26.5	0.0	70	4306	1262.8	4130	52
01/12 -- 05/12	1386	41.9	15.3	0.0	144	4267	1824.8		75
08/12 -- 12/12		32.8	22.9				1366.4		54
15/12 -- 19/12	693	14.2	3.9	91.0	178	3733	955.8		89
22/12 -- 24/12		86.5	8.1						
28/12 -- 31/12		28.2	20.3						
05/01/87-09/01		28.6	15.4				1382.2		71
12/01 -- 16/01	1307	52.2	22.5	0.0	50	3639	1491.4	4324	71
19/01 -- 23/01	1890	79.1	35.6	0.0	85	2369	1403.7	4429	42
26/01 -- 30/01	1107	40.0	21.8	0.0	94	8096	2333.2	3973	36
02/02 -- 06/02	1061	40.6	27.2	0.0	141	6365	1799.0	5997	70
09/02 -- 13/02	1194	16.7	8.1	0.0	66	8840	1539.0	5847	54
16/02 -- 30/02	1280	26.5	7.4				1913.4	5291	75
23/02 -- 29/02	1490	37.1	54.7	0.0	216	7476	2672.0	5503	90
02/03 -- 06/03	1748	191.1	173.5				8208.5	6436	52
Average	1319	56.3	32.8	75.2	102	4675	2583.4	3950	55
Std Deviation	523	38.8	30.9	77.3	58	1639	1307.7	1149	25

Table : DC 12 Unit C : Sampling Point C.7

Humus Tank Effluent Recycle

Weekly Averages of Daily Loads (kgs)

Period	COD	Total P	Ortho P	Ammonia	NO3	Chloride	Alkal	Hard	Total Fe
10/03 -- 15/03	632	30.4	18.9	0.0	68	2300	2007.4	2072	6
17/03 -- 22/03	551	18.5	8.0	53.0	33	1621	1588.2	1758	9
24/03 -- 29/03	589	10.0	3.5	14.0	33	2452	1318.5	2311	14
31/03 -- 04/04	344	16.8	7.4				906.5	1998	23
07/04 -- 11/04	554	18.3	10.6	40.0	58	2451	1309.4	2130	24
14/04 -- 18/04	516	24.0	15.8				1697.2	2094	9
21/04 -- 25/04	356	16.0	6.4				1443.2	2148	8
28/04 -- 02/05	413	20.9	12.4	48.0	60	1653	1225.4	2159	16
12/05 -- 16/05	413	15.2	9.2	0.0	30	1390	559.6	1139	4
19/05 -- 23/05	431	21.1	15.4	23.0	30	1407	755.2	1424	18
26/05 -- 30/05	507	37.1	27.7				817.8	962	18
02/06 -- 06/06	306	11.7	5.9	36.0	56		689.5	1097	16
09/06 -- 13/06	277	9.0	3.0				813.7	1056	18
16/06 -- 20/06		17.9	10.2						
23/06 -- 27/06	590	55.6	52.4	49.0	28		2154.7	1188	18
30/06 -- 04/07	823	38.4	21.9	193.0	37	3708	2703.0	3004	68
07/07 -- 11/07	514	18.8	6.2				1908.8	1777	37
14/07 -- 18/07	1324	43.0	15.9	34.0	64	2918	1983.0	2178	63
21/07 -- 27/07	1066	31.7	14.0	61.0	32	1828	1802.5	1694	37
28/07 -- 01/08	950	41.3	19.7	48.0	23	2331	2064.2	1760	28
04/08 -- 08/08	612	25.1	12.5	101.0	22	2414	1945.6	1622	35
11/08 -- 15/08	679	35.7	23.4	49.0	17	1619	1913.6	1357	6
18/08 -- 22/08	992	43.6	25.3				2180.5	2275	53
25/08 -- 29/08	329	20.7	11.3	41.0	34	1935	1099.4	925	14
01/09 -- 07/09	592	43.4	33.1				1935.8	2007	14
08/09 -- 12/09	418	110.2	28.3	28.0	38	1956	1653.8	1985	39
15/09 -- 19/09	856	21.6	10.1	54.0	58	2711	1391.8	1902	30
22/09 -- 26/09	530	28.9	15.2	72.0	29	1980	1203.6	1646	27
06/10 -- 09/10	506	19.1	9.7	52.0	45	1365	817.0	1119	30
13/10 -- 17/10	900	34.8	15.9	79.0	84	3008	1451.0	2269	29
20/10 -- 24/10	951	33.6	17.2	0.0	73	3926	1013.4	2599	20
27/10 -- 31/10	984	40.0	28.4	73.0	47	1304	1048.0	2076	29
03/11 -- 07/11	1062	34.0	24.1	13.0	55	2107	1226.0	2378	48
10/11 -- 14/11	876	50.9	38.2				1651.4	2786	22
17/11 -- 21/11	1793	0.0	0.0		186	4495	862.0	4518	47
24/11 -- 28/11	720	19.3	9.9	0.0	32	1957	460.8	1839	22
01/12 -- 05/12	489	14.3	5.3	0.0	51	1506	643.2		27
08/12 -- 12/12		13.4	8.7				832.2		36
15/12 -- 19/12	141	5.5	1.7	18.0	36	760.0	377.2		34
22/12 -- 24/12		42.5	4.0						
28/12 -- 31/12		9.9	7.2						
05/01/87-09/01		12.0	6.3				571.6		29
12/01 -- 16/01	508	19.0	8.2	0.0	20	1492	571.2	1664	28
19/01 -- 23/01	876	48.4	8.9				702.5	2285	16
26/01 -- 30/01	416	11.6	7.9	0.0	35	3000	848.2	1443	8
02/02 -- 06/02	196	7.4	5.2	0.0	26	1189	352.2	1133	11
09/02 -- 13/02	453	6.5	3.1	0.0	25	3303	593.6	2261	21
16/02 -- 30/02	506	10.6	3.1				752.4	2076	29
23/02 -- 29/02	583	14.3	23.3	0.0	102	3528	1022.8	2140	35
02/03 -- 06/03	476	49.9	45.0				2203.0	1806	15
Average	636	26.4	14.5	36.8	47	2246	1256.8	1908	25
Std Deviation	312	18.4	11.2	40.2	32	893.0	593.3	641	14

Table : DC 13 Unit C : Sampling Point CP7

Effluent to Maturation Ponds

~~Weekly Averages of Daily Loads (kgs)~~

Period	COD	Total P	Ortho P	Ammonia	NO3	Chloride	Alkal	Hard	Total Fe
31/03 -- 04/04	298	14.6	6.4				786.5	1734	20
07/04 -- 11/04	483	16.0	9.2	36.0	54	2267	1144.0	1648	21
14/04 -- 18/04	419	19.3	12.7				1361.8	1694	6
21/04 -- 25/04	339	15.4	6.2				1407.0	2088	7
28/04 -- 02/05	363	18.1	10.7	45.0	56	1534	1066.8	1852	12
12/05 -- 16/05	607	31.6	20.4	0.0	42	1984	947.6	2153	21
19/05 -- 23/05	553	28.9	21.2	39.0	50	2344	946.4	1808	23
26/05 -- 30/05	749	56.6	41.2				1264.8	1472	28
02/06 -- 06/06	577	18.7	9.4	38.0	60		1187.5	1920	31
09/06 -- 13/06	536	17.7	5.8				1636.7	2112	33
23/06 -- 27/06	1059	90.5	85.2	88.0	52		3723.3	1998	31
30/06 -- 04/07	383	17.8	10.1	95.0	18	1832	1263.0	1405	32
07/07 -- 11/07	310	11.3	3.6				1158.2	1100	22
14/07 -- 18/07	682	26.5	11.2	12.0	22	993.0	1224.5	1301	35
21/07 -- 27/07	1116	34.3	15.5	40.0	21	1189	1921.3	1796	39
28/07 -- 01/08	883	38.5	19.0	46.0	22	2220	2024.2	1769	24
04/08 -- 08/08	644	23.3	11.9	118.0	26	2845	1892.2	1580	35
11/08 -- 15/08	766	40.7	26.8	61.0	21	1997	2187.0	1528	7
18/08 -- 22/08	813	35.8	20.8				1787.0	1860	43
25/08 -- 29/08	675	33.4	20.8	25.0	21	1174	1949.0	1755	19
01/09 -- 07/09	436	32.4	25.1				1441.8	1496	11
08/09 -- 12/09	308	82.6	20.5	23.0	31	1608	1186.8	1424	29
15/09 -- 19/09	666	17.4	8.5	40.0	44	2047	1115.6	1507	24
22/09 -- 26/09	490	28.8	14.2	102.0	40	2776	1131.0	1582	28
06/10 -- 09/10	925	39.2	20.8	100.0	87	2629	1737.2	2380	63
13/10 -- 17/10	607	24.6	11.4	47.0	51	1809	961.4	1523	21
20/10 -- 24/10	603	22.8	10.8	0.0	33	1749	666.0	1610	12
27/10 -- 31/10	1158	38.2	24.3	158.0	102	2834	1239.4	2220	43
03/11 -- 07/11	1153	42.9	31.3	21.0	89	3408	1390.2	2656	47
10/11 -- 14/11	747	35.7	25.7				1167.0	2148	11
17/11 -- 21/11	1235	0.0	0.0		128	3093	592.0	3110	32
24/11 -- 28/11	977	24.5	12.5	0.0	38	2349	598.8	2318	30
01/12 -- 05/12	897	27.6	10.0	0.0	93	2761	1181.6		48
08/12 -- 12/12		11.4	7.1				646.8		29
15/12 -- 19/12	552	8.7	2.2	73.0	141	2973	578.5		55
22/12 -- 24/12		44.0	4.1						
28/12 -- 31/12		18.4	13.0						
05/01/87-09/01		16.6	9.1				810.6		42
12/01 — 16/01	799	33.2	14.2	0.0	30	2147	920.2	2660	44
19/01 -- 23/01	398	77.7	20.7				1053.0	2728	36
26/01 -- 30/01	697	20.3	13.8	0.0	59	5096	1456.2	2390	12
02/02 -- 06/02	864	33.2	21.9	0.0	114	5176	1446.8	4864	58
09/02 -- 13/02	741	10.2	5.0	0.0	42	5537	945.4	3586	33
16/02 -- 30/02	774	15.9	4.3				1161.0	3215	45
23/02 -- 29/02	907	22.8	31.4	0.0	114	3948	1649.2	3363	56
02/03 -- 06/03	1272	141.2	128.4				6005.5	4630	37
Average	701	31.7	18.3	41.6	57	2583	1408.2	2155	30
Std Deviation	266	24.6	21.3	42.4	35	1168	895.9	837	15

ANNEXURE E

<u>Analysis method for Total Fe, SG and Free Acid</u>

ANNEXURE E

ANALYSIS METHOD FOR FERRIC CHLORIDE/SULPHATE SOLUTION

1. PROCEDURE FOR TOTAL Fe CONTENT

A. REAGENTS

(i) 0,10N POTASSIUMDICHROMATE SOLUTION

Dissolve 4,903 grammes of A.R. potassium dichromate in 200ml of distilled water and dilute to one litre with distilled water in a volumetric flask.

(ii) CONCENTRATED HYDROCHLORIC ACID C.P. (300 g/l HCI min.)

(iii) MIXED ACIDS

To 700 ml of cold distilled water add 100ml of concentrated sulphuric acid with caution. When ambient temperature add 100ml of concentrated phosphoric acid and dilute the mixture to one litre.

(iv) STANNOUS CHLORIDE SOLUTION 6% m/v

Dissolve 60g of stannous chloride dihydrate C.P. in 300ml of warm concentrated hydrochloric acid. Cool and dilute to one litre with distilled water.

(v) SATURATED MERCURIC CHLORIDE SOLUTION C.P. 7%

Dissolve 70g of mercuric chloride in 1 000ml of hot distilled water.

(vi) SODIUM DIPHENYLAMINE - 4 - SULPHONATE 2g/100ml, (SAARCHEM CAT. NO. 126200)

B. PROCEDURE

Weigh out 25ml of ferric solution accurately and transfer to a 500ml volumetric flask. Dilute to the mark with water. Invert sufficiently to ensure thorough mixing.

Pipette a 25ml aliquot into a 500ml wide mouth Erlenmeyer flask. Add 25ml of concentrated hydrochloric acid and heat to boil. Add 6% stannous chloride solution dropwise until the yellow colour is discharged. Add a few drops in excess. Cool rapidly and add 10ml saturated mercuric chloride solution and let stand for 10 minutes. Add 30ml of mixed acids and dilute the contents of the flask to 200-300ml with distilled water. Add 2,0ml of Sodium diphenylamine sulphonate indicator solution and titrate to a permanent purple end point with 0,10N Po tassium dichromate solution.

With the same reagent and without the ferric solution, perform a blank determination. Subtract the blank determination from the titre.

C. CALCULATION

$$\% \text{ Total Fe} = \frac{\text{Titre (corrected)} \times 11,17}{\text{mass taken}}$$

(this should be 10 $\pm$ 0,5% m/m)

2. PROCEDURE FOR FERROUS CONTENT

A. REAGENTS (same as mentioned under 1A)

B. PROCEDURE

Pipette 5,0ml of ferric sulphate solution into a 500ml wide mouth Erlenmeyer flask. Add 15ml of concentrated hydrochloric acid solution and evaporate to dryness on a hot plate. Cool the flask and contents and redissolve the solids in 15ml of concentrated hydrochloric acid solution. Dilute the flask and contents to 200-300ml with distilled water. Add 30ml of mixed acids followed by 1,0ml of barium diphenylamine sulphonate indicator solution to a permanent purple end point. Perform a blank determination as mentioned under 1A and deduct this figure from the titration figure.

C. CALCULATION

$$\% \text{ Ferrous m/m} = \frac{\text{Titre (corrected)} \times 0,117}{\text{S.G. of the sample}}$$

(This should not exceed 0,06% m/m)

3. PROCEDURE FOR S.G.

Use a hydrometer in the range 1,3 - 1,4 or 1,4 - 1,5 if required.

4. FREE ACID

A REAGENTS

(i) 0,10N Sodiumhydroxide solution, prepared from A.R. carbonate free sodiumhydroxide pellets. The reagent should be standardised using potassium acid phthalate with phenolphalein as an indicator.

(ii) 18% Potassium fluoride solution. This reagent is prepared by dissolving 180 grams of A.R. potassium fluoride, 800ml of distilled water and diluting of 1 000ml in a volumetric flask. The pH of the reagent is adjusted to 8,5 using a 1% sodium hydroxide solution.

(Method 1) FREE ACID

B. PROCEDURE

Transfer 2,0ml of the ferric solution into a 100ml beaker. Add 10ml distilled water and 10ml of potassium fluoride solution and a TEFLON coated magnet. Place on a magnetic stirrer, insert a pH probe (glass-silver ; silver chloride) coupled to a pH meter and titrate slowly to an end point of pH8,5 on the pH meter.

C. CALCULATION

$$\% \text{ Free acid m/v} = \frac{\text{Titre} \times 4{,}9 \times 100}{2 \times 1\,000}$$

(Method 2) FREE ACID

Measure 10ml ferric solution in a 500ml Erbenmeyer flask, dilute the volume to ± 300ml with distilled water. Add 100ml 20% calcium fluoride solution. Stir well and floc out with 1-2 ml 0,7% "Magnafloc". Add 3 drops phenolphtaleen and titrate with 1N NaOH Solution.

$$\% H_2SO_4 = \frac{TX4{,}9 \times 100}{10 \times S.G.}$$