**UNIVERSITY OF CAPE TOWN**
**Department of Civil Engineering**
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# THE EFFECT OF ALTERNATIVE DETERGENT BUILDERS ON THE NUTRIENT REMOVAL ACTIVATED SLUDGE SEWAGE TREATMENT PROCESS

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# DECLARATION BY CANDIDATE

I

**WENDY ANNE KASCHULA**

hereby declare that this thesis is my own work and has not been submitted for a degree at another University

April 1993

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# SYNOPSIS

Phosphate is an essential nutrient for photosynthetic plant growth. However if over-supplied in a water body, it leads to excessive algal growth, a condition is termed eutrophication. Eutrophication is not only unsightly, but renders the water less usable. Most of the highly eutrophied water bodies with a high phosphorus load still receive up to 90% of their phosphorus input from effluents discharged by sewage treatment works (Pretorius, 1983). The phosphorus content of domestic sewage originates from two main sources, namely human waste (±60%) and detergents (±40%) (Heynike and Wiechers, 1986).

There is an argument for a ban on phosphate in detergents to reduce the phosphate load on sewage treatment plants and thereby limit phosphate discharges via treated municipal effluent. The removal of phosphate from detergent formulations has been an effective way in many countries of reducing the phosphorous load to receiving waters. In South Africa, detergent manufacturers are anticipating consumer pressure to reformulate their detergent products to eliminate phosphate. The two possible replacements for phosphates are zeolite 4A and high surface area (HSA) calcite.

High surface area (HSA) calcite is not yet being used as a detergent builder, but is being seriously considered as a potential replacement for phosphate in South African detergent formulations. Zeolite is already widely used in Europe and North

America as replacement for phosphate and previous research efforts have not shown any harmful effects in conventional (fully aerated) activated sludge systems.

Unlike in Europe and North America, most activated sludge plants in South Africa are based on the biological excess phosphorus removal (NDBEPR) activated sludge system, which embraces unaerated zones to achieve high removals of nitrogen and phosphate. For this reason it is important to investigate the effects of alternative builders on the NDBEPR process before launching zeolite/HSA calcite detergent formulations in South Africa. Thus, Lever Brothers (South Africa) embarked on a research programme in collaboration with the University of Cape Town, to investigate the impact of zeolite and HSA calcite on the NDBEPR process.

The original research strategy was to compare the behaviour of two laboratory nutrient removal activated sludge systems; a control supplemented with a phosphate based detergent formulation, and an experimental supplemented with a zeolite based detergent formulation. This approach led to several operational difficulties and the research strategy was modified to compare the alternative detergent builders only as isolated species.

Two laboratory NDBEPR systems were set up in the Modified University of Cape Town (MUCT) configuration; one Experimental and one Control. The Experimental system was dosed with a

realistic mass of zeolite or HSA calcite while the Control system was operated on normal sewage. The periods of dosing (first with zeolite and then with HSA calcite) were preceded and succeeded with 'baseline' periods when normal sewage was fed to both Control and Experimental systems. The two systems were operated for a period of 289 days and the behaviour of the two systems were monitored daily. After evaluating the reliability of the observed data via COD and N mass balances, the effect of the alternative detergent builders zeolite and HSA calcite on the Experimental system was determined by critical and statistical comparison with the Control system.

From this evaluation and comparison, the following conclusions were made:

1. Good nitrogen balances were achieved (weighted average 89.5%)

2. COD balances were not as good as the nitrogen balances (weighted average 84.3%). This was probably due to a laboratory artefact involving measurement of the oxygen utilisation rate (OUR).

3. Neither zeolite nor HSA calcite had any effect on carbonaceous organic material degradation and there was no statistical difference between the Experimental and Control effluent COD concentrations at the 95% confidence level.

4. Because zeolite is an inorganic insoluble solid it was expected that when zeolite was dosed to the Experimental system, the inorganic suspended solids concentration of the Experimental system relative to the Control would increase by the same amount as the mass dry zeolite dosed. This increase, however was found to be only 180mg compared with the 320mg zeolite dosed. No explanation for this discrepancy could be found. ie. The zeolite did not dissolve and was confirmed not to decompose in the 600°C oven used for VSS determination.

   When dosed with HSA calcite, the increase in inorganic solids concentration of the Experimental system relative to the Control was only 65mg compared with 200mg expected. It was found that the HSA calcite partially dissolved in the wastewater and the portion not dissolved was accounted for by decomposition of the HSA calcite to calcium oxide and carbon dioxide in the 600°C oven used for VSS determination.

5. The addition of zeolite and HSA calcite had no inhibitory effect on nitrification and there was no statistical difference between the filtered effluent TKN concentrations of the Control and Experimental systems at the 95% confidence level. Weighted averages of the Control and Experimental systems were 4.62 and 4.56 mgN/l respectively.

   Nitrification capacity (ie the total mass per day of nitrate and nitrite ($NO_3^- + NO_2^- = NO_x$) generated by nitrification) of the Control and Experimental system were similar except during the intermediate baseline period, when the nitrification capacity of the Control system was higher than the Experimental system by 12 to 15%. This was the result of a comparatively lower N mass balance for the Experimental system during this baseline period.

6. Because both the first and second anoxic reactors were generally underloaded with respect to nitrate, (the first reactor to maximise biological excess P removal and the second to minimise AA or low F/M filament bulking, Casey *et al,* 1992), it was not possible to determine the denitrification rate directly. The apparent rate (varying from 0.024 mg$NO_3$-N/mgAVSS.d to 0.109 mg$NO_3$-N/mgAVSS.d) was always lower than the actual rate (0.224 to 0.296mg$NO_3$-N/mgAVSS.d, Clayton *et al.,* 1989; Musvoto *et al.,* 1992) and depended more on the influent TKN and the a-recycle than on the denitrification rate, because these two parameters control the nitrate load on the anoxic reactors.

7. During and after zeolite dosing, both the Control and Experimental systems showed signs of AA filament bulking, with more severe bulking in the Experimental system (DSVI ±150ml/g) than in the Control system (±135ml/g). It was concluded that this bulking was the result of incomplete denitrification in the second anoxic reactor and not due to the effect of zeolite (Musvoto *et al,* 1992).

During HSA calcite dosing, the Experimental system showed a sharp decrease in DSVI relative to the Control (Experimental 100ml/g; Control 150ml/g). Since denitrification was complete during this period, this decrease in DSVI of ±50 ml/g can be attributed to the presence of 20mg/l HSA calcite in the Experimental system influent sewage feed.

8. Only 60% (12 mgP/l instead of 20 mgP/l) of the expected P removal was achieved. This was not due to experimental error or the effect of zeolite or HSA calcite because the other MUCT systems in the laboratory also yielded only 60% of the expected P removal. No assignable cause for the poor P removal in the laboratory could be identified.

   During zeolite dosing to the Experimental system, the Experimental system showed P removal 1.25 mg-P /l higher than the Control. No assignable cause for the increased P removal could be identified.

   During HSA calcite dosing to the Experimental system, there was no difference between the P removal of the Control and Experimental systems.

From the above observations, it would appear that the substitution of phosphates in detergent formulations with zeolite or HSA calcite will not have any adverse effects on the biological excess phosphorus removal sewage treatment process.

No effect of zeolite or HSA calcite could be established on COD removal, nitrification, volatile solids production, pH and denitrification. The mass of sludge production would increase (which is to be expected from the addition of inorganic material to the sewage), but this increase is likely to be very small - only 56% and 32% of the respective zeolite and HSA calcite dose was recovered in the sludge. The presence of zeolite and HSA calcite are not likely to adversely affect sludge settleability - indeed it appeared that HSA calcite may have a small beneficial effect. Zeolite also appears to improve biological phosphate removal, but the reason for this is unclear.

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# CHAPTER ONE : INTRODUCTION

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## 1.1 EFFECTS OF PHOSPHORUS IN WATER BODIES

Phosphorus, principally found in water bodies in the orthophosphate form, is an essential nutrient for photosynthetic plant growth. The phosphorus acts as a fertiliser when present in sufficient quantity. In the natural environment, the concentration of phosphorus is generally low, which in turn limits plant growth. In contrast, if a waterbody contains high levels of phosphate, excessive algae and other water plant growth can be stimulated to such an extent that it becomes a nuisance in respect of the following:

- Potable water treatment problems,
- health effects due to primary and secondary micro-organism contamination,
- interference with recreation,
- interference with irrigation,
- aesthetic problems.

The excessive growth of algae and water plants is termed eutrophication, from the Greek word eutrophos, meaning "well nourished". Eutrophication is a problem in many South African inland waterways and impoundments as a result of the discharge of phosphate and nitrogen from diffuse and point sources. Diffuse sources include the phosphorus and nitrogen in surface water runoff from urban and agricultural areas, while point sources includes nitrogen and phosphorus in treated municipal waste water effluents.

In contrast to the eutrophic state, if an impoundment has low concentrations of phosphate with limited algal growth, the condition is termed oligotrophic. These two trophic states are separated by a relatively narrow transition band of phosphorus concentration. Thus if eutrophication is to be avoided, the phosphate concentration needs to be sufficiently reduced to such a level that oligotrophic conditions prevail, otherwise very little is achieved in controlling eutrophication.

## 1.2 ORIGINS OF PHOSPHATE IN WATER BODIES: POINT AND NON-POINT SOURCES

In addition to the municipal treated effluents, which is one of the principal point sources of nutrients, diffuse (non-point) sources also account for a significant contribution of the phosphorus load to many impoundments. These diffuse sources include storm water run-off, soil erosion, air pollution and agricultural activities.

In the United States it was estimated that more than 50% of the total phosphorus and 75% of the total nitrogen in surface waters originate from non-point sources (Pretorius, 1983). No extensive survey of this kind has been conducted in South Africa. To make an estimate for South Africa, Bolitho, (1976) assumed that in the PWV region, the nutrient contribution from diffuse sources is only 10% of the municipal sewage point source contribution. On the basis of this assumption, he calculated that these diffuse sources alone would contribute between 1 and 3 times the phosphorus tolerance levels of the water bodies of the PWV region. Indications are that, with few exceptions, the phosphorus contribution from non-point sources probably exceeds the 'dangerous' limit in most South African impoundments. On this basis, Pretorius, (1983) concluded that even a total elimination of phosphorus from point source pollution would be of little or no value in eutrophication abatement.

Most of the highly eutrophied impoundments with a high phosphorus load still receive up to 90% of their organically available phosphorus input from effluents discharged by sewage treatment works (Pretorius, 1983). Of the phosphorus from sewage effluents, 85% to 90% is organically available whereas only 20% to 25% of the phosphorus in non-point sources is organically available. For this reason, there is still a strong argument for removing phosphorus from treated sewage effluent before it enters the water system. Since August 1985, a phosphate limit of 1 mgP/l dissolved ortho-phosphate was imposed on sensitive catchment areas in South Africa.

## 1.3 OBJECTIVES OF WASTEWATER TREATMENT

In the treatment of municipal waste flows, the organic material in the sewage is virtually completely removed, which limits the heterotrophic organism growth and hence reduces river deoxygenation. However, if the nutrients nitrogen and in particular phosphorus are not removed, the algae and water plants proliferate by photosynthesis, thus reintroducing organic material into the water body. This leads to a resurgence of the deoxygenation problems by heterotrophic organism proliferation. For this reason, the objectives of municipal waste water treatment can be summarised as follows:

- Reduce organic material content (or energy) to a level where it will no longer sustain heterotrophic organisms growth and thereby avoid deoxygenation.

- Oxidise ammonia to nitrate to reduce its toxic effects and oxygen demand.

- Reduce eutrophic substances, nitrogen and phosphate to levels where photosynthetic growths (eg algae) are limited.

## 1.4 PHOSPHORUS REMOVAL FROM POINT SOURCES

The phosphorus content of domestic sewage originates from two main sources, namely human waste and detergents which contain phosphate. The detergent phosphate contribution to domestic sewage is normally taken to be approximately 40% (Heynike and Wiechers, 1986), but can increase to as much as 70% (Pretorius, 1983). The argument against banning phosphate from detergent formulations hinges around the fact that a technology to remove phosphate biologically from point sources is available and is being applied successfully. The replacement of phosphate in detergent formulations by alternative products may be counterproductive as this introduces untested substitute compounds not only into the sewage treatment processes but also into the water bodies via the treated effluents. In contrast, the argument for a ban on phosphate in detergents hinges around the fact that the ban would reduce the phosphate load on sewage treatment plants and thereby limit phosphate discharges via treated effluents. The relevance of each of these arguments can be evaluated by discussing the processes by which phosphate can be removed from municipal effluents.

### 1.4.1 Chemical Phosphate Removal

Phosphate can be removed from sewage effluent chemically by precipitating it with alum [$Al_2(SO_4)_3$] or ferric chloride [$FeCl_3$]. This method of removal is practised with success in many developed countries. However this practise is expensive and chloride and sulphate salts are formed as a byproduct of the precipitation reaction. These salts enter the water system, increasing the total water salinity.

Apart from the cost disadvantage, South African water is re-used several times before being released to the sea. Chemical precipitation of phosphate, with associated increase in salinity over time, would render the water less valuable for industrial and agricultural purposes. This problem is known as mineralisation. In South Africa, although biological excess phosphorus removal in activated sludge is widely implemented, up to 50% of municipal sewage in the Pretoria-Witwatersrand-Vereeninging (PWV) area is still treated in trickling filters (Dept of Health, quoted by Brodisch, 1985). Because this area incorporates two of the most sensitive catchments to eutrophication, chemical P removal is required after treatment by trickling filters. Sodium tripolyphosphate (STPP) is currently a major ingredient in detergent formulations. Thus if STPP were to be substituted by zeolite in South Africa, it is anticipated that the phosphate load on water courses will decrease, leading to reduced costs of treatment, mineralisation and sludge production.

### 1.4.2 Nitrification-Denitrification Biological Excess Phosphate Removal (NDBEPR)

To reduce running costs and to avoid the mineralisation problem of removing phosphate chemically, South African wastewater treatment engineers and scientists investigated and developed a nitrification denitrification biological excess phosphorous removal (NDBEPR) technology. This technology makes use of unaerated zones to remove both nitrogen and phosphate in the activated sludge process. The extent of biological phosphorous removal depends principally on the influent wastewater characteristic readily biodegradable COD (RBCOD) concentration. Often the phosphate concentration of the influent sewage is too high for the influent wastewater RBCOD concentration and the P concentration cannot be reduced to the required limit of 1 mgP/l. This can be remedied by:

- reducing the influent phosphorus concentration (eg banning phosphorus in detergents),
- increasing the influent RBCOD concentration (eg. by primary sludge acid fermentation) or
- precipitating the remaining phosphorus chemically.

## 1.5 LIMITATION OF PHOSPHATE IN DETERGENT FORMULATIONS

The extent of P removal by the NDBEPR process is limited by supply of RBCOD in the approximate ratio 0.10mgP/mg influent RBCOD. Because the contribution of detergent phosphate to the total phosphorus load in municipal wastewaters is significant (approx. 40%), the following question is often raised: Should the authorities give consideration to banning detergent phosphate ingredients? This ban would reduce the phosphorus load on sewage works which would reduce effluent phosphorus concentration and therefore reduce the phosphorus load on the water environment.

### 1.5.1 International Detergent Phosphate Regulations

The removal of phosphate from detergent formulations has been perceived in many countries as an effective way of reducing the phosphorous load to receiving waters. In the USA, phosphorous detergent bans have reduced phosphate loads on wastewater treatment plants by as much as 50%. In Canada, limiting phosphorous in laundry detergent formulations to 2.2%, has resulted in a 36% decrease of the phosphorous concentration in municipal sewage. Phosphorous loadings on the Great Lakes from municipal treatment plants in Michigan have been decreased by 20% as a result of the maximum limit of 0.5% phosphate in detergent formulations (Hartig and Horvath, 1982). In the United Kingdom, however, eutrophication problems are essentially localised in nature, with the major input of phosphorous being from human waste and agricultural practises. In these cases a detergent phosphate ban has been an ineffective method of limiting eutrophication (UK Dept of Environment 1991). Questions as to the effectiveness of a total phosphate ban on Swiss detergents were raised even before legislation was enforced which suggests that a total detergent phosphate ban was expected to reduce phosphorous loads to major Swiss lakes by only 10%.

Several studies, (Maki *et al.,* 1984; Lee and Jones, 1986; Booman and Sedlak, 1986; Cullen and Forsberg, 1988 and Lund and Moss 1980) have found little evidence of significant improvements to eutrophication problems as a result of the banning of detergent phosphate in the countries where it has been undertaken. In general, phosphate free laundry detergents have been found to be less effective cleaning agents than phosphate containing detergents. This has led to an increase of 15.5% in detergent usage in Switzerland, where detergent phosphate is banned (Swiss Institute for Marktanalyses AG, 1988 as quoted in UK Dept. of Environment).

### 1.5.2 Detergent Phosphate Regulation in South Africa

The issue of a banning or regulating detergent phosphate in South Africa has been investigated by the Department of Water Affairs (Heynike and Wiechers, 1986). This involved an assessment of the impact of detergent phosphate on eutrophication in South African waterbodies. The purpose of the study was to determine whether a ban on detergent phosphate should be imposed in South Africa. The study found that detergent phosphates represent a significant source of phosphate to the South African water environment, comprising between 35 to 50% of the total phosphate load on domestic sewage works.

The following benefits were anticipated should the phosphate content of detergents be decreased:

- Reduced phosphate load on water courses;
- reduced treatment costs by savings in energy usage, chemical consumption and sludge production in waste water treatment plants practising chemical phosphate removal;
- reduced mineral load on the water environment as a result of reduced usage of chemicals to precipitate phosphate from effluents;
- more favourable P:COD ratios in sewage which will be advantageous for biological phosphate removal;
- less variable phosphate loads on sewage purification works which would facilitate simpler and more effective process control;
- reduced impact of unsewered households, on sewage treatment works which are at present not required to

remove phosphate, and by sewage collection systems and malfunctioning sewage treatment plants.

Should South African detergents be reformulated to eliminate phosphate, the following implications also need to be considered:

- Cost of reformulation to the detergent industry, the raw material suppliers, and consequently the consumer,
- availability of replacement chemicals, both locally and overseas,
- possibility of manufacturing these replacement chemicals locally,
- environmental and other aspects of the various substitutes as applied to South African conditions.

In their investigation, which included interviews with the detergent manufacturing industry, Heynike and Weichers, (1987) recommended that a ban should not be imposed on detergent phosphate for the following reasons:

- South Africa already has a comprehensive strategy of limiting phosphate discharge to the water environment via the 1 mgP/l dissolved ortho phosphate effluent standard.
- At the time of the study, no generally accepted alternative compound for phosphate had been developed.
- Replacement of phosphate by another suitable builder would present significant cost to the detergent industry and its raw material suppliers. Based on projections of overseas experience, this would cost 5

to 13 times more than if the detergent phosphate was removed at the sewage treatment plant.

- A total ban on detergent phosphates would result in, at best a reduction of phosphorus load to sensitive catchments of 45%. These eutrophic and hypertrophic catchments, however, require reductions in their total phosphate loads of 70% or more to bring about measurable improvements in their trophic status.
- The detergent industry would prefer self-imposed restrictions on phosphate in detergents to be driven by market forces due to public awareness.

## 1.6 ALTERNATIVE DETERGENT BUILDERS

In spite of the recommendation by the Department of Water Affairs (Heynike and Wiechers, 1986) not to ban phosphate in detergents, South African consumers have become increasingly aware of environmental issues in the past few years. Recently, the consumer attention has been focused on the environmental impact of phosphate as a builder in detergents. Due to consumer pressure, detergent manufacturers may need to replace phosphate builders with alternative builders, such as zeolite or high surface area (HSA) calcite.

Zeolite is currently being used extensively around the world as an effective replacement for phosphate. Another alternative builder being considered is HSA calcite. The latter has not been implemented in a large scale anywhere in the world, principally because Lever Brothers holds a patent on it. Once manufacturing problems have been resolved, this may be seriously considered as a replacement for phosphate in South Africa.

Although most research efforts indicate that the use of zeolite and HSA calcite has relatively little impact on conventional activated sludge systems, their behaviour in South African NDBEPR activated sludge is unknown. Thus, Lever Brothers (South Africa) embarked on a research programme in collaboration with the University of Cape Town, to investigate the impact of alternative builders in detergents on this type of activated sludge system.

## 1.7 DETERGENT LAWS

The world detergent industry is dominated by 4 major multinational companies viz. Procter and Gamble (USA), Lever Brothers (UK), Henkel (Germany) and Colgate Palmolive (USA). The environmental compatibility of their products is governed by strict legislation on the detergent industry which differs from country to country and also by voluntary agreements between the multinational companies. Since South Africa uses mainly NDBEPR activated sludge systems, in contrast with the fully aerated systems employed overseas, it is possible that overseas legislation may not be directly applicable to this country and consequently may will need to be modified. A great deal of literature is available on the effects of zeolite in conventional activated sludge systems, but no research has been published on the effect of zeolite on NDBEPR systems. The effect of HSA calcite as a potential detergent builder on biological sewage treatment plants has not been investigated for any type of activated sludge system. Consequently, it is appropriate to investigate the effects of these two alternative detergent builders on the NDBEPR activated sludge system. The details of such an investigation are outlined in this thesis.

## 1.8 SCOPE OF INVESTIGATION

The research is limited to two potential alternative detergent builders; zeolite 4A and high surface area (HSA) calcite. These are the most likely phosphate substitutes in the South African context and are widely regarded as being environmentally safe.

### 1.8.1 Comparison of Alternative Detergent Formulations

The original research strategy was to compare the behaviour of two laboratory nutrient removal activated sludge systems; a control supplemented with a phosphate based detergent formulation, and an experimental supplemented with a zeolite based detergent formulation. The reason for using the whole formulation instead of isolating the builders was to observe the overall effect if phosphate was replaced as a builder.

However the effect of the unnaturally high level of non-spent detergent (ie. not only that ordinarily present in the sewage albeit partially spent, but also the fresh detergent added for experimental purposes) dominated the system response to such an extent that the effect of the two different builders could not be distinguished from each other. Both systems were observed to bulk and foam severely (DSVI > 300ml/g) as a consequence of the fresh detergent feed (one phosphate based and one zeolite based). Structural modifications had to be made to prevent the secondary settling tanks from becoming overloaded and losing sludge with the effluent. Also, dosed detergents contributed significantly to the influent COD and phosphate concentrations of the sewage feed and thus the phosphate removal behaviour of both systems was different from what it would have been without the dosed detergent.

### 1.8.2 Comparison of Alternative Builders as Isolated Species

Due to the above difficulties, the research strategy was modified by dosing the alternative detergent builders only as isolated species. Two separate phases were involved; the first was a comparison of an Experimental system dosed with zeolite and a Control system, and the second phase was a comparison of an Experimental system dosed with HSA calcite and a Control system. The two laboratory systems, were fed with real sewage which ordinarily contains the phosphate builder because at present, household detergents in South Africa are phosphate based. The Experimental system was dosed with a realistic mass of zeolite or HSA calcite should they be selected as alternative builders, while the Control system was operated on normal sewage.

The periods of dosing (first with zeolite and then with HSA calcite) were preceded and succeeded with 'baseline' periods when normal sewage was fed to both Control and Experimental systems. The purpose of the baseline period was to ensure that both systems exhibited statistically similar behaviour with no alternative builders dosed to the Experimental system. The baseline period would thus give the required background response to identify the effect of the dosed builders. At the time of this investigation, other laboratory units similar to the Control and Experimental systems were receiving the same sewage and were being operated in the laboratory for other nutrient removal research. The responses of the Control and Experimental systems were also compared qualitatively with the responses of these other systems.

The two systems were operated for a period of 289 days and the baseline and dosing periods were as follows:

| | | |
|---|---|---|
| Day 0 to 43 | : | No dosage to either unit. (Baseline period) |
| Day 44 to 101 | : | Zeolite dosed to Experimental system. (Zeolite test period). |
| Day 102 to 184 | : | No dosage to either system. (Baseline period). |
| Day 185 | : | Control and Experimental systems switched |
| Day 185 to 244 | : | Calcite dosed to Experimental system. (Calcite test period). |
| Day 245 to 289 | : | No dosage to either system. (Baseline period). |

The results obtained from the daily monitoring of the two systems were comprehensively evaluated to identify possible effects of the alternative builders on the biological nutrient removal activated sludge system.

## 1.9 LAYOUT OF THESIS

In Chapter 2, a literature review discusses the role of the detergent builder in the washing process and the structure and properties of zeolite. Also, because zeolite has been used as an alternative builder for some time now, a review of the effects of zeolite in the aerobic activated sludge systems is presented. No information was found to be available on its effects on nutrient removal activated sludge plants, so this could not be reviewed. Similarly, it was found that the effect of HSA calcite has not been investigated for any type of activated sludge sewage treatment system, so no information on this potential alternative builder is available in the literature. This is probably due to the fact that Lever Brothers holds a patent on the use of HSA calcite as detergent builder. For this reason, the literature review concentrates on zeolite.

In chapter 3, the experimental investigation is described and the results are discussed in detail. In chapter 4 the conclusions of the investigation are presented.

# CHAPTER 2

# LITERATURE REVIEW AND DISCUSSION OF RELEVANT THEORY

## 2.1 INTRODUCTION

Phosphate is an extremely effective detergent builder, but because of its link to eutrophication, alternative builders are in use in many countries of the world. This review discusses previous research into the effects of the alternative detergent builders zeolite and HSA calcite on sewage treatment processes. The nitrification-denitrification biological excess phosphorus removal (NDBEPR) activated sludge process was developed in South Africa and is not extensively implemented in other countries. In addition, almost all the detergent formulations[1] available in South Africa contain phosphate as a builder. Consequently, no previous research has been done on the effects of alternative detergent builders on the NDBEPR process and the literature reviewed therefore concentrates instead on the fully aerated activated sludge process and chemical sewage treatment.

In this review, the theory of the washing process is briefly presented focusing on the function of the builders in detergent formulations. In South African detergent formulations, the principal building agent is Sodium Tripolyphosphate (STPP) and thus is the main source of phosphate in the detergent formulation. After describing the characteristics of STPP, alternative builders and their functions are presented, focusing

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[1] Detergent formulation refers to the complete washing product as sold.

on zeolite and High Surface Area (HSA) calcite. These are the likely replacements for STPP in the South African context.

### 2.1.1 THEORY OF THE WASHING PROCESS

The theory of the washing process is based on Unilever Document No.1 (1989).

#### 2.1.1.1 Detergent Molecule

In order for a detergent[2] to be effective, it must attract fatty dirt deposits while remaining soluble in water. The detergent molecule has a polar sulphonate group on one end, making this end soluble in water. The other end of the detergent consists of a long hydrocarbon chain which attracts soil and fatty deposits and is insoluble in water.

The most commonly used anionic detergent is alkyl benzene sulphonate (ABS). The structure of ABS is shown in Figure 2.1:

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[2] Detergent refers to the actual wetting agent (Alkyl benzene sulphonate, ABS)

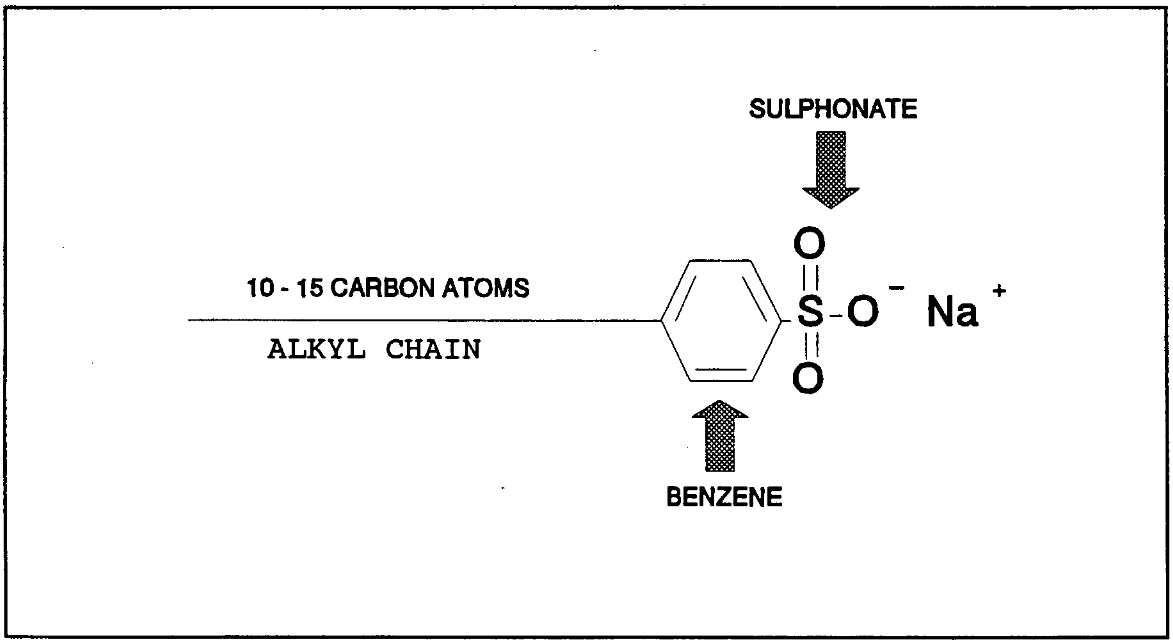

**Figure 2.1:** Alkyl benzene sulphonate structure

or simplified by grouping the benzene and sulphonate groups as follows (Figure 2.2):

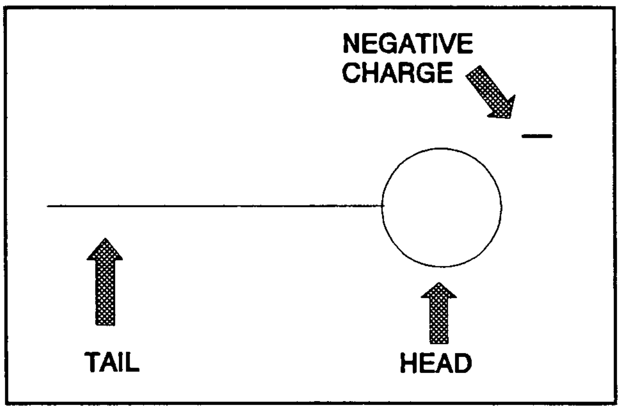

**Figure 2.2:** Simplified detergent molecule (ABS)

Water, due to its surface tension, does not wet a greasy surface This can be seen when water forms droplets rather than a film on a greasy surface. Detergent added to water will lower the surface tension and thus provide a solution with improved wetting properties.

Surface tension is lowered by a detergent in the following way: The carbon chain "tail" of the detergent molecule is hydrophobic and thus has an affinity for fatty particles, air and the walls of the container, seeking to draw away from the water. The sulphonate end or "head" is hydrophilic, making this end of the molecule soluble in water. These opposing properties of the detergent molecule's tail and head, make it a bridge between the water and insoluble dirt particles.

When detergent is added to water, surface tension decreases until the water is saturated. If more detergent is added, the detergent ions form spherical bunches with the hydrophobic ends pointing inwards. These bunches are called micelles. (A schematic diagram of the detergent molecules forming micelles is shown in Figure 2.3). The micelles are formed spontaneously as a means of minimising the degree of contact between the hydrophobic tails and the water. Only the ABS heads of the micelles are exposed to water which is the most stable (lowest energy) configuration for higher concentrations of ABS.

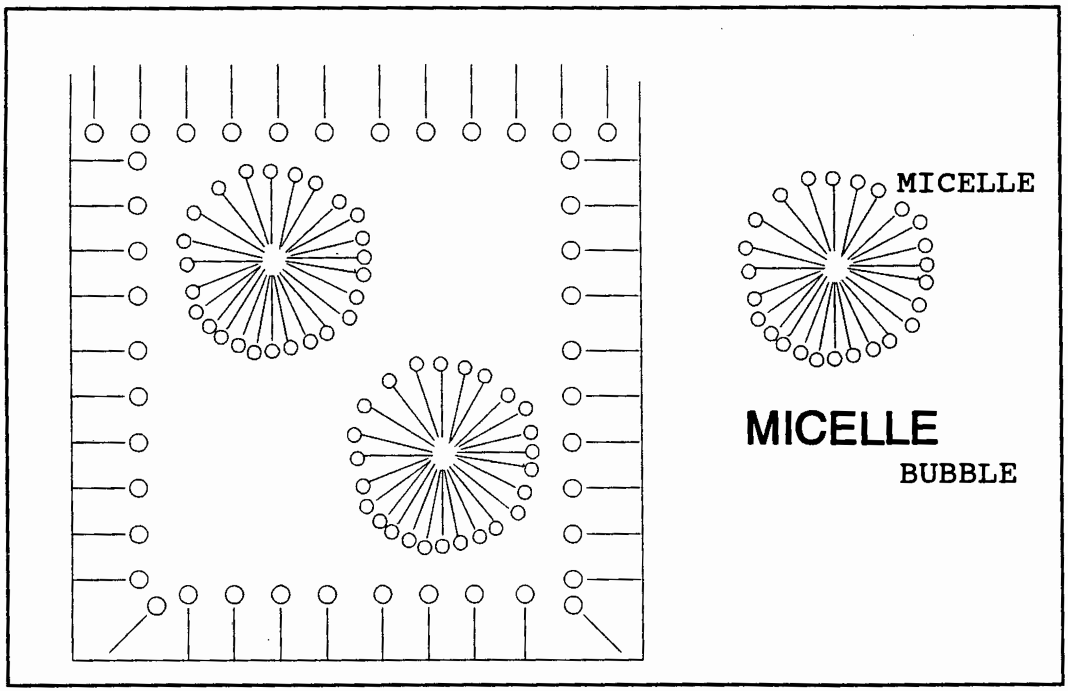

**Figure 2.3:** Detergent molecules forming micelles

Micelles are very important to detergent properties because:

1. They provide a reservoir of detergent to keep the surface tension to a minimum.
2. They can solubilise fatty soil deposits. The interior of a micelle is almost like a hydrocarbon solvent which can solubilise fatty soils and carry it away in the wash liquor. ie. soils are removed from fabrics and are held "bound" in the middle of micelles.

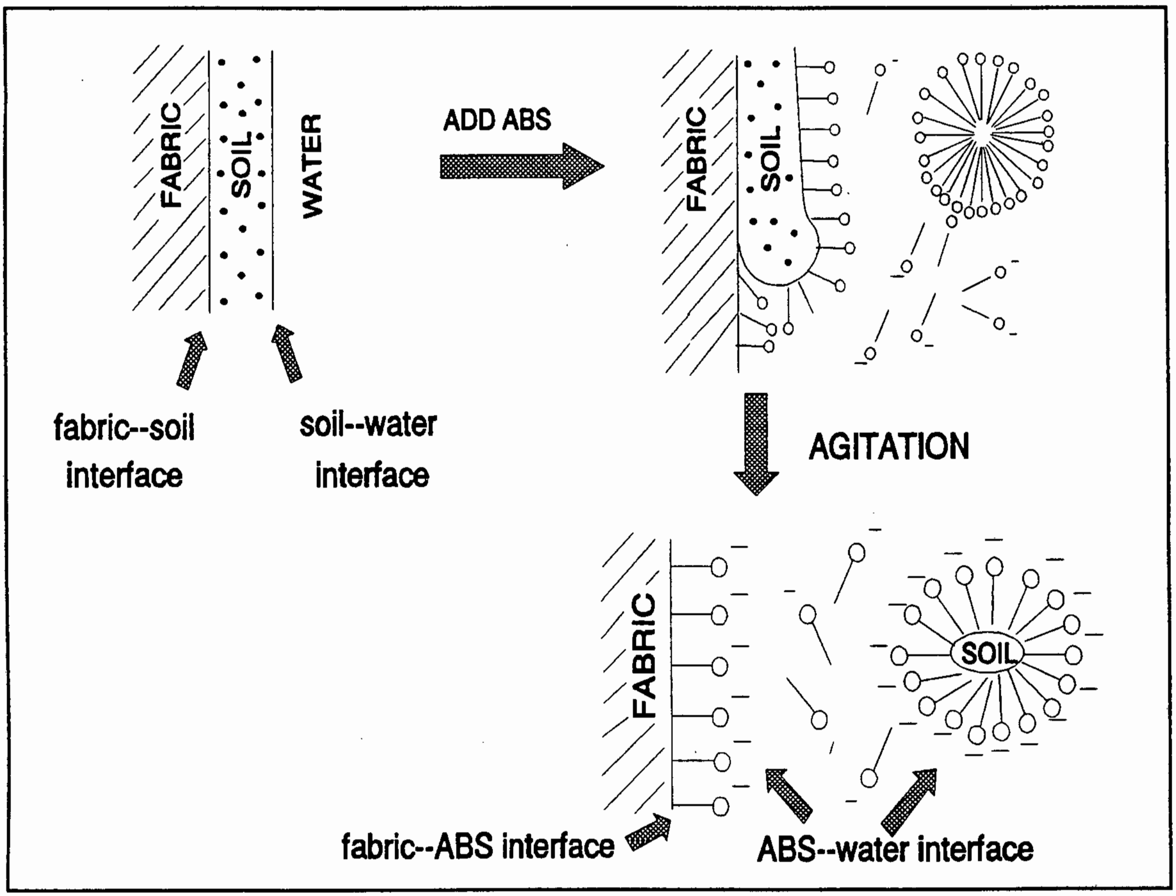

**Figure 2.4:** Removal of soil by detergent molecules

From Figure 2.4 above, it can be seen that the detergent in the form of micelles perform the washing process. The detergent also forms bubbles or foam. At the water-air interface, a thin film of water is "captured" with the ABS heads dissolved in the water film and the tails in the air. A dome of spherical shape is adopted to achieve a minimum surface tension and energy level. Bubbles or foam are therefore, like micelles, a sink of available detergent.

When a fabric is introduced to the water-detergent solution, the hydrophobic ABS tails align themselves on the fabric surface with their hydrophilic heads projecting into the water. The ABS head groups on the cleaned fabric and in micelles all carry a negative charge. As negative charges tend to repel, the micelles containing the dirt tend to be kept away from the cleaned fabric and from one another. These repulsive forces, however, are relatively weak and can be easily neutralised by positively charged cations in the water like calcium and magnesium

#### 2.1.1.2 Negative effects of calcium and magnesium on detergency

All tap water contains varying quantities dissolved calcium and magnesium. If present only in small quantities, the water is termed "soft" and detergency will not be seriously affected. If calcium and magnesium are present in large quantities, negative repulsive forces can be neutralised and the effectiveness of the detergent reduced. This water is termed "hard". In inland areas of South Africa, the level of dissolved calcium and magnesium is 200ppm as calcium carbonate ($CaCO_3$) which is moderately hard by world standards. In contrast, the coastal areas of South Africa have soft waters, with calcium and magnesium concentrations of 40ppm as $CaCO_3$. Dissolved calcium and magnesium have a detrimental effect on detergency, and calcium (but not magnesium) a detrimental effect on bubble formation. (ie. lather or foam volume)

The positively charged calcium and magnesium ions attract negatively charged ions. Therefore calcium and magnesium reduce the repulsive forces between the cleaned fabric and micelles and also between one micelle and another. This results in the flocculation of micelles and the redeposition of soil back onto the fabric. This mechanism is shown in Figure 2.5 below.

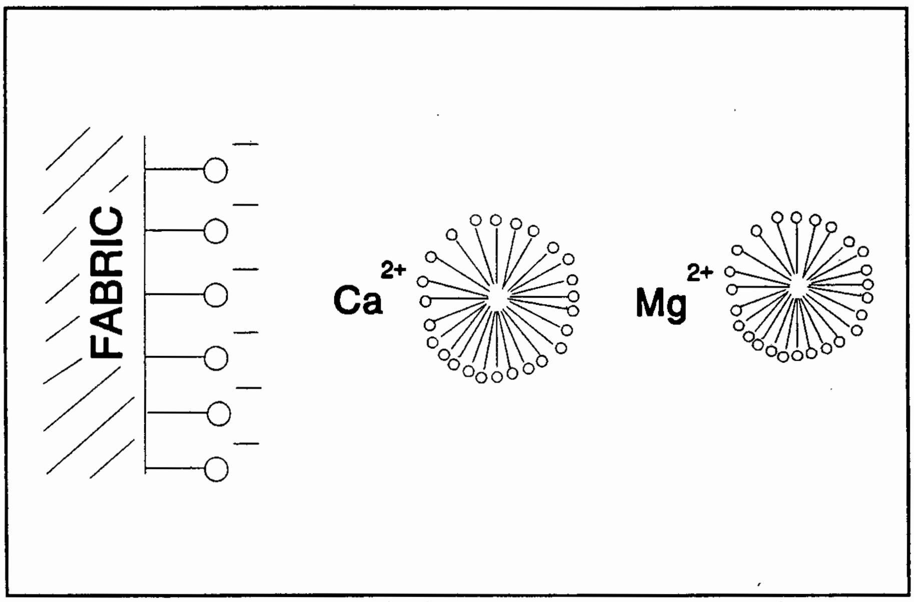

**Figure 2.5:** Neutralising effect of calcium and magnesium on micelles and clean fabric

In addition to the effects on the micelles and cleaned fabric, the calcium cation also neutralises the negative charge on the detergent molecules (Figure 2.6), causing them to precipitate out of solution to form a floating scum. This reduces the amount of detergent available for micelle formation (washing) and bubble formation (foaming).

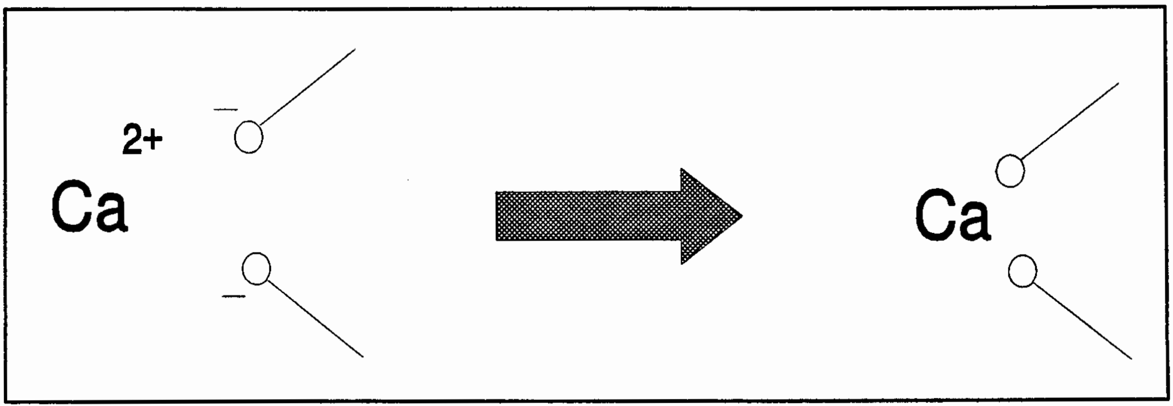

**Figure 2.6:** Neutralisation of detergent molecule by calcium ion.

Water softening (removal of calcium and magnesium) is thus an important process for detergent effectiveness and economy.

### 2.1.1.3 Detrimental effects of $H^+$ ions

Free $H^+$ ions, (ie. low pH) binds to micelles in a similar way as calcium and magnesium. The $H^+$ ions neutralise the negative charge of the micelle eliminating the repulsion between the micelles and the cleaned fabric. Therefore it is important to maintain high pH (ie. few $H^+$ ions) for detergent effectiveness and economy.

## 2.1.2 DETERGENT BUILDERS

### 2.1.2.1 Requirements of Detergent Builders

Detergent builders play a central role in the washing process. According to Jakobi and Lohr (1987) their functions are:

- To counteract the effect of hardness ions (eg calcium, magnesium and iron) in the washing process

- To suspend soil in micellular form (increases the repulsive forces between micelles and cleaned fabric and between micelles themselves).
- To buffer the washing solution pH in the desired region for optimum washing and non-redeposition of soil.

Other criteria used by Jakobi and Lohr, (1987) for a viable builder include:

- Commercial properties eg. chemical stability, handleability, non hydroscopic tendencies, optimal colour and odour qualities and compatibility with other detergent ingredients.
- Human toxicological safety assurance
- Biodegradability
- Environmental properties to reduce: negative influence on biological systems found in sewage treatment plants and surface water; uncontrolled accumulation; heavy metal remobilisation; eutrophication; detrimental effects on drinking water quality.

### 2.1.2.2 Sodium Tripolyphosphate

For many years the most common and efficient builder has been sodium tripolyphosphate (STPP). The chemical formula for STPP is shown in Figure 2.7:

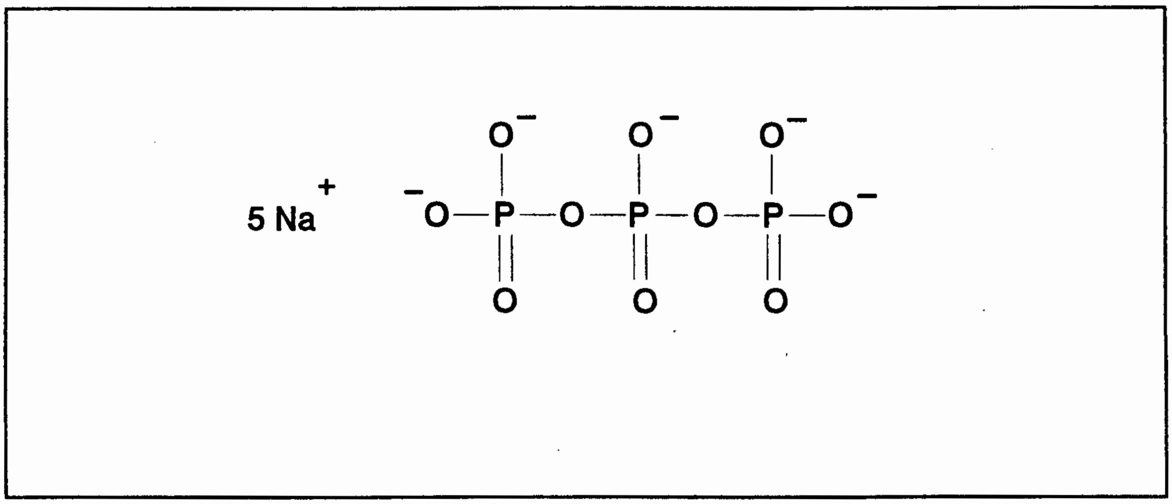

**Figure 2.7:** Chemical formula and structure of the STPP molecule

The properties of STPP that make it a good builder are:

- Sequestering of calcium and magnesium (softening):

  The STPP binds the cations to itself and thus inactivates the negative charge repression effect that the cations have on the micelles or on the detergent molecule.

- Micelle Dispersion:

  STPP has 5 negative charges (cf. Figure 2.7). These five negative charges on STPP enhance the repulsive forces between the micelles and the cleaned fabric and micelles, thus ensuring a stable suspension.

- pH buffer:

  STPP is extremely effective in maintaining high pH, as it sequesters $H^+$ ions as effectively as it sequesters calcium and magnesium.

Sodium tripolyphosphate is capable of retarding, hindering and otherwise interfering with the precipitation of insoluble salts, even in substoichiometric amounts. Its action also induces salts to precipitate amorphously, thereby reducing the tendency toward formation of crystals such as calcite, whose sharp edges can be damaging to fabrics.

Despite the many desirable properties shown by STPP in the washing process, its continued use has been the subject of an international environmental debate in the industry for many years. The phosphate component of STPP can contribute to over-fertilisation of water bodies, which in turn encourages excessive algal growth which is known as eutrophication. Recognition of the problem has led to an intense worldwide search for suitable replacements. Developments have been concentrated on sequestering agents, ion exchangers and specific alkaline substances such as sodium carbonate and sodium silicate. Zeolite A is an ion exchanger which is the most common alternative to STPP in Europe and North America. A variation of zeolite A that contains sodium as the exchanging cation, is zeolite type 4A, is the most common zeolite used as a detergent builder. In the remainder of this review, zeolite 4A will refer to the zeolite in the sodium form as found in the detergent before it enters the sewerage system, while zeolite A is a more general term which includes any other cation exchanged form of zeolite A. HSA calcite is also an alternative to phosphate, but is not yet in large scale circulation. The effect of the alternative builders zeolite 4A and HSA calcite on biological nutrient removal activated sludge plants is the subject of this thesis. (cf. section 1.6). Before the characteristics and effect of these builders are reviewed, a brief summary is presented below of the remaining ingredients (other than detergent and builder) in the detergent formulation.

### 2.1.3 OTHER INGREDIENTS IN DETERGENTS

The type, function and action of the remaining detergent formulation ingredients can be summarised as follows:

Sodium Perborate:

This is a bleach which oxidises soils or specific stains, thereby removing these from the fabric or chemically breaking down the coloured component of stains. Examples of such stains are blood, tea, coffee, ink, chocolate pudding. Biological sewage treatment is unaffected by the presence of sodium perborate, but its breakdown releases sodium borate, with resulting increase in boron concentration (Jakobi and Lohr, 1987).

Sodium Carboxymethyl Cellulose:

Sodium carboxymethyl cellulose (SCMC) carries an extremely high negative charge density, and is a polymer that adsorbs strongly onto clean pure cotton. The high charge density assists with the repulsion of soil bearing micelles. SCMC is non-toxic to fish and no ecological problems are known to be associated with its use.

Sodium Silicate:

Sodium silicate has a glass-like crystalline structure, which is essential to provide the powder with acceptable structure and flow properties. It is an anti-corrosion additive for machine washing and also sequesters $H^+$ ions in formulations that do not contain STPP.

Enzyme:

These are used to hydrolyse protein stains making them more readily removable by the detergent. It is unstable and quickly biodegraded by sewage treatment facilities.

Optical Brightener (Flourescer):

One or more flourescers are added to detergent formulae to impart whiteness rejuvenation to white articles and brightness to coloured articles which would otherwise dull with age. Flourescers have become increasingly regarded by environmental pressure groups as unnecessary ingredients in detergent formulations (UK Dept. of Environment). However 96% elimination has been observed in sewage treatment plants (Jakobi and Lohr, 1987).

Perfume:

Perfumes have no technical benefit, but impart a pleasant smell to the washed clothing, which is an important consumer perceived benefit. Trace residues of perfume that may escape into the environment are in such small quantities to be ecologically insignificant.

Complexing Agents:

Trace metals from raw material impurities inevitably will occur in the detergent formulation due to impurities. Even in low concentrations these trace metals have a negative effect on the detergent efficiency because they are cations like calcium and magnesium. Also certain of these trace metals can cause skin irritations in consumers with sensitive skins. Low concentrations of complexing agents (usually ethylenediaminetriacetic acid, EDTA) are included in the detergent formulation to complex these metals. The effect of EDTA in sewage treatment is discussed in detail in section 2.1.4.2

Colour:

Some brands of detergent powder have dye included in the formulation. This is for aesthetic purposes and has no technical benefit.

Sodium Sulphate:

Sodium sulphate is used as a filler to increase the mass of lower quality formulations. No technical benefit is obtained, but the sodium sulphate contributed to the increased mineralisation of water bodies as it is not removed in conventional sewage treatment processes.

Water:

The correct water content must be carefully determined to avoid the detergent formula being too sticky (too much water) or too dusty (insufficient water).

### 2.1.4 ALTERNATIVE BUILDERS

Numerous alternative builders are available and generally set into the following groups:

1. Alkaline substances such as sodium carbonate and sodium silicate
2. Complexing agents like sodium diphosphate, sodium triphosphate, nitrilotriacetic acid (NTA) or ethylenediaminetriacetic acid (EDTA).
3. Ion exchangers such as water soluble polycarboxylic acids, citrates and insoluble zeolites (eg. zeolite 4A)

Since complexation of calcium and magnesium is one of the principal functions of a builder, the calcium binding capacity of the alternative builders is an important characteristic. Zeolite can bind more calcium per gram than STPP, but this happens much slower, so more zeolite than STPP must be included in the formulation.

#### 2.1.4.1 Alkalies

The activities of alkalies as builders such as potash (KOH) and soda-ash (NaOH) are based on the fact that soils and fibres become more negatively charged as the pH increases, resulting in increased mutual repulsion. Alkali also precipitates calcium and magnesium ions that contribute to water hardness.

Modern builders no longer precipitate water hardening agents as precipitation is not only inefficient, but also leads to troublesome deposits on clothing and laundering apparatus. Instead the water hardening agents are removed by complexation or ion exchange at near neutral pH rather than by raising the pH as with alkalies.

### 2.1.4.2 Complexing Agents

By contrast with the alkalies, complexing agents form stable, water soluble complexes with calcium and magnesium, as well as with traces of heavy metals present in water. In the biological sewage treatment with no complexing agents in detergent formulations, heavy metals in the sewage attach themselves to the biological sludge and are removed from the system in the insoluble form via the waste sludge stream. The heavy metals are thus removed from the wastewater and prevented from entering the environment in an uncontrolled fashion. Complexing agents, such as EDTA, however, keep these heavy metals in solution. It is extremely difficult to remove heavy metals complexed in solution and this is usually not practised because of the expense involved. Thus in the presence of large quantities of complexing agents, heavy metals normally are not removed to the same extent from the sewage effluent and greater quantities enter the natural water system.

When a non-complexing builder like STPP for example, is used instead of complexing agents, a very small amount of complexing agent eg. EDTA is nevertheless added to the detergent formulation (cf. section 2.1.3 above). This is because even in trace amounts heavy and trace metals, can have a negative effect on the washing process in the same way as calcium and magnesium. (cf. section 2.1.3 above)

### 2.1.4.3 Ion Exchangers

Prior to the early 1970's, zeolite was not found in any commercial laundry detergent product. From the 1980's to the present, zeolite type 4A has become firmly established as a high quality detergent builder in Europe and North America.

Until a few years ago, the idea of introducing water-insoluble ion substances into detergents had never been seriously investigated. This was because the known materials lacked sufficient calcium binding ability and were deemed impractical for economic reasons (Coffey and Gudowicz, 1992). Success was first achieved through research in the field of sodium aluminium silicates. Those with a regular crystalline form were found to be the most suitable to minimise fabric abrasion, in particular the zeolite 4A. The ion exchange behaviour of this particular zeolite depends on ionic size and the state of hydration of the ions. In addition to calcium and magenesium, exchange also takes place with lead, copper, cadmium, zinc and mercury ions bringing these heavy metals into the solid form (rather than complexing them and retaining them in solution). The elimination of calcium and to a lesser extent magnesium ions is of greatest importance in the wash process, but removing heavy metal ions from solution is also important from an ecological standpoint. Therefore ion exchangers in principal are superior builders to the complexing agents.

Ion exchange is dependent not only on ionic size, but also on concentration, temperature, pH and time. Calcium ions are exchanged very rapidly. Exchange occurs more slowly with magnesium because of the larger hydration shell surrounding the magnesium ion, which hinders exchange at low temperature; however at higher temperature, the hydration shell is destroyed making exchange faster. If zeolite is used alone in the washing process, its performance as a builder does not compare with STPP because although its calcium binding capacity is high, ion exchange is too slow. To improve the performance zeolite in the wash process, it is common practise to include a water soluble co-builder in the detergent formulation.

### 2.1.5 ZEOLITE 4A - CO-BUILDER SYSTEM

Ion exchange with zeolite occurs in a heterogeneous medium ie. between water and insoluble solid. This type of ion exchange, is accelerated by combining zeolite with water soluble sequestering agents. Thus in order to compete with STPP, zeolite 4A is used in conjunction with small amounts of water soluble builders which can be either maleic and acrylic salts, or more usually acrylic carboxylates (AC). These have the ability to remove polyvalent cations from a soil surface, transport them through as aqueous medium, and then release them to the zeolite ion exchanger. This property is described by Jakobi and Lohr, (1987) as a carrier effect. Other excellent co-builders for zeolite are STPP, NTA and water soluble polycarboxylic acids.

The high selectivity of zeolite to calcium can be considered positively because a residual concentration of magnesium can contribute to detergency by counter ion effects in the stabilisation of oils and dyes. Co-builders aid in soil dispersion and, as water soluble compounds, they are able to bind calcium ions faster than zeolite 4A. In the zeolite/co-builder mixture, calcium is first bound to the co-builder and then most of the remaining calcium ions are exchanged by zeolite. Thus by partially substituting zeolite with cobuilder, almost the same level of detergent efficiency can be achieved as with STPP.

#### 2.1.5.1 Concentration of Zeolite in Detergent Products

To reformulate a phosphate based detergent for a zeolite based detergent in South African conditions, one mass part STPP should be replaced by 1.2 mass parts anhydrous zeolite in the detergent formulation. Since the zeolite contains 22% water, the mass concentration of hydrated zeolite in the detergent is 1.54 parts hydrated zeolite per part STPP (Welch and Duggleby, 1990).

Projected concentration of zeolite A in detergent products is 17-35% anhydrous basis. With this proportion, concentrations in domestic wastewater have been projected by the (Dept of the

Environment London, 1991) to be in the range 30-60mg/l.

### 2.1.6 EFFECTS OF SUBSTITUTION ON THE PHOSPHORUS CONTENT OF SEWAGE

(cf. Chapter 1, sect. 1.2)

The phosphorus content of domestic sewage originates from two main sources namely human waste and detergents. The detergent contribution to domestic sewage is normally taken to be approximately 40% (Heynike and Wiechers, 1986), but can rise to as much as 70% (Pretorius, 1983). Most of the highly eutrophied impoundments with a high phosphorus load receive up to 90% of their phosphorus input from sewage treatment works. Therefore, although diffuse sources of phosphorus also contribute to the eutrophication problem, there remains a strong argument for removing phosphorus from sewage effluent point sources before entering the water system. Removing phosphate from detergent formulations will make a major contribution in assisting sewage treatment plants to achieve lower effluent phosphorus concentrations.

In certain states of the USA, phosphorous detergent bans reduced phosphorous loads to wastewater treatment plants by as much as 50% and in Canada by 36%. Phosphorous loadings to the Great Lakes from municipal treatment plants in Michigan have been decreased by 20% as a result of the imposition of maximum limit of 0.5% phosphate in detergents. (Hartig and Horvath, 1982).

In South Africa, although biological excess phosphorus removal in activated sludge is widely implemented, up to 50% of municipal sewage in the Pretoria-Witwatersrand-Vereeninging (PWV) area, is still treated in trickling filters (Dept of Health, quoted by Brodisch, 1985). Because this area incorporates two of the most sensitive catchments to eutrophication, chemical P removal is required after treatment by trickling filters. Thus if STPP were to be substituted by zeolite in South Africa, it is anticipated that the phosphate load on water courses will decrease, leading to reduced costs of treatment, mineralisation and sludge production (cf Chapter 1, sect 1.4.1).

The remainder of this literature review examines zeolite builders and their action in greater depth as well as assessing their effect on the sewage treatment process.

## 2.2 PROPERTIES OF ZEOLITES

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### 2.2.1 HISTORY

The term zeolite was originally coined in the 18th century by a Swedish mineralogist named Cronstedt. Cronstedt observed that when a natural zeolite is heated, the zeolite stones began to dance about as water evaporated from the stones. (Rock and Muck, 1985) Using the Greek words that mean "stone that boils", he called this material a zeolite.

### 2.2.2 SOURCES OF ZEOLITES

Zeolites may be mineral (ie. naturally occurring) or synthetic. There exist currently 34 types of mineral zeolites, however synthetic zeolites are better suited to research and industrial applications as there is a greater uniformity in composition and purity. (Breck, 1974)

### 2.2.3 STRUCTURE

Zeolites are alumino-silicate solids with large interstitial pores. The structure consists of tetrahedrally linked aluminium and silicate molecules. The silicon atom, with a +4 charge is balanced by the 4 negative charges from the shared oxygen atoms. However the +3 charge on the aluminum, also surrounded by the four shared negative charges from the oxygen molecules, results in a net negative charge. This negative charge near the aluminium atom is balanced by the positive sodium ion which exists next to the aluminium atom within the framework. It is this sodium ion which is free to be exchanged for calcium and other cations.

Zeolite 4A is a type of zeolite that has a 3-dimensional intersecting channel structure formed by 8 membered oxygen rings with a free diameter of 4.2 to 4.3 Angstrom. The size of the opening changes with temperature and during adsorption of cations. Larger cations can also block the entrance to the pores, making the pore effectively smaller, thus creating an additional molecular sieve effect (Breck, 1974).

Cations with a small enough cross sectional area may pass through the pores and become adsorbed within the cage structure. Hence these cations are selectively adsorbed and the zeolite acts as a molecular sieve.

### 2.2.4 ZEOLITE 4A

Zeolite 4A is a type of synthetic zeolite which is mass produced for use in detergents. It consists of cubic crystals with rounded corners and edges. This unique particle form minimises fabric damage. It is a free flowing white powder with individual cubic crystals ±2 microns across. Usually several particles group together so that the resulting mean particle size is 4-6 micron. Most of the particle sizes fall in a narrow range and this ensures that large particles will not become encrusted on laundry.

## 2.2.5. CHEMICAL PROPERTIES AND REACTIONS OF ZEOLITES

### 2.2.5.1 Cation Hydrolysis

In the aqueous environment, the cation within the zeolite may be partially hydrolysed and replaced by the hydronium ion ($H_3O^+$). The consequent excess hydroxyl in the surrounding medium causes a pH of 9 - 12 in water. This hydrolysis reaction is speeded up in a low pH medium.

### 2.2.5.2 Strong Acids

Direct treatment of silica-rich zeolites with acid results in the progressive replacement of the cation with the hydronium ion. Further treatment, however, removes the framework aluminium ions, which are replaced by groups of hydroxyls. When treated with strong acids, many zeolites decompose and appear to dissolve (Breck, 1974).

### 2.2.5.3 Ion Exchange

The ion exchange behaviour of zeolites depends on the nature of cation species, temperature, concentration of cation species, associated anion and structural characteristic of the zeolite.

a. <u>Ion Exchange Equilibria in Aqueous Solution</u>

Zeolite ion exchange capacity increases with decreasing SiO2/Al2O3 ratio, and varies with the specific exchanging cation.

Decreasing selectivity in zeolite 4A can be summarised as:

Univalent : Ag > Ti > Na > K > NH4 > Rb > Li > Cs

Divalent Zn > Sr > Ba > Ca > Co > Ni > Cd > Hg > Mg

b. Cation Sieve Effects:

Zeolites behave as molecular sieves in that they can:

- Adsorb one cation in preference to another in accordance with the thermodynamic stability of the complex.

- Block the adsorption of a specific cation if the cation is too large to enter the small channels and cavities within the zeolite structure.

- Block the release of a cation held within the structure if the pores become blocked or the cation is locked in during synthesis of the zeolite.

- Release a cation held within its structure when the complex is exposed to cations which would form a more stable complex.

If a cation is hydrated, the surrounding water molecules may make the hydrated cation too large to pass through the apertures of the zeolite. An exchange of solvent molecules must first occur in order to allow the cation to diffuse through the apertures. Thus a molecular sieve effect is exerted on the kinetics of ion exchange.

### 2.2.2.5 Calcium and Magnesium Exchange

For zeolite to soften water, calcium and magnesium ions must diffuse from the bulk solution into the crystal and an equivalent number of sodium ions must diffuse out. This process involves a number of steps, and the rate determining step is the diffusion of calcium or magnesium into the zeolite crystal. Magnesium ions diffuse more slowly than calcium because they have more hydration water molecules associated with them - these water molecules need to be shed by the ions as they pass from cavity to cavity within the crystal (Newton, 1990).

Zeolite 4A has a calcium exchange capacity of 300 mg as $CaCO_3$ (0.00352 moles) per gram anhydrous zeolite. When a zeolite particle is placed in hard water, calcium diffuses into the crystal and replaces 2 sodium ions to maintain a charge balance. (Rock and Muck, 1985). The degree of exchange is a function of the concentration of the calcium and magnesium in solution and more dilute solutions result in a more complete exchange.

a. <u>Rates of Exchange</u>

The rates of exchange with hardness ions has been investigated by Unilever (Newton, 1990). This depends largely on the calcium:magnesium ratio. Pure calcium exchanges ten times faster than pure magnesium. Time constants for 50% exchange were 9s and 250s for calcium and magnesium respectively. If ratio of calcium:magnesium is greater than 2:1, then the presence of magnesium does not decrease the rate of exchange found with pure calcium solutions. If calcium:magnesium ratio decreases to 0.5:1, rate of exchange is considerably reduced (Table 2.1). In this case, the magnesium ions with their associated hydration water molecules block the pores controlling access by the calcium ions to the channel network.

**Table 2.1: Kinetics of Ion Exchange in Zeolite 4A:**

| Initial solution phase Ca:Mg | pure Ca | 2:1 | 1:1 | 1:2 | pure Mg |
|---|---|---|---|---|---|
| Diffusion Coefficient D ($10^{-15}m^2/s$) | 1.67 | 1.7 | 1.38 | 0.62 | 0.18 |

b. Zeolites as a Detergent Builder

Elimination of calcium and magnesium from the water is slower by zeolites than by STPP. Whereas STPP removes magnesium almost entirely, magnesium exchange by zeolite is negligible (Newton, 1990). Since the concentration of calcium in the wash water is more than 10 times that of magnesium, the zeolite still performs satisfactorily as a detergent builder and is used extensively as a detergent builder in Europe and North America. The following section discusses the known effects of zeolite on the sewage treatment process.

## 2.3 ZEOLITE IN SEWAGE TREATMENT

Since laundry wash water is usually disposed of via the sewerage system, it is important to know whether or not there are any adverse effects of the detergent builder on the operation of the sewage treatment plant. Since the nutrient removal activated sludge process is not widely used outside South Africa and since South African detergents are at present almost exclusively phosphate built, no previous experience is available on the influence of alternative builders on the nutrient removal activated sludge process.

### 2.3.1 DETERGENT PHOSPHATE CONCENTRATION IN SEWAGE

In the United Kingdom, detergents are generally phosphate built. The UK Soap and Detergent Industry Association (SDIA) estimates that a maximum of 40% of total wastewater phosphorous might be detergent derived (SDIA 1989 as quoted by Dept of Enironment, London, 1991). In South Africa, where detergents are also phosphate built, it is estimated that the detergent contribution to the phosphate load on sewage plants is between 35 and 50%, depending on the geographical location (Heynike and Wiechers, 1986).

### 2.3.2 CONTRIBUTION OF LAUNDRY WATER TO SEWAGE LOAD

Laundry wash water is normally diluted in the sewerage system by a factor exceeding 10 (Jakobi and Lohr, 1987). Table 2.2 shows the calculated theoretical estimates of average concentrations of the most important detergent components in public wastewater. These estimates are derived from statistical data collected in the Federal Republic of Germany, and depend on detergent consumption and per capita water consumption.

**Table 2.2: Average detergent concentrations in the Federal republic of Germany.**

| Component (1980 estimate) | Daily per capita concentration | Calculated average concentration in municipal sewage, mg/l |
|---|---|---|
| Average household water use | 200L | |
| Detergent consumption (750 000 t/a) | 33.3g | 167 as ABS |
| Anionic detergent consumption (151 000 t/a) | 6.71g | 33.5 |
| Nonionic detergent consumption (91 700t/a) | 4.07g | 20.3 |
| Cationic detergent consumption (26 100 t/a) | 1.16g | 5.83 |
| Phosphorus consumption in detergents (56 800 t/a) | 2.52g | 12.6 as P |

From the data in Table 2.2, which was obtained from Schulze-Rettmer, (1980 - as quoted by Jakobi and Lohr, 1987) the per capita amount of laundry wastewater generated daily is 8-16L which is 4-8% of the total hydraulic load reaching a sewage treatment plant. The phosphate content of this wash water is 150-300mgP/l.

Table 2.3 shows the extent to which different types of water are altered by soil and detergent chemicals in the course of the laundering process:

**Table 2.3: Extent of soil load carried by various waters:**

| Parameter | Unit | Drinking water | Mixed wastewater derived from laundering | Municipal sewage |
|---|---|---|---|---|
| Transparency | cm | 700 | 2 | 1-4 |
| Temperature | °C | 15 | 25* | 10-20 |
| pH | | 7.3 | 8-10 | 6.5-8.5 |
| COD | mg/l | 3-10 | 900-1300 | 200-600 |
| BOD(5) | mg/l | 1 | 400-1000 | 150-400 |
| Total N | mg/l | 5 | 15-65 | 40-80 |
| Total P | mg/l | 0.2 | 100-300 (200)* | 2-41 (20)* |
| Anionic detergents | mg/l | 0 | 15-180 (75)* | 5-35 |
| Nonionic detergents | mg/l | 0 | 5-90 (37)* | 2-25 |
| Soaps | mg/l | 0 | 5-20 (12)* | <2 |

* Average

Only one half or less of the biodegradable organic contaminants load comes from the organic compounds in the detergent, the remaining half is due to laundry soil.

### 2.3.3 REMOVAL OF ZEOLITE DURING PRIMARY SEDIMENTATION

Owing to the molecular sieve properties of zeolite A, Rossin *et al.*, (1982), expressed concern that it may adsorb objectionable organics whilst in contact with sewage. These organics may then be remobilised into receiving waters with detrimental effects. Consequently it is important to remove Zeolite A as completely as possible during waste water treatment. Removal of zeolite during primary sedimentation was reported by Carrondo *et al.*, (1981) to be unaffected by influent concentrations, being between 55 and 60% for normal primary settling tank retention times of 1 hour and 2 hours respectively.

### 2.3.4 EFFECT ON SEWAGE TREATMENT PARAMETERS

Hopping, (1978) investigated the removal of zeolite A using a packaged activated sludge plant serving 81 homes. Overall, zeolite had no adverse effect on the operation of the activated sludge plant. The zeolite became associated with the sludge and accumulated within the plant to a steady state level, as would any readily settleable inorganic particulate material. The difference in COD values of the control and test units were not statistically significant. Evidence for improved nitrification in the presence of zeolite is also inconclusive. In all sampling periods, marginally better phosphate removals were detected in the presence of zeolite A. Fischer *et al.*, (1978) also found no evidence of zeolite A having an adverse affect on wastewater treatment.

#### 2.3.4.1 Settleability, Dewaterability and Clarification

Improved settleability of zeolite-containing activated sludge has been reported by Hopping, (1978) and Carrondo *et al.*, (1987). Carrondo *et al.*, (1980) also investigated the influence of zeolite A on treatment parameters in activated sludge pilot plant operations. Activated sludge settleability was found to be improved in the presence of zeolite A, as was sludge dewaterability. Zeolite concentrations in the final effluent varied between 2 and 4 mg/l.

In a study by Roland and Schmidt, (1978) zeolite A did not affect the dewaterability of sewage sludges at high or low concentrations. However very small zeolite particle size may lead to clarification problems in sewage treatment plants (Welch and Duggleby, 1990).

#### 2.3.4.2 Nitrification

In a study reported by Fischer and Gode, (1978), mobile activated sludge units were fed primary effluent from a municipal plant. Control and test units were operated in parallel, and the influent to the test unit was dosed with 50mg/l of calcium exchanged zeolite. This study was designed to assess the potential effects of nitrification and substantial enhancement of nitrification in the zeolite unit was observed after an initial 20 day period. In the experiments of Olah *et al.*, (1989), upon zeolite addition to a fully aerated activated sludge plant, a 60% increase in nitrification rate was observed. Berth, (1980) also studied the effect of type A zeolite on nitrification in activated sludge treatment in a 1-year field study. Residents of the town served by the sewage treatment plant were supplied with detergent containing zeolite, but no enhancement of nitrification was observed. Thus it appears questionable whether Type A zeolite will significantly enhance nitrification on full scale plants.

#### 2.3.4.3 Phosphorous Removal

In practise contaminants often remain in the sewage effluent in unacceptable amounts after sewage treatment. In order to remove the remaining impurities, expensive chemical methods are usually applied. As a result, wastes are formed which contaminate the environment by increasing salinity. Zeolite can be used as an alternative to these chemical methods. The use of zeolites as ion exchangers and/or adsorbers is much cheaper and the impurities are removed in less hazardous forms.

Olah *et al.*, 1986, found increased removal of suspended solids, phosphate and ammonium ions during sewage treatment upon adding zeolite-containing powder to the wastewater. The philosophy was that the zeolite:

- increased the biological activity of the sludge
- increased the removal of suspended solids,
- improves the phosphate removal efficiency by improving the activity of trivalent ions ($Fe^{3+}$, $Al^{3+}$)

Thus ammonium and dissolved colloidal and organic substances which remain after biological treatment, can be removed in an ion exchange column filled with clinoptilonite, a natural zeolite which is selective for ammonium ions.

In the experiments of Olah *et al.*, 1986, chemical removal of phosphate was significantly improved when clinoptilonite (a natural zeolite) was used in conjunction with a concentrated solution of iron(III) salt. Continuous experiments were carried out in a pilot plant and in large scale plants. The two large scale plants had sludge ages of 17.7 and 15.5 days respectively. The extent of phosphate removal with trivalent ions in the presence of zeolites was as follows:

If 1g of clinoptilonite zeolitic rock has been exchanged with calcium or magnesium and is placed in an environment where ammonium and iron is present, the calcium and magnesium exchanges for ammonium and so the calcium and magnesium become free ions in the medium. In this way, 1g of zeolite itself removes 6.4 mg phosphorous owing to the remobilised calcium and magnesium ions forming phosphate-iron precipitates. The observed effect of clinoptilonite is 3-4 times greater than the value of 6.4 mg/l.

The reason for this effect is the retention of iron in the zeolite in the mixed liquor. The residence time of zeolitic rock with iron occluded is longer than that of a non-fixed iron solution and so more insoluble iron phosphate is formed than without zeolite present.

### 2.3.4.4 Removal of Suspended solids

In the study of Lo and Hung, 1990 clays and zeolites proved to be rather ineffective in decreasing turbidity of settled wastewater. The TOC removal efficiency ranged from 14 to 34% at a zeolite concentration of 1000 mg/l.

In the experiments of Olah *et al.*, 1986 lower effluent suspended solids concentration was obtained when the biological treatment of the sewage was carried out in the presence of the zeolite with the iron(III) salt than with the iron (III) salt alone. It was concluded that the zeolitic particles preferentially adsorb colloids, and coagulation seeds were thus formed. As a result of the zeolite treatment in the experimental set-up:

- The concentration of the settled return activated sludge increased from 15 to 30 g/l in the secondary settling tank,
- Dewaterability improved
- DSVI decreased significantly.

### 2.3.4.5 Sludge Production

The use of zeolite A has no adverse effect on the volume of wet sludge production. This is because although the mass of sludge solids increases, sludge settleability is improved and therefore sludge concentration also increases. Where sludges are filtered, pressed, centrifuged or dried, the presence of zeolite would result in a larger quantity for disposal. On the basis of zeolite 4A content in detergent formulations of 20%, the mass of wastewater sludge would be expected to increase by 10-15% on a dry basis. (Dept of the Environment London, 1991)

#### 2.3.4.6 COD Removal

Fischer *et al.*, (1978) demonstrated that the removal of organic matter and detergents as measured by the COD test actually increased while dosing with SASIL Zeolite type A.

In the experiments of Olah *et al.*, 1986, with the same sludge ages, the COD of the zeolite treated filtered effluents were regularly lower than the control. Biological activity of the sludge can be expressed in terms of the rate of COD uptake per mass of VSS g COD/(gVSS.h). Pilot plant experiments showed an activity of 52g COD/(gVSS.h) in the control and 65g COD/(gVSS.h) in the presence of zeolite. Corresponding values in other full scale operating plants were 35 and 44g COD/(gVSS.h) respectively. These examples point to an increase of the biological activity by about 25% due to zeolite addition.

The increase in biological activity effected through zeolite addition was explained by Olah *et al.* as follows:

- Zeolite particles are seeds for bacterial flocs, which are therefore formed in greater number and smaller size. The transport of oxygen and nutrients is faster in the smaller flocs than in the larger ones.
- Zeolite particles adsorb ammonia which thus becomes concentrated on the zeolitic crystals, accessible for nitrification bacteria; thus the nitrification rate accelerates.
- The biological composition of activated sludge changes favourably in the presence of zeolites. The "predator ciliates" multiply. Nematodes also appear in the sludge. These animals feed on the free swimming bacteria in the liquid phase.

### 2.3.5 ENVIRONMENTAL ASPECTS OF ZEOLITES

A programme was initiated by Unilever Port Sunlight (Llenado, 1990) to evaluate the environmental safety of zeolite A in sewage treatment plants. The studies demonstrated effective removal by sedimentation and no adverse effects on the system performance. Zeolite A does not alter the distribution of heavy metals in the environment nor provide a surface for adsorption of organics.

#### 2.3.5.1 Degradability

Zeolite 4A is a synthetic sodium aluminosilicate empirically similar in composition to naturally occurring kaolin clay. It is non biodegradable as it is an inorganic compound. However zeolite is metastable, so when it re-enters the environment, it decomposes back into its mineral constituents, silica and alumina. (Coffey and Gudowicz, 1990).

#### 2.3.5.2 Drinking Water

Concern has been expressed regarding the possible hydrolysis of aluminium from zeolite under adverse environmental conditions. This process is pH dependent and is not thought to occur at pH values >5.0. Normal abstraction and treatment processes throughout Europe take place at neutral/alkaline pH values and thus should not lead to the release of free aluminum. (Newton, 1990)

### 2.3.6 DETERGENT LAWS

According to the German Detergent Law, placement of detergents and cleansers on the market is permitted only if the absence of all avoidable deterioration in the quality of surface water can be ensured. Particular attention is devoted to the drinking water supply and to problems related to the operation of sewage treatment plants. (Jakobi and Lohr, 1987)

#### 2.3.6.1 Biodegradability

Detergents and laundry soil represent the largest nonfecal burden on the sewage treatment plants in the former Federal Republic of Germany. In 1961 the German Detergent Law placed a strict requirement of >80% biodegradability on all detergents. Thus the poorly biodegradable detergents with a branched alkyl group (hard detergents) were replaced by linear alkyl benzenesulfonate (LAS) (soft detergents). By 1965 foaming problems in German sewage treatment plants and surface waters had been eliminated. Further developments in the last 25 years include corresponding regulations and voluntary agreements in various parts of Western Europe, North America, Brazil and Japan.

In addition to the general requirements for biodegradability, a specific statute was developed in 1977 which spelled out concretely test methods for the measurement of this biodegradability. The OECD confirmatory test is based on a fully aerated model sewage treatment plant, using a control and a test set-up.

Years of systematic monitoring of sewage treatment plants and rivers have shown that, in general, residual concentrations of detergents in streams is extremely small. (Jakobi and Lohr, 1987)

### 2.3.6.2 Regulation of maximum phosphate concentrations in detergents

Laws and voluntary agreements with respect to the use of phosphate in detergent exist in several countries. Germany has a limit of 2% phosphate in detergent formulations. Certain states in the USA have limits ranging from a total ban to 8.7% phosphorous. In Canada, the limit is 2.2% in detergent formulation and in Italy 1%. Norway has set a limit of 12%, in Japan 90% of all detergents produced are phosphate free. Some countries, notably Sweden have concluded that the best approach is through tertiary treatment, and by the end of 1983, Sweden had constructed 850 such plants serving nearly 80% of the Swedish population. Switzerland has perhaps the most severe eutrophication problems in Europe because of its unique geology. After 1 July 1986, the use of all phosphates in laundry detergents was banned completely. In the vast majority of cases, phosphate has been replaced by zeolite 4A, and to a lesser extent by NTA.

A thorough study of phosphates entitled "Phosphorous: Pathways and Fate in the Federal Republic of Germany" was commissioned by the German Federal Ministry of the Interior (Hauptausschuß, 1978 as reported in Jakobi and Lohr, 1987). More than 90% of the phosphate produced in or imported into the Federal republic of Germany in 1975 (807 000 t P/a) was found to be used in the fertiliser and feed industries, and only 8.6% (69 000 t P/a) was used in the detergent and cleanser industries. By 1985 the phosphorus used in detergents had declined further to 35 000t P/a as a result of the continuing replacement of detergent phosphate builders by substitutes. The same study led to the conclusion, however, that ±60% of the phosphate encountered in municipal sewage (as opposed to general run-off) originated from detergents and cleansers. This phosphorous balance shows that the removal of phosphates from detergents alone is likely to reduce the phosphorus load on municipal treatment works, but cannot possibly solve the entire problem of surface water eutrophication.

In Sweden, phosphate in detergents is not banned, while in Switzerland phosphate is banned in detergents. Both countries use chemical precipitation to remove phosphate from municipal wastewaters however this method is relatively expensive and increases the salinity of the receiving waters. In South Africa biological phosphorous removal technology has been developed in and is in use countrywide, avoiding the cost and mineralisation problems associated with chemical precipitation. The availability and use of this technology has been a major factor in allowing the continued use of phosphate built detergents in South Africa.

#### 2.3.6.3 Human Toxicology

The human toxicology and the ecological characteristics of zeolite A has been the subject of major research programmes since 1973 in Germany and the USA (Jakobi and Lohr, 1987). The comprehensive nature of this investigation is unprecedented for a detergent raw material and all of these investigations have led to the same conclusion: there is no basis for concern regarding the use of zeolite 4A in detergents. Natural zeolites possessing a fibrous morphology are capable of producing tumours when ingested, unlike zeolite A, which consists of cubic crystals.

#### 2.3.6.4 Ecotoxicology

Toxicological studies indicate that zeolites are toxic to aquatic organisms only at very high concentrations ( >680mg/l). Algal growth may be inhibited at zeolite levels >50mg/l, possibly due to increased turbidity and adsorption of trace elements and micronutrients on the surface of the insoluble silicate. (Maki and Macek, 1978). Zeolites have no stimulative effect on the growth of algae at high or low concentrations and cannot act as a nutrient source. (Newton, 1990)

## 2.4. HEAVY METALS

### 2.4.1 INTERACTIONS BETWEEN ZEOLITE 4A AND HEAVY METALS

In addition to calcium and magnesium, ions such as silver, lead, copper, cadmium and zinc are all exchanged by zeolite 4A. These metal cations thus form an insoluble complex with zeolite and are removed from the sewage treatment process with the waste activated sludge. Iron, aluminium and chromium in the environment are usually in the form of oxides which are difficult to dissolve and therefore are unlikely to be available for exchange with zeolite (Newton, 1990). In wastewater treatment, Fe, Al and Cr are in the solid phase, they are removed and become part of the sludge mass produced.

Obeng *et al.*, (1981) investigated metal removal in the presence of zeolite A during laboratory activated sludge experiments (fully aerated). The heavy metals cadmium, chromium, copper, nickel, lead, zinc were added in concentrations typical of mixed domestic/industrial wastewaters. No adverse effect on metal removal occurred when zeolite A was present. King *et al.*, (1980) and Obeng *et al.*, (1981) carried out a series of tests in sedimentation columns to investigate the influence of zeolite A on heavy metal removal. Results from these experiments showed no significant differences in metal removal with or without the addition of zeolite A.

'Wash day' phenomena (high concentrations of detergent chemicals in the sewage), were simulated by Stoveland *et al.*, (1980) to determine whether zeolite A influences heavy metal transfer in activated sludge. Under conditions of constant loading zeolite A did not significantly affect the concentrations of cadmium, chromium, copper, nickel, or lead but did have a significant adverse effect on zinc removal. Although cadmium and nickel removal appeared to improve slightly in the presence of zeolite A, these were not significant compared with the improvement in removal achieved for all metals under similar operating conditions in the presence of STPP.

Ion exchange of zeolite was reported by Schwuger *et al.*, (1976 -

as reported by Schwuger, 1986) to increase with decreasing water hardness, increasing temperature, increasing pH of the solution and decreasing concentration of heavy metals. At a concentration of 100 mg/l zeolite and 1 mg/l each of lead, silver, copper, cadmium and zinc together in a water solution of hardness 110 mg/l as $CaCO_3$ at 23°C and pH 7, only lead and silver were completely removed after 1 hr. After 24 hrs, 50% of the copper, 25% of the cadmium and 10% of the zinc were removed. Thermodynamic data on ion exchange as reported by Obeng *et al.*, (1981), indicate that the nickel and chromium forms of zeolite type A are not as stable as other forms of zeolite type A. Thus it can be expected that at a sewage treatment works, nickel and chromium will not be removed from suspension as easily as other metals. In primary sedimentation, with the presence of zeolite within the range of its expected environmental concentrations, the removal of the metal ions was neither enhanced nor adversely affected to any significant degree.

### 2.4.2 REMOVAL OF CALCIUM AND MAGNESIUM

Magnesium concentration decreased with addition of synthetic zeolite type A, but significant reduction was present only at concentrations in the region of 500 mg/l. This is an order of magnitude higher than the concentration expected through the use of zeolite based detergents. At concentrations of ±30 mg/l as used in this thesis, the magnesium concentration is expected to drop by only 0.4mg/l (Lo and Hung, 1990).

Rate of removal of calcium hardness from the wastewater samples was a function of the calcium hardness present in the sample. High concentrations of zeolite removes all the metals except chromium from the water (Obeng *et al.*, 1981).

### 2.4.3 RELEASE OF ALUMINIUM AND OTHER HEAVY METALS

In the zeolite crystal, the aluminium is bound with silicates in the crystal structure. However, when the sludge is applied to land, circumstances may arise when breakdown of the Al:Si complex may occur releasing free aluminium. Allen *et al.*, (1983 - as quoted by Dwyer *et al.*, 1990) reported that zeolite hydrolysed extensively at rates which were highly dependent on hydrogen ion concentration, with half lives of one to two months being common for waters with a neutral pH. Heavy metals previously adsorbed during the sewage treatment process may be remobilised when the sludge is disposed of, either on land or at sea.

## 2.5. HIGH SURFACE AREA CALCIUM CARBONATE

### 2.5.1 CARBONATES IN SURFACE WATERS

Carbonate and Bicarbonate ions exist naturally in surface waters and contribute to the alkalinity or hardness of the water. They are non-toxic to aquatic organisms and act as pH buffers. Surface waters with low carbonate species tend to be low in biological production. However a very large input of carbonates into a receiving water body can cause pH to rise which may increase the

# CHAPTER 3

# EXPERIMENTAL INVESTIGATION

## THE EFFECTS OF ALTERNATIVE DETERGENT BUILDERS ON THE PERFORMANCE OF THE NUTRIENT REMOVAL ACTIVATED SLUDGE SYSTEM

### 3.1. INTRODUCTION

In order to examine the effect of alternative detergent builders on nutrient removal activated sludge plants, two laboratory scale modified UCT activated sludge systems were set up, one Control and one Experimental. Both systems were operated at a long sludge age (20 days), with a real sewage feed (from Mitchell's Plain, Cape) and at a controlled temperature of 20°C. The effect of dosing the Experimental system with alternative detergent builders was assessed by comparing the Experimental system performance with that of the Control system. Initially during 1991 (phase 1), the complete zeolite based detergent formulation was dosed to see the overall effect of replacing a phosphate-based detergent with a zeolite-based detergent. Because real sewage, which already "naturally" incorporated phosphate based detergent was fed to the two systems, the Control system was dosed with an equivalent mass of phosphate-based detergent formulation while the Experimental was dosed with the zeolite-based detergent formulation. This approach led to a number of difficulties which required the testing procedure to be changed. Briefly the difficulties were:

1. Sludge bulking, suspected to be due to the unusually high

fresh concentration of detergent in the sewage;

2. Foaming arising from fresh detergent ingredients;
3. Very low VSS solids concentration in the mixed liquor due to the bulking and foaming in the aerobic zone;
4. Aberrant activated sludge behaviour resulting from acetate dosing to the sewage feed to increase the biological excess phosphate removal. This aberrant behaviour included very poor P removal, COD removal and nitrification.

To eliminate the above problems, from 1992 (phase 2), dosing of the complete formulation was stopped and the alternative builders ie. zeolite and HSA calcite were dosed as isolated species to the Experimental system. The Experimental and Control systems therefore became identical in all respects, except that an alternative detergent builder (first zeolite, then calcite) was dosed into the Experimental system. This approach proved successful and was maintained for the remainder of the investigation ie 289 days. In the interests of brevity, details of the experimental procedure and results of the phase 1 experiments are not discussed in this chapter, these are given in Appendix 1. Instead, emphasis will be placed on the phase 2 experiments which produced the more meaningful and useful results.

## 3.2 DESCRIPTION OF OPERATION OF LABORATORY SCALE SYSTEMS

The Modified University of Cape Town (MUCT) configuration chosen for the Experimental and Control systems is shown in Figure 3.1.

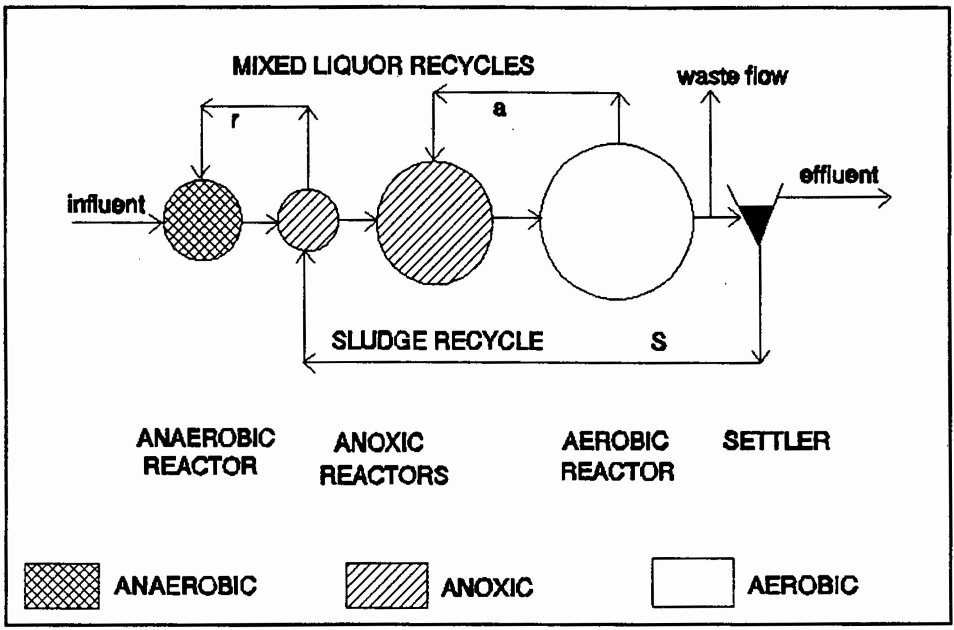


**Figure 3.1** Modified UCT configuration

The combined volume of the reactors is 23 litres. The anaerobic zone occupied 6 litres and was divided into two identical 3 litre reactors. Because the anaerobic sludge is diluted 1:1 by the influent sewage, its mass concentration in the MUCT system is only half of the remaining reactor concentration. The anaerobic reactors therefore effectively contribute only 3 litres of system volume at the anoxic and aerobic reactors' concentration making the effective system volume only 20 litres at the anoxic and aerobic reactors' sludge concentration. Consequently the anaerobic sludge fraction is 3 in 20 litres, or 15%. The first anoxic reactor occupied 4 litres which is a sludge mass fraction of 20%. The second anoxic and aerobic reactors each occupied 6.5 litres therefore each representing a 32.5% sludge mass fraction. These mass fractions were adopted because they were approximately those normally used in the laboratory and in the field to provide a balanced design for high removals of N and P. Details of the design and operating parameters are given in Table 3.1.

**Table 3.1 : Initial design and operating conditions of the laboratory scale systems. (Control & Expt identical)**

| PARAMETER | CONTROL / EXPERIMENTAL SYSTEMS |
|---|---|
| System configuration | Modified University of Cape Town. |
| Aerated volume (mass fraction) | 6½l (32.5 %) |
| Dissolved oxygen concentration | 2 - 3 mg/l |
| Temperature | 20 °C |
| Sludge age | 20 days |
| Influent COD concentration | 1000 mg/l |
| Influent TKN concentration | 70 - 130 mg/l |
| Influent Phosphate concentration (no additives) | 16 - 22 mg/l as P |
| Influent flow | 10 litres per day continuous |
| Feed source | Mitchell's Plain unsettled |
| Volume (mass fraction) of reactors | |
| anaerobic (l,%) | 3l+3l(at half concentration)= 3l (15%) |
| anoxic (l,%) | 4l+6½l=10½l (20%+32.5%=52.5%) |
| aerobic (l,%) | 6½l, (32.5%) |

| | | |
|---|---|---|
| Nominal hydraulic retention time (system) | 55.2 hours | actual retention times given for a,r and s recycles of 2.75, 1.0 and 1.3 respectively |
| 1st & 2nd anaerobic reactors (nominal; actual) | (14.4 hrs; 7.2 hrs) | |
| 1st anoxic reactor (nominal; actual) | (9.6 hrs; 2.9 hrs) | |
| 2nd anoxic reactor (nominal; actual) | (15.6 hrs; 3.1 hrs) | |
| aerobic reactor (nominal; actual) | (15.6 hrs; 3.1 hrs) | |
| Mixed liquor pH | 7.4 - 8.0 | |
| Underflow s-recycle (clarifier - 1st anoxic) | 1 - 1.6 | |
| Mixed liquor a-recycle (aerobic - 2nd anoxic) | 2.5 - 3 | |
| Mixed liquor r-recycle (anoxic - anaerobic) | 1.0 | |

The aerobic reactor was aerated with low pressure compressed air and maintained at an average dissolved oxygen (DO) concentration of 2 - 3 mgO/l. Nitrate rich mixed liquor from the aerobic reactor was pumped back (via the a-recycle) at some specified mixed liquor recycle ratio (usually 3:1) to the second anoxic reactor where the nitrate was denitrified to nitrogen gas. Aerobic reactor outflow mixed liquor was passed over a U-tube to the clarifier from where the settled underflow sludge was recycled to the first anoxic reactor at a recycle ratio (s) of 1 to 1.3. The clear supernatant from the clarifier was collected and accumulated in an effluent bucket over 24 hours. After 24 hrs, grab samples were then taken from the effluent bucket for analysis of effluent quality. Small concentrations of solids settling in the effluent bucket were settled out and returned to the aerobic reactor. The underflow recycle stream from the clarifier contained low concentrations of nitrate (<10mg/l) so that the first anoxic reactor was under-loaded with respect to nitrate and it always contained below detectable concentrations of nitrate and nitrite. This led to generally below detectable concentrations of nitrate and nitrite in the first anoxic reactor (ie <0.5 $mgNO_3$-N/l and <0.2 $mgNO_2$-N/l). Mixed liquor from the first anoxic reactor was pumped to the first anaerobic reactor (via the r-recycle) at a recycle ratio of 1:1 and mixed with the influent sewage. The low levels of nitrate and nitrite took place in the first anoxic reactor ensured that no interference of nitrate and nitrite on biological P release, and hence excess P removal. To ensure that the anoxic and anaerobic reactors did not entrain oxygen, the reactor lids were sealed with a gasket and the sample port closed with a rubber stopper. Covers (eg. plastic balls or polystyrene floats) on the liquid-air interface in the reactors were not used, because these tend to encourage the growth of organisms on the water/cover interface.

Before commencing phase 2 of the study, tests were carried out to determine the extent of oxygen entrainment due to mixing in the anaerobic and anoxic reactors. The anaerobic and anoxic reactors were filled with tap water which was de-oxygenated by the addition of 63 mg/l reactor volume sodium sulphite ($Na_2SO_3$), which is sufficient to deoxygenate 8 mgO/l in the tap water. Over a period of 24 hours, the oxygen entrainment was measured with a DO probe and plotted on a strip chart recorder. No significant oxygen entrainment was observed in either the Control or Experimental system reactors. The two systems were also physically identical in the following respects:

1. Identical stirrers and stirrer speed in corresponding reactors.
2. Reactor supports arranged to give identical head differences for gravity flow between the reactors in both systems.
3. The influent containers of the two systems were kept at the same temperature, the same influent pipe length and the same mixing intensity.
4. Inter-reactor connecting tubing cut to identical lengths.

These modifications were completed by the end of March 1992, and new sludge was collected from the Mitchell's Plain sewage works to restart the systems.

Both systems were operated at a 20 day sludge age which was controlled hydraulically by wasting a total of 1 litre of mixed liquor from the aerobic reactor daily (1/20th of net system volume). Mixed liquor required for sampling and analysis was included in the 1 litre/day sludge wastage. A sludge age of 20 days is typical of full scale plants that achieve high removals of both N and P. The effects of alternative detergent builders on waste sludge treatment and disposal were not studied in this investigation.

For the first 44 days of the investigation, both systems were fed raw sewage at the rate of 10 litres per day. The sewage was collected from the Mitchell's Plain sewage works which is a 30Ml/d nitrification/denitrification Modified Ludzack-Ettinger (MLE) plant treating only domestic sewage.

The sewage collected from this source (in batches of about 1000l) was stored at 4°C in the laboratory cold room and fed to the two laboratory systems after appropriate dilution with tap water to 1000 mgCOD/l. The sewage batches were used for a period of 2 to 3 weeks after which a new batch of sewage was collected to avoid septic sewage. Because the sewage was poorly buffered ($H_2CO_3^*$alk approximately 150mg/l as $CaCO_3$), a teaspoonful of $NaHCO_3$ was added to the final 10l volume of sewage fed to the two systems daily to buffer the influent and maintain the pH in the system above 7.0. A summary of the initial operating conditions of the two systems is given in Table 3.1.

During the investigation, a number of changes were made to the two laboratory systems. The objectives of these changes were to dose first zeolite and then HSA calcite to the Experimental system, alternating each dosing period with a baseline period, which would be long enough to allow both the Control and Experimental systems to reach steady state. A comprehensive list of the changes, the days on which they were made and the reason for making them is given in Table 3.2.

**Table 3.2 : Operational changes made to the laboratory systems**

| Day No | Change | Reason |
|---|---|---|
| 1 | Set up laboratory systems as per Table 3.1. Both Control and Experimental systems run on unaltered sewage | Initial baseline period to check that both systems are similar |
| 43 | Dose 400mg zeolite per day to Experimental system | Zeolite testing period |
| 104 | End zeolite dosing. Both systems run on unaltered sewage. | Final baseline period for zeolite and initial baseline period for HSA calcite. |
| 184 | Rename Control system as Experimental and visa versa | Prevent any possible influence of zeolite dosing on HSA calcite results |
| 185 | Dose 200mg HSA calcite per day to new Experimental system | HSA calcite testing period |
| 243 | End HSA calcite dosing. Both systems run on unaltered sewage | Final baseline period for HSA calcite |
| 289 | Terminate investigation | End of final baseline period |

## 3.3 ZEOLITE AND HSA CALCITE DOSAGE

The zeolite was dosed into the Experimental system in the form of a daily slurry addition to the influent sewage. The zeolite was kept in suspension by the gentle mixing of influent (±30 rpm). The mass dosage was determined as follows:

Based on correspondence from Unilever dated 6 February 1992, phosphate based detergent contains 26% sodium tripolyphosphate (STPP), while zeolite and HSA calcite based detergents contain 28% zeolite and 15% HSA calcite respectively.

From laboratory testing on STPP, 1g STPP contains 0.12g phosphate as P. Thus 1g P based detergent contains 0.26*0.12g =0.0312g phosphate as P.

Assuming that in sewage, the detergent P contribution in the sewage is 40%, and the average total P concentration is 18mg/l, then the theoretical mass of P based detergent in 10 litres of domestic sewage is:

10l * 18mgP/l * 0.4mgdetP/mgP * 1/(0.12mgdetP/mgdet)

ie. 600mg P based detergent per 10l daily feed (ie.60mg/l)

Assuming that mass usage of detergent powder will remain constant if a switch to alternatively built detergents is made, the daily dose of zeolite based detergent will also be

600mg/day. Since this contains 28% pure zeolite, the pure zeolite dose is 168 mg/day. However the actual zeolite material is only 78% pure (contains 22% water) so that the hydrated zeolite dose is 215 mg/day. To produce an exaggerated effect, a concentration of 400mg/day hydrated zeolite was dosed into the Experimental system.

Making the same assumptions above as for zeolite, the daily dose of HSA calcite based detergent will also be 600mg/day. Since this contains 15% HSA calcite, the calcite dose is 90 mg/day. To produce an exaggerated effect, a dosage of 200mg/day was used. i.e. a concentration in the sewage of 20 mg/l.

The zeolite and HSA calcite samples used in this investigation were obtained from the Product Development Department at Lever Brothers in Durban. They were tested for their activity and found to be within the range for acceptable detergent formulation raw material.

## 3.4 EVALUATION OF SYSTEM PARAMETERS

In order to evaluate the performance of the Experimental and Control systems during the investigation, the following parameters were measured virtually daily:

1. Influent (unfiltered) and effluent (filtered) COD concentrations.

2. Influent (unfiltered) and effluent (filtered) TKN concentrations
3. Total phosphate concentrations (as P) in influent (unfiltered), in each reactor and effluent (filtered sample).
4. Total nitrate and nitrite concentrations in each reactor and effluent (filtered sample)
5. Aerobic reactor MLTSS, MLVSS and MLISS concentrations (Mixed liquor total volatile and inorganic suspended solids).
6. Oxygen Utilisation Rate (OUR) in the aerobic reactor
7. Sludge settleability in terms of diluted sludge volume index (DSVI).
8. Filament identification
9. pH in the aerobic zone

The results of the routine monitoring on the two laboratory systems are depicted graphically in Figures 3.2 to 3.10, and listed in Appendix 2. Before these results can be discussed in detail, COD and N mass balances are performed over the system to check the reliability of the data. These COD and N mass balances are discussed in detail in section 3.5.1 below.

## 3.5 LABORATORY SYSTEM PERFORMANCE

### 3.5.1 COD and N Balances

To gauge the reliability of the experimental data, N and COD mass balances were conducted on the measured data. To do this, the routine data measured on the Control and Experimental systems were divided into steady state periods. The 289 days during which the Control and Experimental systems were operated simultaneously was initially divided into 5 steady state periods, conforming to the periods when the systems were dosed with zeolite and HSA calcite interspersed with baseline periods (cf. Table 3.2):

1. Initial baseline no supplement added to either system.
2. Zeolite dosing to Experimental system
3. Intermediate baseline, no supplement added to either system
4. HSA calcite dosed to the Experimental system
5. Final baseline no supplement added to either system.

During each of the above steady state periods, new batches of sewage were used every 10 to 14 days. If the new batch of sewage had very different characteristics (eg. influent TKN concentration) from the previous batch, the steady state period needed to be further subdivided to take account of the new sewage batches. Accordingly, each of the 5 steady state periods were subdivided into two, except the final baseline period. Hence for the COD and N mass balance evaluation, 9 steady state periods are recognised. In certain steady state periods, the influent TKN concentration of the new batch of sewage was substantially different from the previous batch, causing the nitrate and nitrite concentrations to increase or decrease over a few days of the next steady state period. In these cases, the data measured over the first few days of the steady state period were discarded for the purpose of the balance. As far as possible, the operational changes were made at the same time as a new sewage batch was commenced in order to minimise the number of steady state periods. Commencement of new sewage batches is indicated on the data graphs (Figures 3.2 to 3.11) by an * along the upper horizontal axis.

With the aid of a spreadsheet programme (Quattro-Pro), into which all the routine results were entered, the averages of the various system parameters for each steady state period were calculated. From these averages, given also in Appendix 2, the N and COD mass balances were calculated for each steady state period. The procedure for the COD and N mass balance calculation is set out in concept below. A detailed calculation and print-outs of the results are given in Appendix 3.

### 3.5.1.1 Nitrogen Balance

The N mass balance is checked by reconciling the mass of TKN entering the system with the mass of N leaving the system where the latter is given by the sum of the TKN and nitrate and nitrite in the effluent, the mass of nitrogen in the sludge wasted and the mass of nitrate and nitrite denitrified. The nitrogen content of the waste sludge ($f_n$ mgN/mgVSS) was not measured and therefore assumed to be the equal to the generally accepted value of 0.10 mgN/mgVSS).

### 3.5.1.2 COD Balance

The COD balance involves reconciling the influent COD mass ($MS_{ti}$), with the outflow COD mass where the latter is the sum of the masses of effluent COD ($MS_{te}$), COD in the wasted sludge ($MS_{ws}$), and the effective mass of oxygen consumed in COD utilisation, $MO_c$

(including oxygen recovered via denitrification). The influent COD, effluent COD and the VSS of the wasted sludge were measured daily. The COD of the wasted sludge ($MS_{ws}$) was calculated from the mass of VSS wasted daily and the COD/VSS ratio of the sludge which not measured but assumed to be equal to the generally accepted value of 1.48 mgCOD/mgVSS.

The N and COD balances achieved in the two systems for each steady state period are given in Table 3.3

**Table 3.3:** **COD and N mass balances on laboratory data**

| Batch No. | Dosage | Day No. | COD Balance | | TKN Balance | |
|---|---|---|---|---|---|---|
| | | | C | E | C | E |
| 1 | Baseline | 0 - 14 | 83.7 | 85.4 | 74.7 | 74.5 |
| 2 | Baseline | 15 - 43 | 85.8 | 83.2 | 95.1 | 94.7 |
| 3 | Zeolite | 44 - 80 | 104 | 104 | 84.3 | 86.0 |
| 4 | Zeolite | 81 - 104 | 89.8 | 90.7 | 90.2 | 90.1 |
| 5 | Baseline | 105 - 140 | 73.3 | 75.8 | 108 | 98.2 |
| 6 | Baseline | 141 - 184 | 82.7 | 84.3 | 96.3 | 88.4 |
| 7 | Calcite | 185 - 209 | 81.0 | 82.5 | 83.5 | 89.1 |
| 8 | Calcite | 210 - 244 | 87.6 | 83.4 | 97.3 | 99.1 |
| 9 | Baseline | 245 - 289 | 87.6 | 89.7 | 87.5 | 96.2 |
| Weighted average | | | 84.5 | 84.1 | 89.7 | 89.3 |

### 3.5.1.3 Discussion

Table 3.3 shows that reasonably good nitrogen mass balances were obtained on the Control and Experimental systems, with weighted averages of 89.7 and 89.3% respectively, indicating that the data pertaining to nitrogen are reasonable and the laboratory analysis can be taken to be accurate. Similar N mass balances were obtained by Clayton *et al.*, (1989), and Musvoto *et al.*, (1992), who both operated MUCT nutrient removal systems. The nitrogen content of the sludge ($f_n$) was not measured in this investigation but was assumed to be 0.10 mgN/mgVSS. If the actual value was slightly greater than this, the nitrogen balance would improve.

The COD balances are not as good as the N balances, with weighted averages of 84.5 and 84.1% respectively for the Control and Experimental systems. These are somewhat lower than the COD balance attained by Clayton *et al.*, (1989), and Musvoto *et al.*, (1992) with MUCT N&P removal systems; they obtained COD balances of 85 to 100% (weighted avg. 92.3%) and 82 to 120% (weighted avg 94%) respectively.

The COD balances are thus relatively poor compared with the COD balances of Clayton *et al.*, (1989), and Musvoto *et al.*, (1992). It is possible that some of the assumptions made in the COD balance such as the usually accepted stoichiometric constants 4.57 mgO utilised/mg N nitrified and 2.86 mg O/mg $NO_3$-N denitrified and the COD/VSS ratio of 1.48 mg COD/mg VSS were slightly different from the actual values in the investigation. It is also possible that the oxygen utilisation rate (OUR) decreased progressively over the course of the day and the measured value usually taken some 16h after the days feed commenced, thus under-representing the actual average.

### 3.5.2 Carbonaceous organic material degradation

The influent (unfiltered) and effluent (filtered) COD concentrations for both systems were monitored on a daily basis, and the results are plotted in Figure 3.2. According to the activated sludge models developed at UCT (WRC, 1984) the influent COD may be broken down into biodegradable and unbiodegradable fractions. The biodegradable fraction comprises two subfractions - a readily biodegradable soluble fraction (RBCOD) and a slowly biodegradable particulate fraction (SBCOD). The readily biodegradable fraction $f_{bs}$ was determined from the results of a cyclically fed system which was operated in the UCT laboratory for this specific purpose. This system was fed the same sewage as the two systems operated in this investigation. From the method outlined by Ekama *et al.*, (1986) and WRC, (1984), the readily biodegradable COD fraction with respect to the biodegradable COD ($f_{bs}$) was measured to be 0.23. The remaining biodegradable COD fraction ie. 0.77 is considered SBCOD.

The unbiodegradable fractions of the influent COD may also be subdivided into two subfractions ie. an unbiodegradable particulate fraction ($f_{up}$) and an unbiodegradable soluble fraction ($f_{us}$). The former ($f_{up}$) becomes enmeshed in the sludge mass, adds to the MLVSS in the reactor and is removed from the system via the daily sludge wastage. In contrast, the latter fraction ($f_{us}$) leaves the system unaltered as effluent COD. The steady state activated sludge model set out in WRC, (1984) was accepted as the basis on which to evaluate the experimental results obtained in

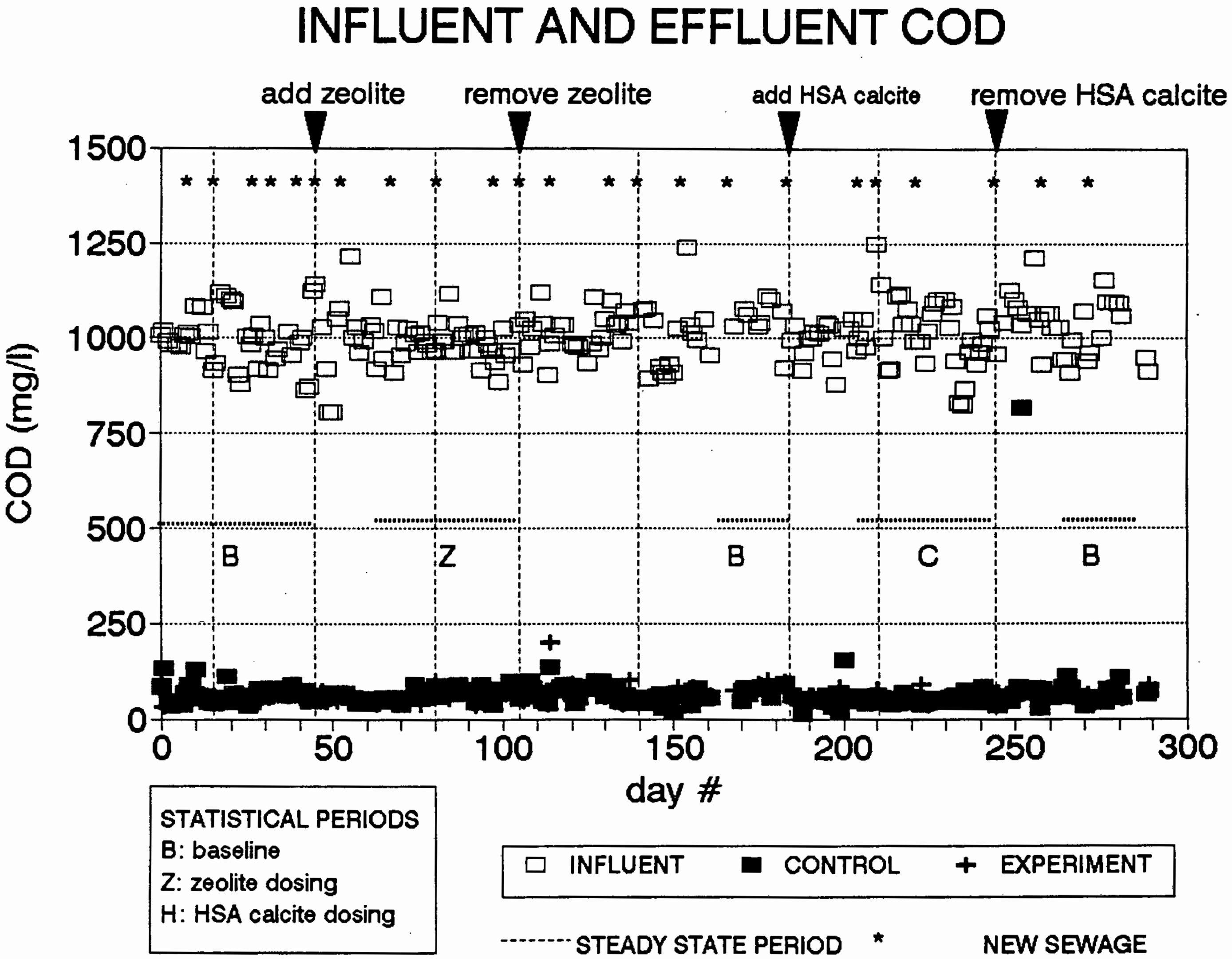
**Table 3.4: Average measured influent (unfiltered) and effluent (filtered) COD concentration (mg/l) and carbonaceous oxygen demand mass (mgO/d) in the Experimental and Control systems for each of the 9 steady state periods.**

| Batch No. | Dosage | Day No. | COD (mg/l) | | | Carbonaceous Oxygen demand (mg/d) | | Unbiodegradable Soluble COD fraction $f_{us}$ | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Filtered Effluent | | | | | |
| | | | Influent | C | E | C | E | C* | E* |
| 1 | Baseline | 0 - 14 | 1009 | 66.8 | 59.1 | 3598 | 3621 | 0.066 | 0.059 |
| 2 | Baseline | 15 - 43 | 979 | 62.2 | 59.3 | 3743 | 3668 | 0.064 | 0.061 |
| 3 | Zeolite | 44 - 80 | 998 | 57.4 | 56.1 | 5724 | 5617 | 0.058 | 0.056 |
| 4 | Zeolite | 81 - 104 | 986 | 70.2 | 66.9 | 4093 | 4150 | 0.071 | 0.068 |
| 5 | Baseline | 105 - 140 | 1013 | 71.0 | 72.9 | 2912 | 3122 | 0.070 | 0.072 |
| 6 | Baseline | 141 - 184 | 1005 | 58.8 | 66.2 | 3648 | 3773 | 0.058 | 0.066 |
| 7 | Calcite | 185 - 209 | 995 | 53.1 | 52.8 | 3833 | 3716 | 0.053 | 0.053 |
| 8 | Calcite | 210 - 244 | 1011 | 51.0 | 55.9 | 4252 | 3785 | 0.050 | 0.055 |
| 9 | Baseline | 245 - 283 | 1030 | 89.1 | 65.5 | 4309 | 4277 | 0.063 | 0.064 |
| Weighted mean | | 1 - 289 | 1005 | 64.8 | 62.1 | 3938 | 3897 | 0.059 | 0.060 |

* $f_{us}$= ratio of unfiltered effluent COD and unfiltered influent COD concentrations

COD concentrations between the two systems is noted and therefore it may be concluded that the addition of zeolite or HSA calcite

FIGURE 3.2: INFLUENT AND EFFLUENT COD CONCENTRATIONS FOR THE CONTROL AND EXPERIMENTAL SYSTEMS



does not affect the effluent COD concentrations. In section 3.6 below the absence of a significant difference between the 2 systems' filtered effluent COD is statistically verified.

The unbiodegradable soluble COD fraction of the influent ($f_{us}$) is the ratio of the filtered effluent COD and the influent total COD concentrations; this fraction for the Experimental and Control systems is also given in Table 3.4. The weighted mean values for the Experimental and Control systems are very similar ie. 0.060 and 0.059 respectively.

### 3.5.3 Volatile Suspended Solids

Both zeolite and HSA calcite are inorganic salts and as such do not contribute to the COD of the influent sewage. Thus one would not expect the dosage of either of these compounds to have any effect on the VSS concentration of the sludge since the VSS develops from the biodegradable and unbiodegradable COD of the influent sewage.

The measured VSS concentrations for the two systems are plotted in Figure 3.3 and listed in Table 3.5. The VSS mass ($MX_v$), consists of 3 components:

$MX_a$ : Active mass

$MX_e$ : Endogenous residue

$MX_i$ : Inert mass arising from the unbiodegradable particulate COD fraction ($f_{up}$) fraction of the influent sewage

### 3.5.3.1 Prediction of the Active and Endogenous Fractions

The solids fractions $MX_a$ and $MX_e$ can be predicted theoretically according to the steady state model detailed in WRC, (1984), from the mass biodegradable COD entering the system. Details of this calculation may be found in Appendix 4. The biodegradable COD is the difference between the total influent COD and the two unbiodegradable COD fractions; soluble unbiodegradable ($f_{us}$) and particulate unbiodegradable ($f_{up}$). The unbiodegradable soluble COD fraction $f_{us}$ has already been calculated in section 3.5.2 above from the COD concentration of the filtered effluent, but $f_{up}$ needs to be calculated using either the WRC, (1984) procedure or the biological excess P removal (BEPR) steady state model of Wentzel *et al.*, (1990).

### 3.5.3.2 Calculation of unbiodegradable COD fractions ($f_{up}$, $f_{us}$)

The $f_{up}$ and $f_{us}$ values for a fully aerated system or N-removal system can be calculated by the WRC, (1984) procedure, which recommends approximate average values of $f_{up}$ of 0.13 and $f_{us}$ of 0.05 for raw waste water. The kinetic model of Wentzel *et al.*, (1990) has been developed specifically for the BEPR system, and takes account of the large number of poly-P organisms. These organisms have a much lower endogenous respiration rate, and as a result contribute more to the MLVSS in the system per COD mass utilised than the ordinary heterotrophs. Therefore for a BEPR system, the kinetic model of Wentzel *et al.*, (1990) should be used rather than the WRC, (1984) procedure which does not take account of the poly-P organisms in the biomass. However other researchers investigating MUCT systems (Clayton *et al.*, 1989 and

Musvoto *et al.*, 1992) have used the WRC procedure to calculate the value of $f_{up}$. Therefore for comparison, both methods will be used to calculate $f_{up}$ for the Experimental and Control systems. Details of this calculation may be found in Appendix 4. A brief description of the two methods follows:

(i) <u>WRC Procedure</u>

In this method, the unbiodegradable particulate COD fraction and hence the theoretical volatile total solids can be estimated from steady state theory if $f_{up}$ is known and $f_{us}$ is fixed. The iterative procedure is as follows:

1. Estimate a value for $f_{up}$.
2. Calculate the $MX_a$ and $MX_e$ from the biodegradable COD mass, and the inert VSS, $MX_i$ from the estimated $f_{up}$.
3. Calculate theoretical $MX_v$ as the sum of $MX_a$, $MX_e$ and $MX_i$.
4. Compare theoretical $MX_v$ with actual measured $MX_v$; if different re-estimate $f_{up}$.
4. Iterate until the calculated $MX_v$ equals the measured $MX_v$.
5. Once $f_{up}$ and $f_{us}$ are established, the heterotrophic active mass fraction is calculated as follows:

$$MX_a = (1-f_{us}-f_{up})MS_{ti}Y_hR_s/(1+b_hR_s)$$

and the active fraction

$$f_{av} = MX_a/MX_v$$

(ii) <u>Kinetic Model of Wentzel *et al.*, (1990)</u>

The kinetic model procedure is as follows:

1. Estimate a value for $f_{up}$.
2. From a steady state equation for the conversion of RBCOD to short chain fatty acids and a mass balance over the anaerobic zone, calculate the RBCOD sequestered by the poly-P organisms.
3. Calculate the mass of poly-P organisms and associated endogenous residue in the system from the mass RBCOD sequestered in the anaerobic zone.
4. Remaining biodegradable COD is utilised to generate normal heterotrophic mass.
5. Calculate the active mass $MX_a$ and endogenous residue mass $MX_e$ accumulated from the normal heterotrophic masses.
6. Calculate the inert VSS ($MX_i$) from the estimated $f_{up}$.
7. Calculate the $MX_v$ as the sum of the 5 VSS components ie. poly-P and normal heterotrophic active, endogenous and inert mass $MX_i$.
8. Compare $MX_v$ calculated in steps 3 to 7 with the measured $MX_v$; if different re-estimate $f_{up}$.
6. Iterate until calculated $MX_v$ equals the measured $MX_v$.
7. The active fraction with respect to the total VSS is given by $f_{av} = MX_a/MX_v$.

Table 3.5 shows the actual $MX_v$, unbiodegradable soluble COD fraction, $f_{us}$, and the two values of $f_{up}$ obtained by the WRC and BEPR steady state models:

Since both zeolite and HSA calcite are inorganic solids, their presence is not expected to have any effect on the $f_{up}$ value, which is a measure of the unbiodegradable organic solids in the

FIGURE 3.3: VOLATILE SUSPENDED SOLIDS CONCENTRATIONS IN THE CONTROL AND EXPERIMENTAL SYSTEMS

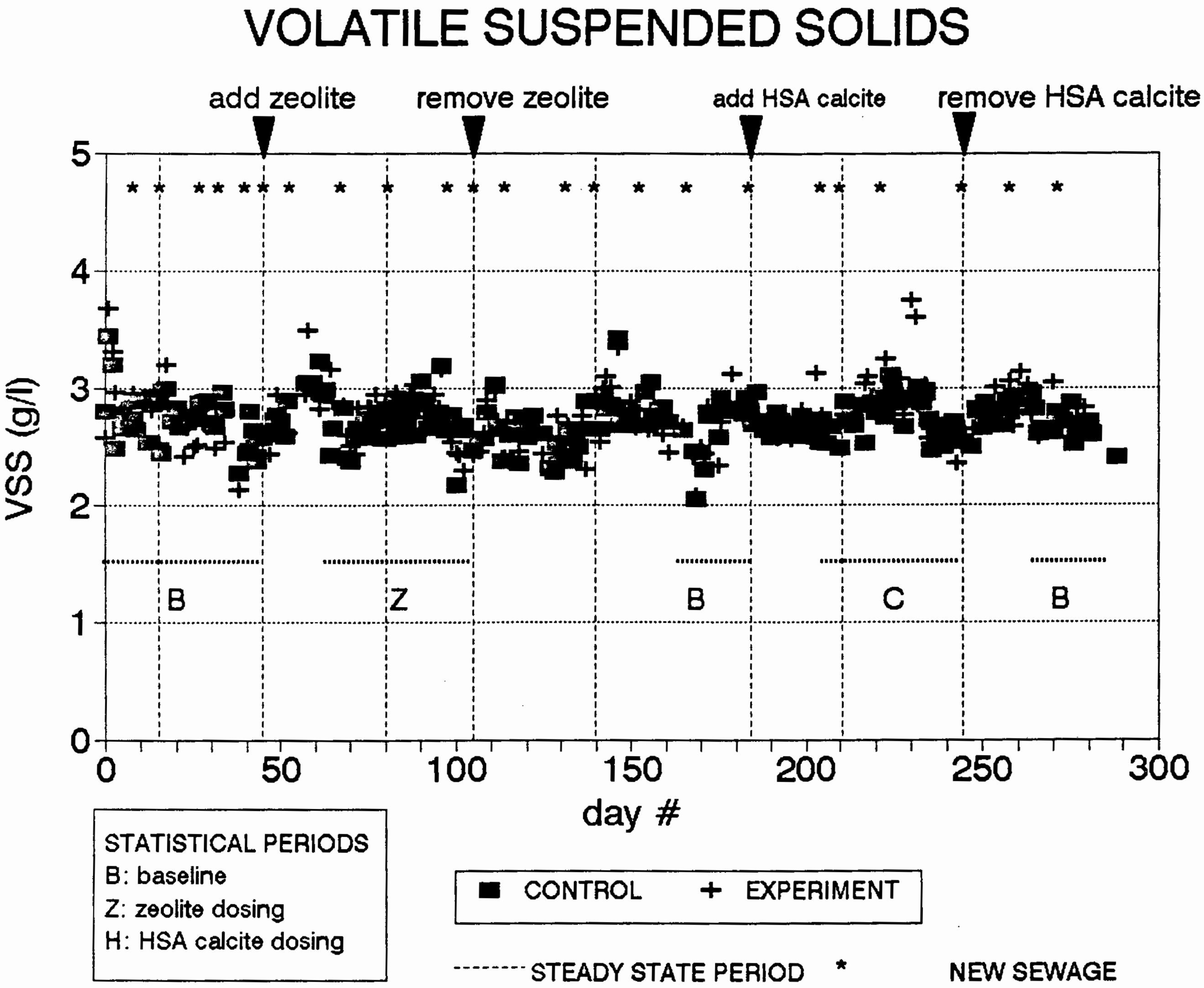


**Table 3.5**: **Volatile suspended solids, $f_{us}$ and $f_{up}$ for each steady state period**

| Batch No. | Dosage | Day No. | MXv g/l | | fup (WRC Method) | | fup (Wentzel Method) | |
|---|---|---|---|---|---|---|---|---|
| | | | C | E | C | E | C | E |
| 1 | Baseline | 0 - 14 | 2.827 | 2.978 | 0.263 | 0.291 | 0.222 | 0.252 |
| 2 | Baseline | 15 - 43 | 2.723 | 2.623 | 0.259 | 0.239 | 0.230 | 0.210 |
| 3 | Zeolite | 44 - 80 | 2.725 | 2.800 | 0.248 | 0.262 | 0.214 | 0.229 |
| 4 | Zeolite | 81 - 104 | 2.741 | 2.782 | 0.261 | 0.269 | 0.227 | 0.231 |
| 5 | Baseline | 105 - 140 | 2.574 | 2.591 | 0.215 | 0.218 | 0.166 | 0.169 |
| 6 | Baseline | 141 - 184 | 2.753 | 2.728 | 0.251 | 0.246 | 0.197 | 0.191 |
| 7 | Calcite | 185 - 209 | 2.716 | 2.664 | 0.236 | 0.246 | 0.186 | 0.197 |
| 8 | Calcite | 210 - 244 | 2.875 | 2.773 | 0.249 | 0.268 | 0.197 | 0.217 |
| 9 | Baseline | 245 - 289 | 2.769 | 2.726 | 0.234 | 0.242 | 0.161 | 0.170 |
| Weighted average | | 1 - 289 | 2.719 | 2.754 | 0.237 | 0.243 | 0.191 | 0.197 |
| Standard deviation | | 1 - 289 | | | 0.015 | 0.020 | 0.024 | 0.026 |

sewage feed. Any difference shown between the Control and Experimental systems would therefore be either random variation in the measurement of VSS or a consequence of different sewage batches. Each new batch of sewage will have a slightly different concentration of particulate unbiodegradable COD, and hence a small variation in the resulting $f_{up}$ values can be expected. Because both the Experimental and Control systems received the same sewage batches, this variation in $f_{up}$ values arising from the sewage batches should be reflected in the Control and Experimental systems concomitantly.

The data in Table 3.5 shows that the $f_{up}$ value obtained from the WRC model is generally about 20% lower than the BEPR model ie. ± 0.25 and 0.20 respectively. Also, irrespective of the model, the data should show a random variability in the $f_{up}$ values varying approximately in phase between the Control and Experimental systems. For the WRC model, the values varied between 0.234 and 0.263 and 0.218 and 0.291 in the Control and Experimental systems respectively. Similar variations are apparent with the BEPR model but with values about 20% lower. During the zeolite and HSA calcite dosing periods, the greatest difference in $f_{up}$ between the Control and Experimental systems is 0.011 mg/l. This difference is substantially lower than the sample standard deviations of 0.025 and 0.027 mg/l for the Control and Experimental systems respectively. Therefore it can be concluded that there is no significant difference in $f_{up}$ value between the Control and Experimental systems; in Appendix 4, the absence of a statistical difference in $f_{up}$ between the 2 systems is statistically verified. This result is expected because with zeolite and HSA calcite being inorganic compounds, there should be no difference in the organic content (VSS) of the sludge.

Musvoto *et al.*, (1992), running an MUCT system with 65% anoxic mass fraction, calculated $f_{up}$ to vary between 0.21 and 0.40 (average 0.321) for the WRC, (1984) model and between 0.18 and 0.42 (average 0.325) for the BEPR model. Clayton *et al.*, (1989), also running an MUCT system with 35% anoxic mass fraction, calculated an average value of $f_{up}$ of 0.20. The value of $f_{up}$ recommended by WRC, (1984) for raw municipal sewage is 0.13. Musvoto *et al.*, (1992) concluded that the most likely feature causing the higher than expected $f_{up}$ valued was the anoxic mass fraction, with the $f_{up}$ value increasing as the anoxic sludge mass fraction increases. The anoxic sludge mass fraction in this thesis is 50%; midway between the anoxic sludge mass fractions used by Musvoto and Clayton. The average $f_{up}$ value for this thesis is 0.24, which lies between the $f_{up}$ values of 0.20 and 0.321 obtained by Clayton *et al.*, (1989) and Musvoto *et al.*, (1992) respectively. This is in accordance with the above conclusion of Musvoto (ie. $f_{up}$ value increases as the anoxic sludge mass fraction increases).

Musvoto *et al.*, (1992) also found $f_{up}$ to correlate with DSVI, but in this investigation a correlation with DSVI could not be confirmed statistically (cf. section 3.5.9 and section 3.5.7.4). In the experiments of Musvoto *et al.*, (1992), the high DSVI resulted from high nitrate and nitrite concentrations in the second anoxic zone. In this thesis, however it was specifically required that any difference in DSVI should arise from the presence of zeolite or HSA calcite in the system, and not be affected by nitrate or nitrite concentrations in the second anoxic zone. Thus the a-recycle ratio of both the Control and Experimental systems were controlled in such a way as to produce complete denitrfication in the second anoxic zone. Since denitrification was complete, the concentrations of nitrite and nitrate were generally low, thus having negligible influence on DSVI.

### 3.5.4 Total and Inorganic Suspended Solids

The measured TSS concentrations for the two systems are plotted in Figure 3.4. The TSS consists of the VSS plus the inorganic suspended solids (ISS) and the ISS concentrations for Control and Experimental systems are shown in Figure 3.5. Because zeolite is inorganic and insoluble, it is expected that when zeolite was dosed to the Experimental system, the inorganic suspended solids concentration would increase by the same amount as the mass zeolite dosed to the system: ie.

Daily zeolite dose = 400mg/d (78% pure, remainder water)
Daily inorganic solids dose = 0.78*400 = 310mg/day
Sludge wastage per day = 1 litre
At steady state, when the zeolite dosed equals the zeolite wasted, the increase in inorganic solids in the sludge is 310 (mg/d)/(l/d)
∴ Predicted increase in ISS = 310 mg/l

With regard to the HSA calcite dosing, the HSA calcite is also an inorganic solid, but it is partially soluble in water. The insoluble portion contributes to the ISS concentration of the sludge. Thus an increase in the ISS concentration is expected, but by a smaller amount than the mass dosed. If all the HSA calcite were insoluble, the expected ISS mass increase in the

FIGURE 3.4: TOTAL SUSPENDED SOLIDS CONCENTRATION IN THE CONTROL AND EXPERIMENTAL SYSTEMS

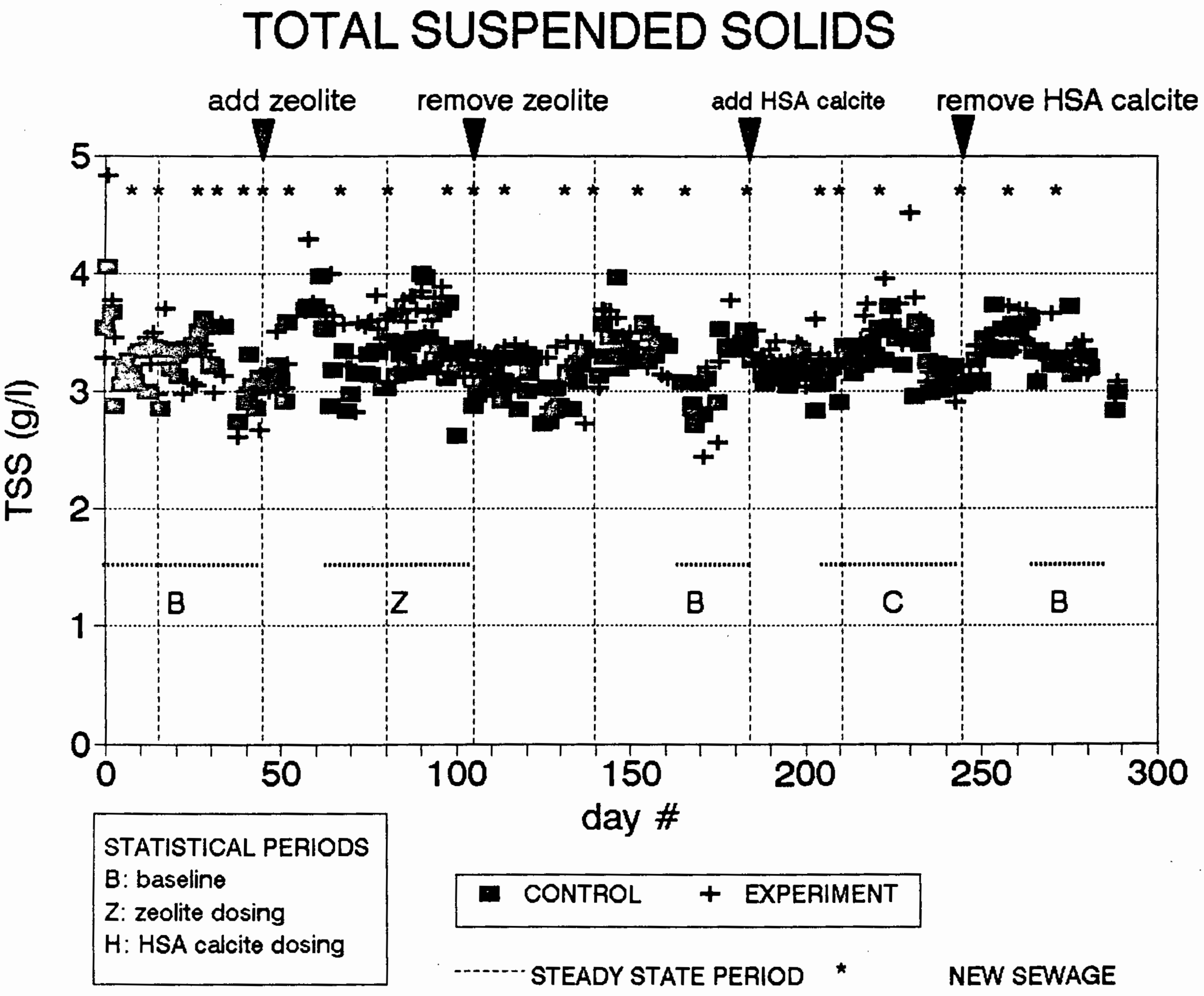
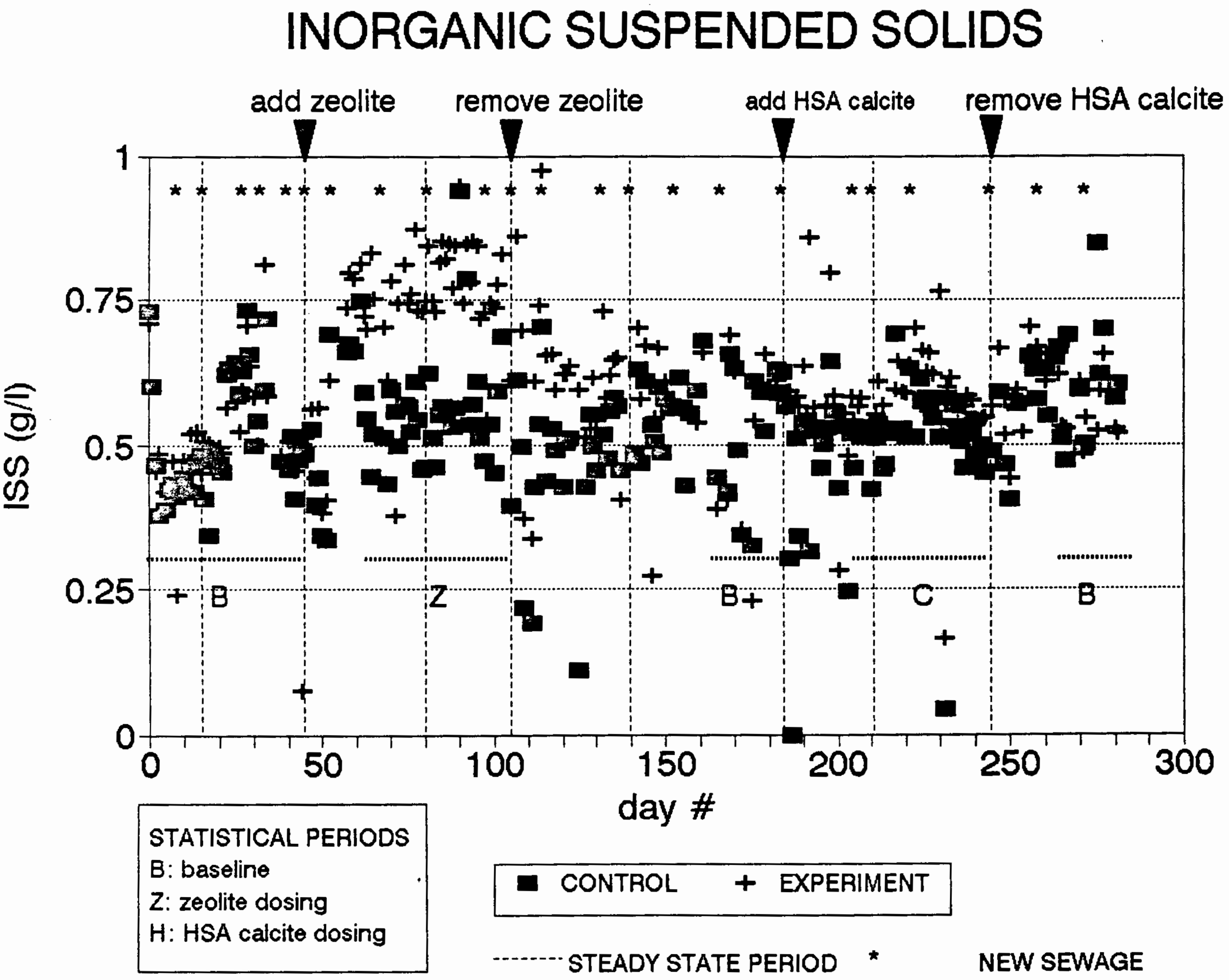


FIGURE 3.5: INORGANIC SUSPENDED SOLIDS CONCENTRATION IN THE CONTROL AND EXPERIMENTAL SYSTEMS



sludge resulting from the 200 mg/d dose can be calculated in the same way as for zeolite ie 200mg/l.

Table 3.6 shows the measured ISS concentrations in the Experimental and Control systems during the baseline and Zeolite and HSA calcite dosing periods, and compares them with the expected increase resulting from the dosing.

**Table 3.6: Increase in ISS shown by the Experimental system when dosed with zeolite and HSA calcite.**

| Data Period | Mass ISS Control system | Mass ISS Experiment system | Actual ISS Increase | Predicted ISS increase |
|---|---|---|---|---|
| Initial Baseline | 504 | 533 | +26 | 0 |
| Zeolite Dosing | 583 | 763 | +180 | 310 |
| Baseline | 530 | 526 | -4 | 0 |
| HSA calcite dosing | 598 | 578 | +65 | 200 |
| Final Baseline | 598 | 577 | -21 | 0 |

i. Baseline Periods

In each of the 3 baseline periods, the difference in ISS is virtually zero, which is expected in the absence of dosing to the Experimental system.

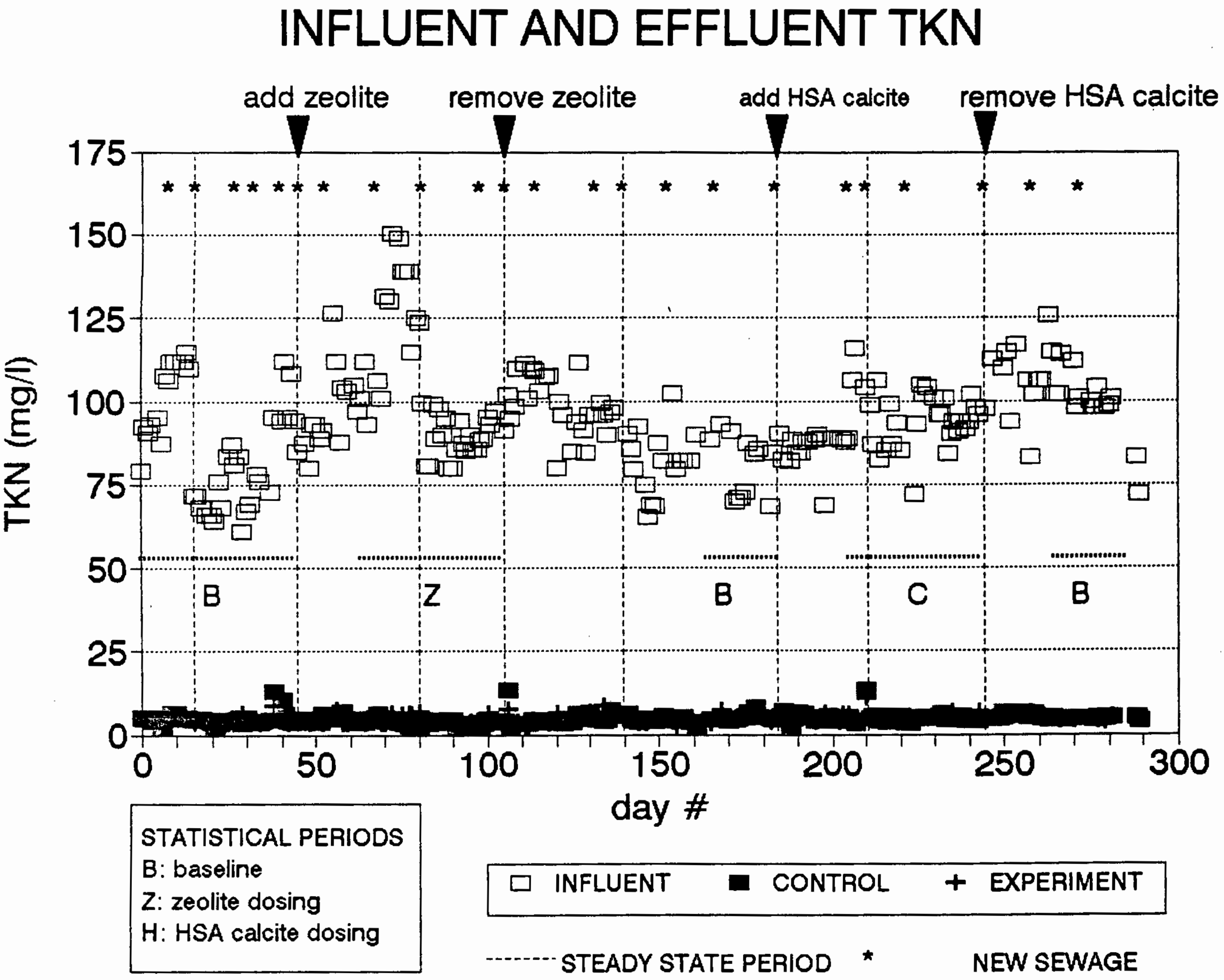
ii. Zeolite Dosing

On the basis that zeolite is insoluble and inorganic, the inorganic mass concentration in the sludge should have increased by 310 mg/l. However the measured ISS increase is only 180 mg/l leaving 130 mg/l (42%) unaccounted for. The ISS (and TSS and VSS) is measured by drying, after centrifugation, a known volume of mixed liquor at 105°C, in a crucible of known mass and then incinerating the dried mass at 600°C, measuring the mass before and after incineration. The remaining ash is taken to be inorganic (ISS), which theoretically includes the zeolite. It was suspected that the zeolite may decompose at 600°C, thus accounting for the apparent mass loss. To check this, a thermogravimetric analysis (TGA) test, was done to observe mass loss of zeolite from 30 to 700°C. The TGA test measures mass loss of a sample at progressively increasing temperature (cf. Figure A8.1, Appendix 8). A mass loss of only 22% was noted and being hydrated zeolite, this accounts only for the water loss. The results of the TGA test are included in Appendix 8. No further reason could be established for the lower than expected ISS concentration in the Experimental system. This low ISS concentration is shown in Table 3.6.

### iii. <u>HSA Calcite Dosing</u>

HSA calcite consists of very small particles of $CaCO_3$, and a portion of this can be expected to dissolve in the sludge if the sludge liquor is under-saturated with respect to calcium. The saturation of calcium carbonate is estimated in Appendix 9. The result of the calculation is that 10-20mg/l influent of the 20mg/l influent HSA calcite dosed can potentially dissolve in the sludge liquor. Further, when the remaining HSA calcite was placed in the 600°C oven, it decomposed to calcium oxide and carbon

FIGURE 3.6: INFLUENT AND EFFLUENT TKN CONCENTRATIONS FOR THE CONTROL AND EXPERIMENTAL SYSTEMS



dioxide gas (50% mass loss). This decomposition was also confirmed by a thermo-gravimetric analysis (TGA) test, included in Appendix 8, Figure A8.2. Since the increase in ISS was only 65mg/l, while the daily dose was 200mg, one can conclude that the remaining 135 mg (ie 62.5%) either dissolved in the sludge or if it did not dissolve, decomposed in the 600°C oven. Hence it is reasonable that only 33% of the HSA calcite was recovered.

### 3.5.5 Nitrification

In the same way as the filtered effluent COD represents the soluble unbiodegradable portion of the influent COD, so also when nitrification is not inhibited and complete (ie. <0.1mg$NH_4$-N/l effluent concentrations which was checked on occasion and found to be the case throughout the investigation), the filtered effluent TKN concentration represents the soluble unbiodegradable organic nitrogen in the influent sewage. Because the Control and Experimental systems were fed the same sewage batches, there should be little difference in the effluent TKN concentration from the two systems. Consequently if there is a difference between the two systems, it can be attributable to the presence of zeolite or HSA calcite dosing to the Experimental system. As for the soluble effluent COD, random variation in effluent soluble TKN concentration is expected as the characteristics of each new batch of sewage varied; but as before, the variation should be small and in the Control and Experimental systems the variation should be in phase.

The daily effluent TKN concentrations for each system are plotted in Figure 3.6, and the averages for each of the nine steady state periods are listed in Table 3.7. In Table 3.7, the nitrification capacity and oxygen demand obtained from the N mass balance is also given. The % difference column in Table 3.7 is the difference in nitrification capacity of the Experimental system with respect to the Control system.

From Table 3.7 or Figure 3.6, it can be seen that the filtered effluent TKN concentration of the Control and Experimental systems vary not only very closely between 3.5 and 5.0 mg/l, with weighted averages of 4.62 and 4.56 mg/l for the Control and Experimental systems respectively, but also in phase. The low effluent TKN concentrations indicate that a large portion of the biodegradable organic nitrogen was ammonified to ammonium in the aerobic zone and the ammonium so formed utilised either for cell synthesis or nitrified to nitrate. The low TKN concentrations were attained by controlling the dissolved oxygen concentrations between 2 and 3 mg/l in the aerobic reactor throughout the investigation. This ensured that nitrification was not inhibited by low DO concentrations. Because the filtered effluent TKN concentration was consistently low throughout the baseline and dosing periods, it appears that nitrification was complete and no toxic substances were apparently fed to the systems via the influent sewage. The addition of zeolite and HSA calcite to the Experimental system had no inhibitory effect on nitrification. No significant statistical difference was found between the filtered effluent TKN concentrations of the Control and

**Table 3.7:** **Average measured influent (unfiltered) and effluent (filtered) TKN concentration, nitrification capacity and oxygen demand for nitrification of the Control and Experimental systems for each of the 9 steady state periods.**

| Steady state period | Dosage | Day No. | Infl. TKN mg/d | Effluent TKN mg/d | | Nitrification capacity (mgNO3-N/d) | | Oxygen demand for nitrification | | % diff cf. control |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | C | E | C | E | C | | E |
| 1 | Baseline | 0 - 14 | 103 | 4.9 | 4.8 | 436 | 448 | 1993 | 2047 | +2.7 |
| 2 | Baseline | 15 - 43 | 79 | 4.8 | 4.3 | 430 | 430 | 1965 | 1965 | 0 |
| 3 | Zeolite | 44 - 80 | 110 | 4.3 | 4.3 | 613 | 628 | 2801 | 2870 | +2.5 |
| 4 | Zeolite | 81 - 104 | 89 | 3.5 | 3.7 | 498 | 486 | 2276 | 2221 | -2.4 |
| 5 | Baseline | 105 - 140 | 99 | 4.6 | 4.6 | 763 | 646 | 3487 | 2952 | -15.3 |
| 6 | Baseline | 141 - 184 | 81 | 4.8 | 4.4 | 460 | 403 | 2102 | 1842 | -12.4 |
| 7 | Calcite | 185 - 209 | 89 | 4.8 | 5.0 | 429 | 471 | 1961 | 2152 | +9.7 |
| 8 | Calcite | 210 - 244 | 94 | 5.0 | 5.0 | 589 | 595 | 2692 | 2719 | +1.0 |
| 9 | Baseline | 245 - 283 | 103 | 5.0 | 4.9 | 574 | 661 | 2623 | 3021 | +15.1 |
| Weighted average | | | 94.2 | 4.6 | 4.6 | 531 | 525 | 2426 | 2399 | -1.1 |

Experimental systems (cf. section 3.5.3.5) and because the 2 systems also vary simultaneously with time, one can conclude that the dosing of neither zeolite nor HSA calcite effects nitrification.

The unbiodegradable soluble organic nitrogen fraction, $f_{nu}$ of the influent TKN is approximately given by the ratio of the filtered effluent TKN and influent TKN concentrations. For the Experimental and Control systems, the values obtained are identical ie. the weighted average values are 0.05 for both systems, which is slightly higher than the recommended value for design ie. 0.03 (WRC, 1984).

The nitrification capacity, $MN_c$ is the total mass per day of nitrate and nitrite (ie $NO_3^- + NO_2^- = NO_x$) generated by nitrification and is calculated via the nitrogen balance as the sum of the effluent $NO_x$ mass per day and the nitrogen mass denitrified per day (cf. section 3.6.1). Nitrification capacity is governed more by the influent TKN concentration than the effluent TKN concentration because in the investigation nitrification to nitrate was always complete. The mass of oxygen required for nitrification ($MO_n$) is obtained by multiplying the nitrification capacity by the stoichiometric coefficient 4.57mgO/mg$NO_3$-N generated (cf. N mass balance section 3.5.1.1). The nitrification capacity (mass per day) and the oxygen required for nitrification (mass O/day) for the 9 steady state periods are also listed in Table 3.7. The values for the Control and Experimental systems are paired close together indicating similar behaviour. During steady state periods 5 and 6, however, there is a difference between the nitrification capacities of the Control and Experimental systems. Since this did not occur during dosing of either zeolite or HSA calcite, this difference can not be attributed to the presence of either zeolite or HSA calcite. The difference is a result of a low N mass balance during these periods (cf. section 3.5.1, Table 3.3).

## 3.5.6 Denitrification

### 3.5.6.1. Denitrification rates

The denitrification kinetics in nitrification-denitrification (ND) systems as set out by van Haandel *et al.*, (1981) have previously been accepted for describing nitrification-denitrification in nitrogen and phosphorus removal (NDBEPR) systems as well (WRC, 1984). However the work by Clayton *et al.*, (1989) and Musvoto *et al.*, (1992) have shown that there is, in fact a difference in the denitrification kinetics of nitrogen removal systems and in NDBEPR systems. For ND systems, there is in the primary anoxic reactor an initial rapid denitrification rate, $K_1$ (associated with the utilisation of readily biodegradable COD, RBCOD), followed by a second slower rate, $K_2$ (associated with the utilisation of adsorbed slowly biodegradable COD from the influent and self generated through organisms death and lysis, SBCOD). In the second anoxic reactor, there is a third, slower rate of denitrification $K_3$ associated with the utilisation of self generated adsorbed SBCOD. In the both the primary and the secondary anoxic reactors of the NDBEPR systems, the initial rapid rate $K_1$ is absent and the second rate is considerably faster (by at least 2 times) than the $K_2$ as observed in the ND removal systems.

Clayton *et al.*, (1989) measured the denitrification behaviour in the primary anoxic zone of the MUCT system and found the average nitrate denitrification rate to be 0.224 mgN/(mgAVSS.d). Musvoto *et al.*, (1992) measured the denitrification rate in the primary anoxic reactor of the MUCT system in batch tests and found the rate to vary between 0.202 and 0.441 mg$NO_3$-N/(mgAVSS.d) with an average of 0.296 for nitrate and between 0.162 and 0.276 mg$NO_2$-N/(mgAVSS.d) with an average value of 0.247 for nitrite.

### 3.5.6.2 Incomplete denitrification and sludge bulking

As the nitrate denitrifies in the anoxic reactor, nitrite is generated at a rate approximately $^1/_5$ of the nitrate denitrification rate. The nitrite begins to denitrify only after all the nitrate has been denitrified (Musvoto *et al.*, 1992). If denitrification in the second anoxic reactor of the MUCT primary anoxic zone is not complete, the effluent from this reactor may contain high concentrations of nitrate and nitrite. On entering the aerobic zone, the nitrite and other intermediates in the denitrification pathway to $N_2$ gas, in particular NO, have an inhibitory effect on the oxygen utilisation of the floc forming organisms. This inhibitory effect is absent in the AA (anoxic-aerobic or low F/M) filamentous organisms because, unlike the floc-formers these organisms (it is hypothesised, Casey *et al.*, 1992) denitrify nitrate only as far as nitrite in the anoxic zone and therefore do not accumulate the denitrification intermediates. The filamentous organisms therefore are not inhibited in their oxygen uptake upon entering the aerobic reactor and therefore dominate the biosis and the sludge shows signs of bulking.

To prevent AA (low F/M) filament bulking caused by incomplete denitrification, the second anoxic reactor should always be underloaded with respect to nitrate, ie. the reactor always should be loaded with less nitrate than its denitrification capacity. One of the aims of this experiment was to establish any possible effect of the presence of zeolite and HSA calcite on sludge bulking. It was important, therefore to eliminate as far as possible the effect of incomplete denitrification on sludge bulking as this might mask the effect of zeolite or HSA calcite on sludge bulking and hence sludge settleability. For this reason, the second anoxic reactor was specifically sized large at 32.5% of the total sludge mass. Thus the second anoxic reactor, together with a low mixed liquor a-recycle ratio provided sufficient denitrification potential to ensure that denitrification was generally complete in the second anoxic reactor. At the same time, sufficiently low underflow nitrate concentration was ensured to avoid nitrate interference with biological excess P removal, even at relatively high influent TKN concentrations.

### 3.5.6.3 Apparent nitrate denitrification rate

The second anoxic reactor was generally underloaded with respect to nitrate, (except for a few days during steady state period 3 when the influent TKN/COD ratio was high ie. 0.13 mgN/mgCOD). Therefore, the apparent nitrate denitrification rate, calculated from the mass $NO_3$-N denitrified per day, always would be less than the actual nitrate denitrification rate comparable to that measured by Clayton *et al.*, (1989) and Musvoto *et al.*, (1992). In spite of this, apparent nitrate denitrification rates were nevertheless calculated from the mass of nitrate denitrified to compare with the actual denitrification rates measured from batch tests by Clayton *et al.*, (1989) Musvoto *et al.*, (1992). These rates are expressed in terms of mass nitrate denitrified per day per mass active VSS. The active mass refers to the active mass in the specific anoxic reactor in question; thus to calculate this active mass, the active mass in the system should be multiplied by the mass fraction of the anoxic reactor volume. The active mass in the system can be calculated in one of two ways:

1. With the kinetic model of Wentzel *et al.*, (1990) which takes into account the presence of the poly-P organisms and their inability to denitrify. (cf. section 3.5.3.2(ii)). The denitrification constants listed in Table 3.8 were calculated with this method.
2. With the WRC, (1984) method which ignores the presence of the poly-P organisms (cf. section 3.5.3.2 (i)). The active mass is calculated from the difference between the measured volatile mass and the sum of the inert and the endogenous masses (calculated from steady state theory in WRC, (1984).

Knowing the active fraction of the VSS, $f_{av}$, (cf. section 3.5.3.2 (ii)), the apparent denitrification rate = Mass N denitrified (mg/d) / $f_{av}.X_v.V_{anoxic}$ (mg-N/mgAVSS) was calculated.

The apparent denitrification rates calculated by assuming that only normal heterotrophic organisms can denitrify are given in Table 3.8 below.

**Table 3.8:** **Apparent denitrification rates, assuming poly-P organisms do not denitrify**

| Batch No. | Nitrate Denitrification Rate (mgN/-mgAVSS.d $*10^{-3}$) | | | | Nitrite Denitrification Rate (mgN-/mgAVSS.d $*10^{-3}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1st Anoxic | | 2nd Anoxic | | 1st Anoxic | | 2nd Anoxic | |
| | C | E | C | E | C | E | C | E |
| 1 B | 66.9 | 80.6 | 62.5 | 80.1 | 2 | 1 | -0.2 | 0.4 |
| 2 B | 51.2 | 41.8 | 28.1 | 24 | 23.8 | 25.5 | 25 | 21 |
| 3 Z | 101 | 109.1 | 61.3 | 70.3 | 16.0 | 17.2 | -0.2 | 0.3 |
| 4 Z | 95.6 | 96.8 | 28.3 | 28.8 | 3.6 | 2.6 | 25.2 | 25.1 |
| 5 B | 108.2 | 104.6 | 82.9 | 59.5 | 1.4 | 5.0 | 12.0 | 7.5 |
| 6 B | 68.5 | 53.9 | 93.7 | 73.5 | 3.1 | 4.9 | 3.9 | 2.3 |
| 7 C | 60.8 | 63.8 | 72.9 | 67.2 | 3.3 | 2.6 | 0.6 | 1.9 |
| 8 C | 81.3 | 80.9 | 91.5 | 96.0 | 3.8 | 3.9 | -2.4 | 0.6 |
| 9 B | 87.2 | 95.5 | 93.7 | 102.7 | 6.7 | 6.4 | -1.9 | -2.2 |

#### 3.5.6.4 Denitrification and Generation of Nitrite

Musvoto *et al.*, (1992) concluded from their research that nitrite only begins to be denitrified once all the nitrate has been denitrified. For this reason, a meaningful nitrite denitrification rate cannot be obtained for the second anoxic reactor of the MUCT system. However the nitrite measure is useful because if there is a net generation of nitrite in the reactor, one can conclude that denitrification of nitrate to nitrogen gas is not complete and sludge bulking may be a consequence of this incomplete denitrification. If the nitrite concentration leaving the reactor is below detectable levels, one can conclude that denitrification of nitrate is complete and sludge bulking should either be absent or if present, cannot be attributable to incomplete denitrification, but instead attributable to the presence of zeolite or HSA calcite in the Experimental system.

From the Table, nitrite generation occurs in the Control system in steady state periods 1 and 3. This indicates incomplete denitrification in the second anoxic reactor and this may have resulted in consequent sludge bulking. In steady state period 8, nitrite is also generated in the second anoxic reactor of the Control system and this may have resulted in a slight rise in the DSVI of the Control system on day 230 (cf. Figure 3.7). During the final baseline period, both Control and Experimental systems showed nitrite generation in the second anoxic reactor.

### 3.5.7 DSVI and Anoxic-Aerobic filament bulking

It is has been found (Gabb *et al.*, 1989), that a completely aerated activated sludge system does not exhibit anoxic-aerobic (AA) filament bulking. One of the major problems in operating MUCT systems, however, is the tendency of AA filaments in the sludge to dominate over the floc formers, leading to sludge bulking. Consequently it is important to investigate the impact of zeolite and HSA calcite on the settling behaviour of the activated sludge.

In this investigation, the system DSVI was measured on a daily basis and filament identifications were done about once every 4-5 weeks. The DSVI for the Control and Experimental systems is plotted in Figure 3.7. The average DSVI for each dosing period together with the filament identifications are also shown in Table 3.9.

### 3.5.7.1 Identification of Filamentous organisms

From Table 3.9, it can be seen that the filamentous population did not vary much with respect to the various types identified ie. throughout the investigation in both systems, 0092 was dominant, and other AA filaments such as 0675, 0041 and M.parvicella secondary. Filaments H.Hydrossis, 021N, 0803, thiothrix, 1851 were identifiable and sporadically observed. This approximate similarity in filament population in the Experimental and Control systems indicated that the changes in DSVI of the two systems were probably more affected by changes in numbers of filaments present than by changes in types of filaments.

FIGURE 3.7: DSVI IN THE CONTROL AND EXPERIMENTAL SYSTEMS

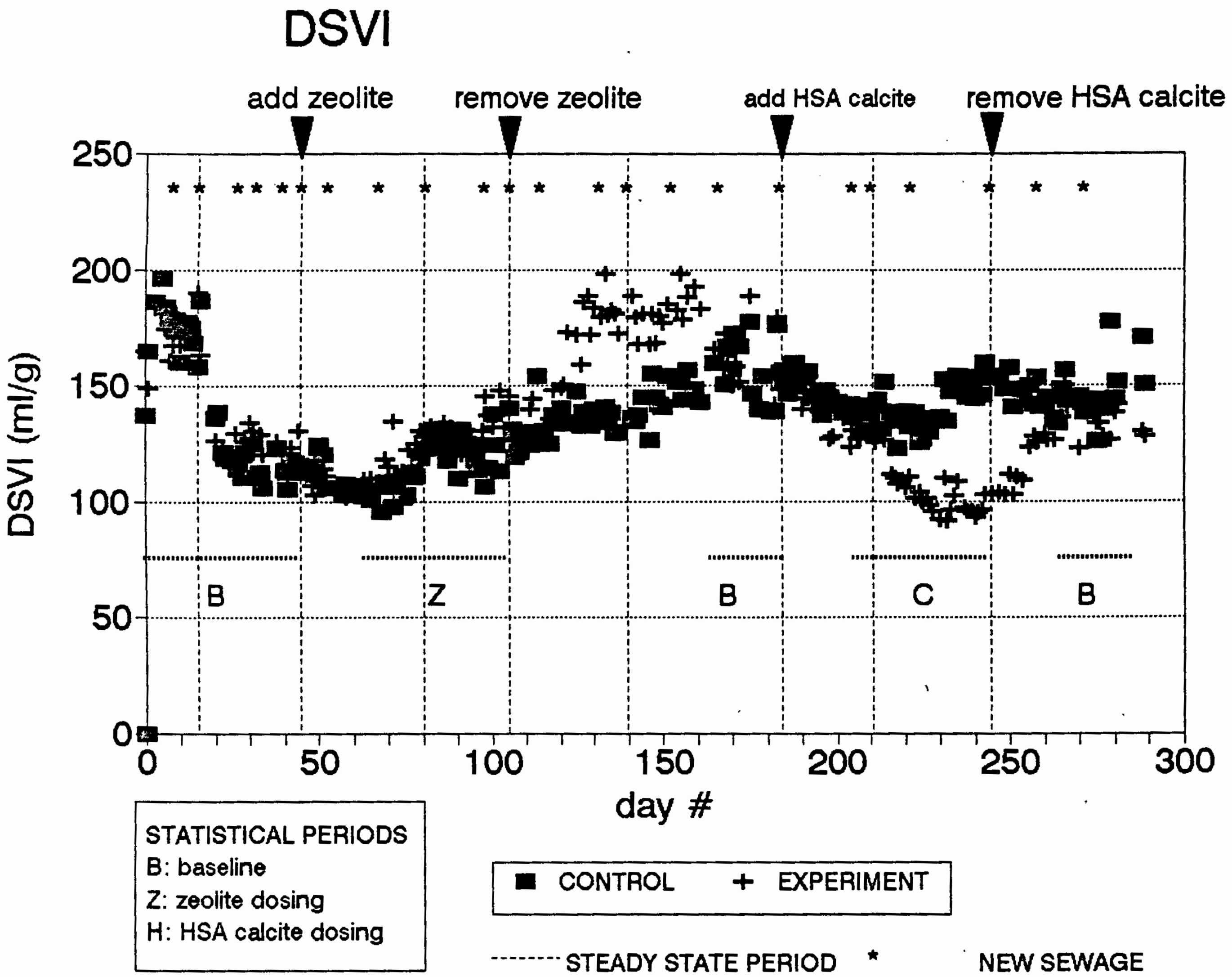


**Table 3.9 DSVI and Filament identification for each steady state period**

| Batch No. | Dosage | DSVI (ml/g) | | Filament Identification (in order of prevalence) and relative amount | |
|---|---|---|---|---|---|
| | | C | E | C | E |
| 1 | Baseline | 176.1 | 171.4 | 0092; 021N; M.parvicella; 1851; 0041.<br>Very common to abundant | 0092; 021N; H.hydrossis; 0041; 1851<br>Very common to abundant |
| 2 | Baseline | 124.3 | 128.8 | | |
| 3 | Zeolite | 108.8 | 114.0 | 0092; 0675; 0041; 021N; H.hydrossis; 0803<br>Very common | 0092; 0675; H.hydrossis; 0041; 021N<br>Very common |
| 4 | Zeolite | 122.3 | 130.7 | | |
| 5 | Baseline | 133.7 | 157.8 | 0092; 021N; 0675; Beggiatoa sp; Thiothrix sp; M.parvicella; 0961<br>Very common to abundant | 0092; 0675; Thiothrix sp; 021N; 0041; M.parvicella<br>Very common |
| 6 | Baseline | 150.2 | 169.4 | | |
| 7 | Calcite | 145.5 | 139.5 | 0092; 021N; M.parvicella; 0041; 0675<br>Very common | 0092; 021N; M.parvicella; H.hydrossis; 0041<br>Common to very common |
| 8 | Calcite | 139.7 | 106.5 | 0092; Beggiatoa; 021N;<br>M.parvicella; 1701<br>Very common | 0092; 021N; 0803; M.parvicella; H.hydrossis; Very common |
| 9 | Baseline | 147.4 | 125.9 | 0092; 0041; 0803; H.hydrossis; M.parvicella<br>Very common | 0092; 0803; 0041; M.parvicella<br>Very common |

### 3.5.7.2 Observations of DSVI trends

From the plot of DSVI in Figure 3.7 and from Table 3.9, the following is observed.

1. The sludge originally taken from Mitchell's Plain wastewater treatment plant was an AA filament bulking sludge; the DSVI dropped from nearly 200ml/g to 100ml/g in the first 44 days (ie. initial baseline period).
2. From day 44 to 104 (ie. zeolite dosing period), the DSVI in both systems increased from 100ml/g to 140 ml/g, with the experimental DSVI slightly higher than the Control, but there was no clear distinction between the DSVI of the two systems.
3. After the zeolite dosing period, the DSVI in the Experimental system increased further to 200ml/g, while the Control system DSVI only increased from 140 to 150ml/g. Dosing of HSA calcite could not commence until the DSVI of the Experimental system had decreased to that of the Control system. This happened on day 164, when the DSVI in both systems was around 160 ml/g.
4. During the intermediate baseline period, (day 164 to 184), both the Control and Experimental systems showed similar DSVI at around 150 ml/g.

5 HSA calcite was dosed to the Experimental system from day 185, and the Experimental system immediately showed a sharp decline from ±135ml/g to ±95ml/g on day 228 and remained steady at 95ml/g, until HSA calcite dosing was terminated on day 244.

6. After termination of HSA calcite dosing to the Experimental system, the DSVI of the Experimental system increased steadily to ±135ml/g.

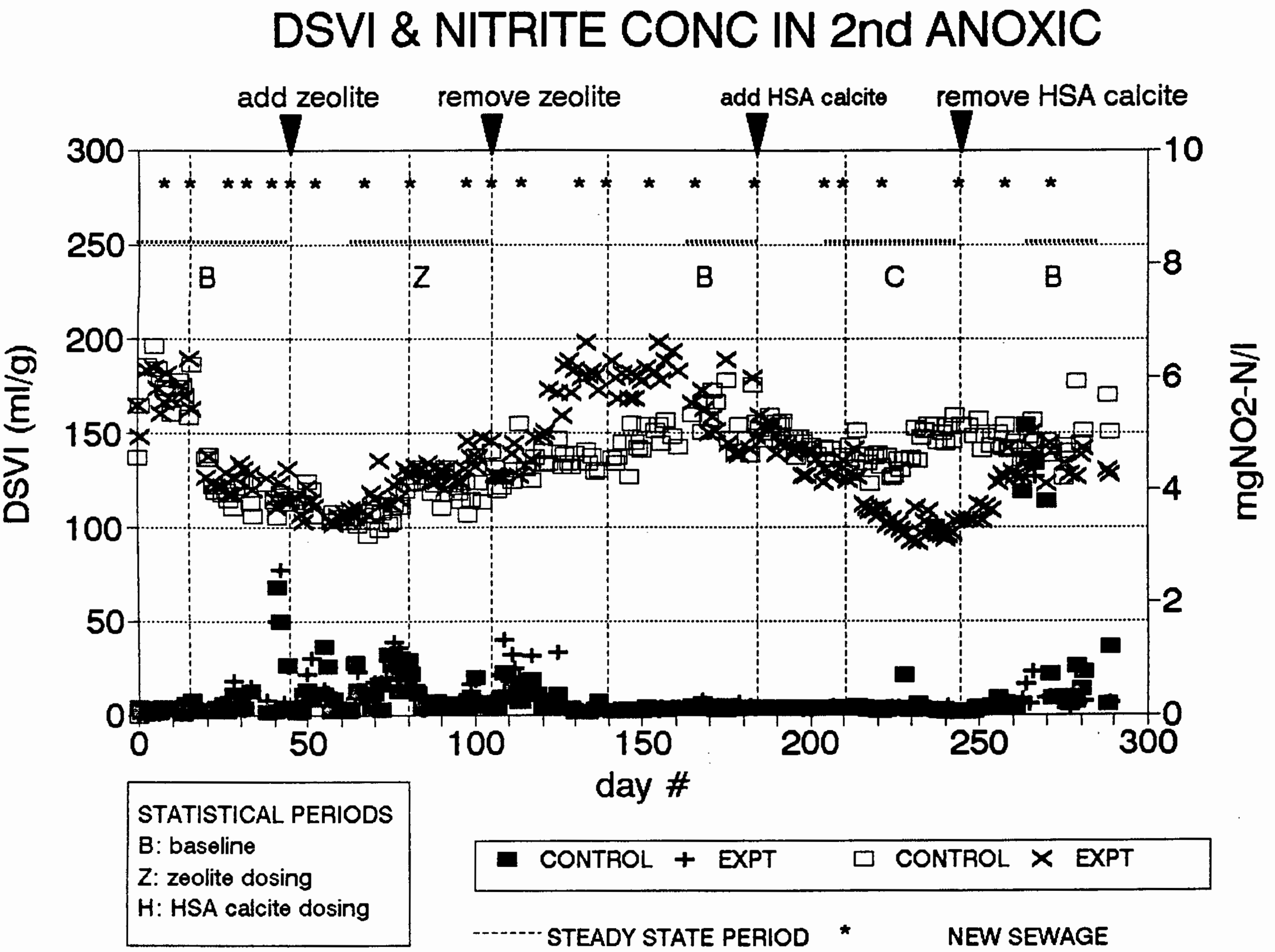
### 3.5.7.3 Discussion

The observations above suggest that the addition of zeolite causes a slight increase in DSVI, while the addition of HSA calcite causes a substantial decrease in DSVI. It is necessary to investigate whether the above observations are the result of zeolite / HSA calcite dosing or whether they are a result of incomplete denitrification in the anoxic zone.

To investigate a possible connection between DSVI and nitrite concentration in the second anoxic reactor, the DSVI should be compared with the nitrite concentration in the second anoxic zone. This comparison is shown in Figure 3.8.

1. From day 35 to day 75, the nitrite concentration in the second anoxic reactor increased steadily from zero to 1.2 mg/l, indicating incomplete denitrification in both the Control and Experimental systems during this period. This may have caused the increase in DSVI shown by both the Control and Experimental systems from days 64 to 104.
2. From days 100 to 125, the nitrite concentration for both systems increased again. This may have led to a slight increase in DSVI of the Control system (from 140 to 150 ml/g during days 150 to 185), and the more severe increase in DSVI of the Experimental system (from 140 to 200 ml/g during days 110 to 160).
3. No further incidences of high nitrite concentration in the second anoxic reactor can be observed, except during the final baseline period.

FIGURE 3.8: DSVI vs NITRITE CONCENTRATION IN THE 2nd ANOXIC REACTOR



### 3.5.7.4 Conclusions

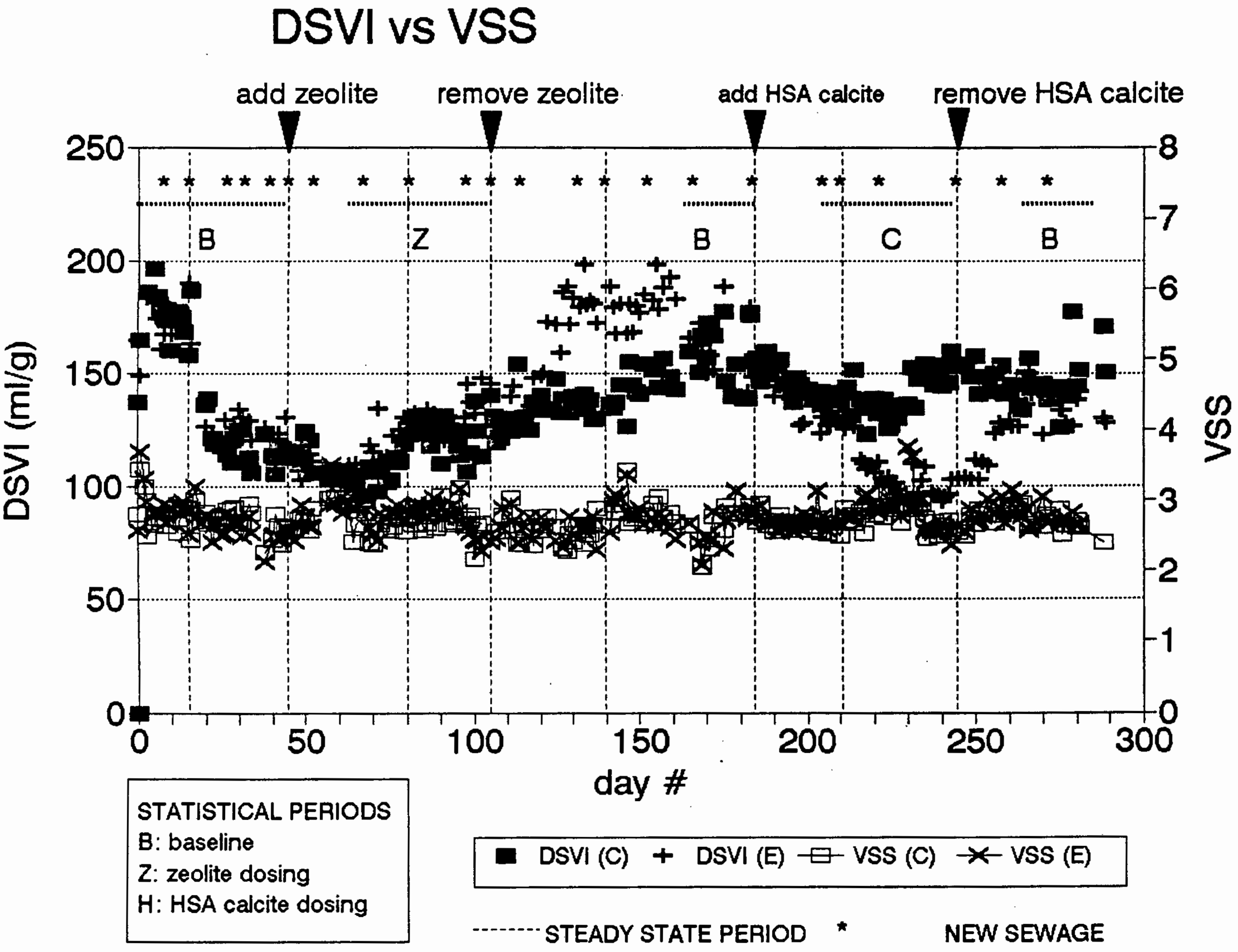
1. Any differences in DSVI between the Control and Experimental systems before day 164 cannot be attributed to the addition of zeolite from day 44 to day 104, as there is a strong possibility that the difference may have arisen from incomplete denitrification in the anoxic reactor.
2. The sharp decrease in DSVI of the Experimental system during HSA calcite dosing cannot be attributed to incomplete denitrification, and thus it can be concluded that the addition of 20 mg/l HSA calcite to the influent sewage causes a DSVI decrease of ±50 ml/g.

### 3.5.7.5 Correlation with MLVSS concentration

Musvoto *et al.*, (1992), investigating nutrient removal MUCT systems, confirmed a correlation between the volatile suspended solids, $MX_v$ and the DSVI, finding that the DSVI increased as $MX_v$ decreased and visa versa. This correlation was linked to whether denitrification was complete - when complete the $MX_v$ increased while the DSVI decreased and when incomplete, the $MX_v$ decreased while the DSVI increased. The DSVI from this investigation is plotted against MLVSS in Figure 3.9 and no clear correlation can be observed. A statistical correlation was also carried out on the data using the r-correlation coefficient to determine significant correlation. (For details of the r-correlation calculation, see Appendix 5). The results of the r-correlation are as follows:

1. Degrees of freedom (n-2) = 16
2. r-correlation coefficient = +0.207

FIGURE 3.9: DSVI vs MLVSS CONCENTRATION FOR THE CONTROL AND EXPERIMENTAL SYSTEMS



The r-correlation coefficient required to give significant trend at the 95% confidence interval is -0.4438 (Table A5 in Appendix 5). Hence the calculated value of 0.207 shows that there is only an extremely small possibility that the DSVI is linked to the VSS concentration. This result is expected because denitrification was complete for the greater part of the investigation so that the complete/incomplete denitrification was not a factor that significantly affected the $MX_v$ and DSVI.

### 3.5.8 Phosphorus Removal

The P release and uptake for each of the 9 steady state periods were compared with the steady state design theory for BEPR of Wentzel *et al.*, (1990).

The fraction of readily biodegradable COD is required to predict the theoretical phosphorus removal. This was measured in an apparatus specifically designed for the purpose (Ekama *et al.*, 1986). Other parameters required for the calculation, including $f_{up}$ and $f_{us}$ were taken as the average for the steady state period.

The phosphorus concentration of the influent, effluent and of the filtered mixed liquor in each of the reactors were measured daily and these concentrations were used to calculate the phosphorus release and uptake in each reactor and in the settling tank. The mass uptake (+'ve) or release (-'ve) in each reactor is given by:

(P concentration IN - P concentration OUT) * flowrate Q

The influent and effluent P concentrations for the Control and Experimental systems are shown in Figure 3.10.

### 3.5.8.1 Phosphorus release

The phosphate released in the anaerobic zone is directly proportional to the RBCOD sequestered by the poly-P organisms (cf. section 3.5.4.1). Assuming that all the RBCOD is sequestered in the anaerobic zone, the ratio of this proportionality, $C_{sp}$=0.5, can be used to calculate the theoretical P release ie. P release = $C_{sp}$ * RBCOD sequestered.

The calculated theoretical and actual P release for each steady state period is shown in Table 3.10.

### 3.5.8.2 P-Uptake

The P uptake in the system is calculated in the same way as the P release around the 2nd anoxic and anaerobic reactors.

Table 3.11 shows the theoretically calculated and total measured P uptake for each steady state period.

FIGURE 3.11: PHOSPHATE REMOVAL IN THE CONTROL AND EXPERIMENTAL SYSTEMS

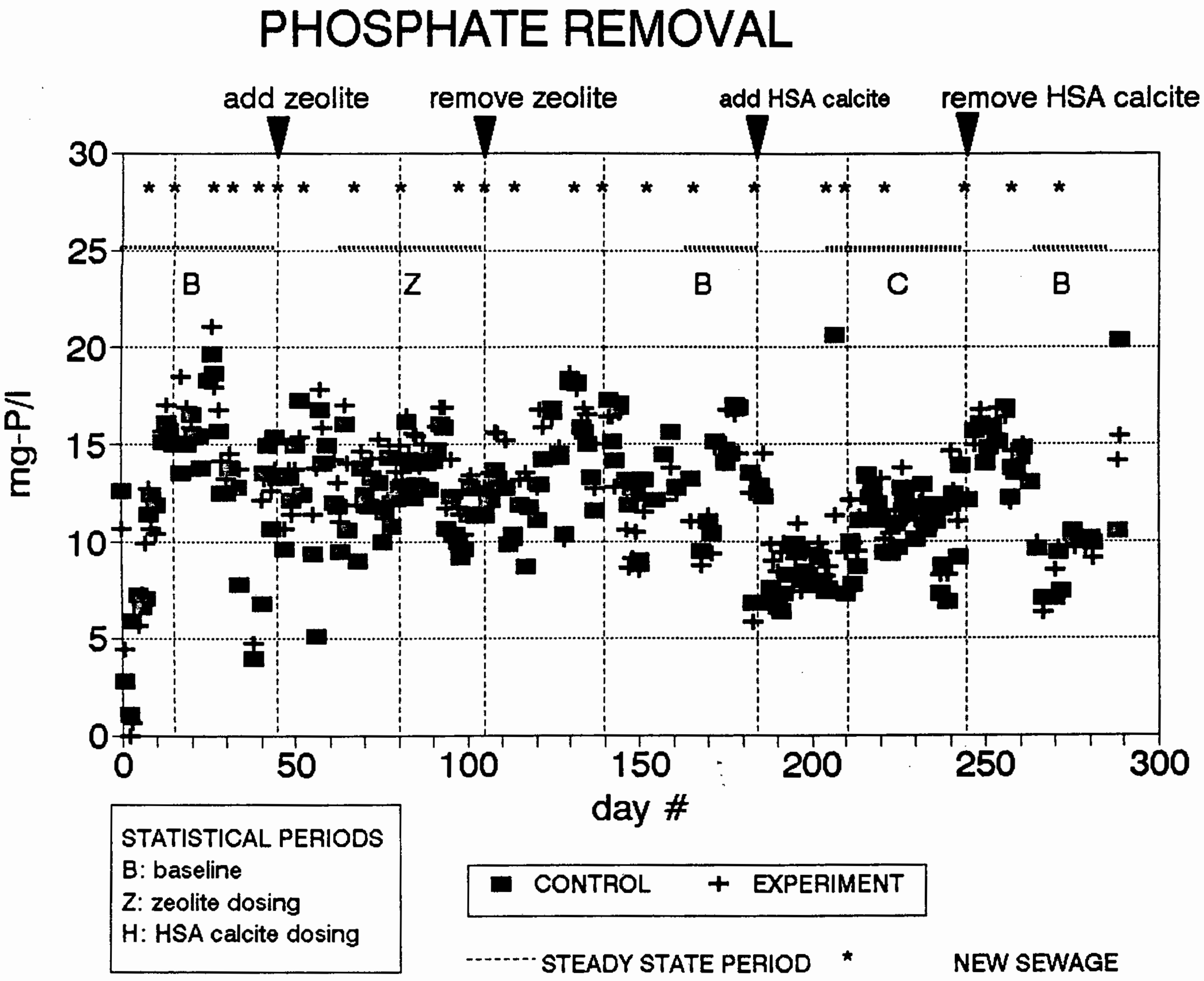


**Table 3.10: Theoretical and actual P release (mgp/l with respect to the influent flow) in the reactors of the Control (C) and Experimental (E) MUCT systems**

| Per | Theoretical Results | | | Experimental Results | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Anaerobic 1 | Anaerobic 2 | Total | Anaerobic 1 | | Anaerobic 2 | | Anoxic 1 | | Total | |
| | | | | C | E | C | E | C | E | C | E |
| 1 | -73.2 | -3.6 | 76.8 | -8.7 | -7.9 | -2.3 | -4.4 | -31.5 | -34.7 | -42.5 | -47.0 |
| 2 | -54.7 | -1.3 | 56.0 | -23.7 | -25.0 | -5.0 | -6.3 | -28.1 | -31.8 | -56.8 | -63.1 |
| 3 | -64.2 | -1.6 | 65.7 | -22.0 | -19.0 | -5.7 | -15.7 | -9.9 | +4.4 | -37.6 | -30.3 |
| 4 | -64.3 | -1.4 | 65.7 | -19.3 | -20.3 | -5.5 | -7.3 | -1.21 | -0.07 | -26.0 | -27.6 |
| 5 | -92.6 | -2.3 | 94.8 | -14.4 | -21.5 | -9.8 | -8.47 | -3.44 | -0.87 | -27.6 | -30.8 |
| 6 | -103.7 | -2.1 | 105.8 | -10.7 | -12.1 | -13.3 | -14.8 | -19.2 | -17.0 | -43.2 | -43.9 |
| 7 | -93.2 | -2.1 | 95.3 | -8.5 | -10.1 | -12.4 | -9.8 | -9.4 | -11.9 | -30.3 | -31.8 |
| 8 | -99.3 | -2.1 | 101.4 | -8.9 | -8.6 | -13.0 | -10.9 | -14.7 | -17.4 | -36.6 | -36.9 |
| 9 | -141.7 | -2.3 | 143.9 | -10.7 | -11.6 | -16.6 | -13.3 | -11.5 | -11.8 | -38.8 | -36.7 |

### 3.5.8.3 Theoretical and measured P removal

Overall P removal is the difference between the influent and effluent measured P concentrations. The P removal is also the sum of the P-releases and P-uptakes in the 5 reactors of the two systems.

The model of Wentzel *et al.*, (1990), predicts separately the phosphorus removed by the heterotrophs and the poly-P organisms. The active, endogenous and inert masses of both these groups have been calculated previously to predict the unbiodegradable particulate influent COD (cf. section 3.5.4.1). The phosphorus removal calculation procedure of the model is as follows:

P removal for the poly-p organisms ($\Delta P_G$) is

$$\Delta P_G = f_{XBGP}\frac{MX_{BG}}{R_s} + f_{XEGP}\frac{MX_{EG}}{R_s}$$

where :$MX_{BG}$ = Mass active poly-P organisms

: $MX_{EG}$ = Mass endogenous poly-P organisms

P removal for heterotrophs ($\Delta P_H$) is

$$\Delta P_H = f_{XBHP}\frac{MX_{BH}}{R_s} + f_{XEHP}\frac{MX_{EH}}{R_s}$$

where :$MX_{BH}$ = Mass active heterotrophic organisms

: $MX_{EH}$ = Mass endogenous heterotrophic organisms

P removal from wasting of inert mass ($\Delta P_I$) is

$$\Delta P_I = f_{XIP}\frac{MX_I}{R_s}$$

where :$MX_{BH}$ = Mass active heterotrophic organisms

: $MX_{EH}$ = Mass endogenous heterotrophic organisms

The symbols f are multiplication constants referring to the proportion of P in the various solid fractions. Total P removal ($\Delta P$) is given by the sum of the component P removals

$$\Delta P = \Delta P_G + \Delta P_H + \Delta P_I \text{ (mg/day)}$$

### 3.5.8.4 Discussion of P release and removal results

The sludge used to start up the laboratory systems was taken from Mitchell's Plain sewage treatment works, which is a Modified Lutzak-Ettinger (MLE) nitrification/denitrification system, not a BEPR system. Nitrification-denitrification systems contain poly-P organisms only in very small quantities, thus it took 3-4 weeks for the poly-P organisms to establish themselves in the laboratory MUCT system.

As the poly-P organisms established themselves in sufficient numbers, the phosphorus removal also increased until the actual P removal was very close to the theoretical removal calculated from the RBCOD in the sewage influent ie ±20mgP/l. However, the P-removal declined steadily until the actual removal was only 50% of the theoretically expected removal. Other MUCT systems operated in the laboratory were also showing similarly poor phosphorus removal, suggesting that the poor phosphorus removal was unlikely to be a result of experimental error or zeolite and HSA calcite dosing. No assignable cause for the poor P removal in the laboratory could be identified.

**Table 3.11: Theoretical and actual P uptake and removal for each steady state period**

| Per. | Theoretical | | Actual | | | |
|---|---|---|---|---|---|---|
| | Uptake | Removal | Uptake | | Removal Rem. | |
| | | | C | E | C | E |
| 1 | +98.2 | 21.3 | +52.0 | +56.1 | 9.4 | 9.1 |
| 2 | +73.0 | 17.0 | +70.5 | +77.7 | 13.7 | 14.6 |
| 3 | +84.6 | 18.9 | +50.0 | +43.9 | 12.4 | 13.6 |
| 4 | +84.5 | 18.8 | +38.7 | +41.6 | 12.7 | 14.0 |
| 5 | +117.8 | 23.0 | +40.8 | +45.2 | 13.1 | 14.3 |
| 6 | +130.8 | 25.0 | +56.2 | +55.9 | 13.0 | 12.0 |
| 7 | +118.7 | 23.3 | +38.8 | +41.7 | 8.5 | 9.8 |
| 8 | +126.0 | 24.6 | +47.2 | +48.2 | 10.6 | 11.3 |
| 9 | +174.8 | 30.8 | +50.8 | +49.2 | 12.1 | 12.5 |

Although the poor phosphorus removal shows significant deviation from theoretical predictions, a comparison between the Control and Experimental systems is still valid because both systems showed similar deviations at the same time and both systems showed similar P removals to the other MUCT systems operated in the laboratory.

From Figure 3.10, a slight difference in the effluent phosphate concentrations of the Control and Experimental systems can be observed during the zeolite dosing period. No clear differences between the Control and Experimental systems can be observed during the HSA calcite dosing period. Because these differences are small, and observed from the graph, they need to be confirmed by statistical analysis. This statistical analysis is discussed in section 3.5.9

### 3.5.9 Statistical Analysis of Data

#### 3.5.9.1 Data periods used for Statistical Analysis

The mass balances (section 3.4) required subdivisions recognising influent TKN and COD concentrations and hence all the data was divided into 9 steady state periods to evaluate system performance. The statistical comparison between the two systems does not require influent data, hence only 5 steady state periods need to be recognised; 3 baseline periods and 2 dosing periods for zeolite and HSA calcite. Not all the data were used for the statistical analysis as there is a time lapse between making a change in the system dosage and reaching a new steady state. For the baseline periods, the systems were run until at least 20 consecutive days of data could be obtained that showed no significant difference between the two systems, whereafter the next dosing period would begin. For the dosing periods, the systems were allowed one sludge age (20 days) to reach steady state and then 40 days (2 sludge ages) of data was collected for statistical analysis. The periods used for statistical analysis are shown in Table 3.12 (a) and are identified on Figures 3.2 to 3.11.

**Table 3.12(a):** **Data Periods used for Statistical Analysis**

| Description | Initial baseline data period | Zeolite dosing data period | Intermediate baseline data period | HSA calcite dosing data period | Final baseline data period |
|---|---|---|---|---|---|
| Period Day No. | 0 to 44 | 62 to 102 | 164 to 184 | 205 to 244 | 264 to 284 |

### 3.5.9.2 t-Distribution

The data was analyzed as 2 samples from 2 populations that may or may not be significantly different. The normal distribution with population standard deviation does not apply in this case because there is an insufficient number of data points. The t-distribution, however, can be applied because it takes into account the size of the sample and uses a sample variance as an estimate of the population standard deviation. Hence the data was analyzed statistically with the t-distribution.

To establish a statistical difference between the two populations, one must first postulate a null hypothesis that states that the two populations are statistically similar as regards a specific parameter eg. effluent COD concentration. If the result of the t-test disproves the null hypothesis at the 95% confidence interval, the null hypothesis is rejected and the two populations are accepted to be statistically different with respect to that specific parameter.

of the t-test disproves the null hypothesis at the 95% confidence interval, the null hypothesis is rejected and the two populations are accepted to be statistically different with respect to that specific parameter.

### 3.5.9.3 Interpretation of t-Statistic

Details of the statistical calculations are found in Appendix 6. The averages for each steady state period are summarised in Table 3.12 (b). Table 3.12 (c) shows the data t-statistic calculated for each parameter for the 5 steady state periods. The value of the data t-statistic in Table 3.12 (c) and the degrees of freedom obtained from the number of observations, give the percentage probability that the two sets of data (Control and Experiment) are statistically different. Only those parameters that have probability of difference >95% are filled in on the Table 3.12 (c). Those not filled in can be accepted as statistically similar at the 95% confidence interval. Appendix 6 gives the theoretical t-statistic with the probability of significance for a given number of data points.

**Table 3.12 (b): Summary of Statistical Analysis**

| Variable | Initial baseline data period | | Zeolite dosing data period | | Intermediate baseline data period | | HSA calcite dosing data period | | Final baseline data period | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | E | C | E | C | E | C | E | C | E |
| DSVI | 142.7 | 143.9 | 115.8 | 124.6 | 156.4 | 157.9 | 139.4 | 108.5 | 146.6 | 134.6 |
| TSS | 3.264 | 3.281 | 3.287 | 3.557 | 3.202 | 3.224 | 3.275 | 3.435 | 3.280 | 3.287 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ISS | 0.504 | 0.533 | 0.583 | 0.763 | 0.532 | 0.541 | 0.513 | 0.578 | 0.598 | 0.577 |
| VSS | 2.759 | 2.748 | 2.704 | 2.794 | 2.653 | 2.657 | 2.762 | 2.857 | 2.699 | 2.754 |
| VSS/TSS | 0.846 | 0.838 | 0.824 | 0.786 | 0.835 | 0.832 | 0.844 | 0.831 | 0.818 | 0.827 |
| Effluent TKN | 4.8 | 4.5 | 3.6 | 4.0 | 5.1 | 5.3 | 4.9 | 5.0 | 4.7 | 4.5 |
| Effluent COD | 63.8 | 59.2 | 66.0 | 63.0 | 80.3 | 68.8 | 50.7 | 55.3 | 67.7 | 66.2 |
| pH | 7.87 | 7.90 | 7.82 | 7.88 | 7.86 | 7.81 | 7.85 | 7.80 | 7.73 | 7.75 |
| PHOSPHORUS | | | | | | | | | | |
| anaer 1 | 36.2 | 38.4 | 31.1 | 32.4 | 34.3 | 31.4 | 29.3 | 29.0 | 29.0 | 28.9 |
| anaer 2 | 38.1 | 40.7 | 33.5 | 35.7 | 39.8 | 37.4 | 34.7 | 33.4 | 34.9 | 34.3 |
| anoxic 1 | 35.0 | 38.3 | 24.4 | 24.8 | 34.1 | 32.5 | 29.6 | 29.0 | 28.2 | 27.9 |
| anoxic 2 | 19.7 | 14.6 | 13.6 | 13.1 | 21.7 | 19.9 | 16.9 | 16.9 | 15.4 | 16.6 |
| aerobic | 9.5 | 8.1 | 8.7 | 8.5 | 10.0 | 9.5 | 10.2 | 9.6 | 11.2 | 10.7 |
| effluent | 7.6 | 7.2 | 7.3 | 6.0 | 9.4 | 8.8 | 9.6 | 8.9 | 10.8 | 10.1 |
| removal | 12.2 | 12.8 | 12.4 | 13.8 | 12.2 | 12.6 | 10.2 | 10.6 | 6.9 | 7.2 |
| NITRITE | | | | | | | | | | |
| anaer 1 | 0.091 | 0.075 | 0.117 | 0.120 | 0.164 | 0.21 | 0.173 | 0.242 | 0.238 | 0.271 |
| anaer 2 | 0.075 | 0.077 | 0.112 | 0.110 | 0.170 | 0.22 | 0.173 | 0.194 | 0.240 | 0.269 |
| anoxic 1 | 0.090 | 0.085 | 0.138 | 0.142 | 0.140 | 0.13 | 0.094 | 0.106 | 0.219 | 0.220 |
| anoxic 2 | 0.235 | 0.252 | 0.355 | 0.433 | 0.148 | 0.13 | 0.219 | 0.102 | 1.969 | 0.533 |
| aerobic | 2.193 | 2.161 | 1.334 | 1.098 | 0.227 | 0.28 | 0.123 | 0.163 | 0.282 | 0.387 |
| effluent | 2.248 | 2.599 | 1.189 | 0.786 | 0.735 | 0.55 | 0.422 | 0.441 | 1.001 | 0.786 |
| NITRATE | | | | | | | | | | |
| anaer 1 | 0.399 | 0.209 | 0.220 | 0.336 | 0.121 | 0.276 | 0.087 | 0.186 | 0 | 0.010 |
| anaer 2 | 0.095 | 0.090 | 0.223 | 0.204 | 0.115 | 0.122 | 0.076 | 0.072 | 0 | 0 |
| anoxic 1 | 0.129 | 0.109 | 0.338 | 0.330 | 0.084 | 0.111 | 0.038 | 0.034 | 0 | 0 |
| anoxic 2 | 0.295 | 0.196 | 1.613 | 1.828 | 0.075 | 0.089 | 0.086 | 0.007 | 0 | 0 |
| aerobic | 5.068 | 4.896 | 14.03 | 11.25 | 7.32 | 8.79 | 8.443 | 8.819 | 10.04 | 11.23 |
| effluent | 7.662 | 7.206 | 15.65 | 15.22 | 7.35 | 9.16 | 9.001 | 9.139 | 9.792 | 11.50 |

**Table 3.12 (c): t-Statistic for each Steady State Period**

| Variable | Initial baseline data period | Zeolite dosing data period | Intermediate baseline data period | HSA calcite dosing data period | Final baseline data period |
|---|---|---|---|---|---|
| DSVI | -0.170 | -3.654 >99.9% | +0.290 | -10.607 >99.9% | -3.302 >99.% |
| TSS | -0.228 | -4.541 >99.9% | +0.187 | +2.606 >98% | +0.090 |
| ISS | -0.969 | -6.452 >99.9% | +0.168 | +2.755 | -0.647 |
| VSS | +0.183 | -2.053 >95% | -0.040 | +1.673 | +1.049 |
| VSS/TSS | +1.150 | +6.280 >99.9% | -0.163 | -1.953 | +1.212 |

| | | | | | |
|---|---|---|---|---|---|
| Effluent TKN | +0.818 | -1.744 | +0.279 | +0.212 | -1.061 |
| Effluent COD | +0.969 | +0.820 | -1.435 | +1.687 | -0.229 |
| pH | -0.522 | -1.221 | -0.963 | -1.459 | +0.447 |
| PHOSPHORUS | | | | | |
| anaer 1 | -1.607 | -2.261 >95% | -1.507 | -0.262 | -0.046 |
| anaer 2 | -1.774 | -3.876 >99.9% | -1.128 | -0.831 | -0.639 |
| anoxic 1 | -2.013 >95% | -0.546 | -0.738 | -0.514 | -0.265 |
| anoxic 2 | -1.225 | +1.392 | -1.221 | -0.111 | +1.804 |
| aerobic | -0.211 | +0.701 | -0.515 | -1.148 | -0.877 |
| effluent | +0.349 | -5.104 >99.9% | -0.698 | -1.233 | -1.101 |
| removal | -0.569 | -3.170 >99.5% | | | |
| NITRITE | | | | | |
| anaer 1 | +0.978 | -0.262 | 1.240 | +2.130 >95% | +1.295 |
| anaer 2 | -0.203 | +0.202 | +1.553 | +1.140 | +1.335 |
| anoxic 1 | +0.260 | -0.160 | -0.387 | +1.450 | +0.039 |
| anoxic 2 | -0.143 | -1.047 | -1.034 | -1.167 | -2.681 >98% |
| aerobic | +0.029 | +1.152 | +1.945 | +2.547 >98% | +1.670 |
| effluent | -0.346 | +1.787 | -1.874 | +0.273 | -0.531 |
| NITRATE | | | | | |
| anaer 1 | +1.698 | -1.835 | +1.851 | +1.986 | +0.711 |
| anaer 2 | +0.305 | +0.461 | +0.687 | -0.104 | +0.488 |
| anoxic 1 | +0.770 | +0.086 | +1.182 | -0.276 | +0.234 |
| anoxic 2 | +1.482 | -0.477 | +0.417 | -1.090 | +0.533 |
| aerobic | +0.240 | +1.541 | +1.449 | +0.350 | +0.612 |
| effluent | +0.512 | +0.201 | +1.849 | +0.123 | +1.020 |

> 95% means that the probability of making an error in accepting the data sets from Control and Experimental as being from the same population is greater than 95%.

### 3.5.9.4 Discussion of Statistical Comparison

#### i. Baseline Periods

The 3 baseline periods were identical in all respects except the following:

1. The initial baseline period showed a slight difference in P concentration in the first anoxic reactor.
2. The final baseline period showed that the DSVI in the Experimental system was lower than in the Control, but to a much lesser extent than during the previous HSA calcite dosing period. It is possible that the system was not allowed

sufficient time to reach steady state after ending the HSA calcite testing period. A difference was also found on the nitrite concentration in the second anoxic reactor.

### ii. Zeolite Dosing Period

The presence of zeolite in the system had no significant effect on effluent TKN, effluent COD, pH, nitrite or nitrate concentrations.

Since the zeolite is an inorganic solid, the inorganic solids concentration increased in the Experimental system, but not to the same extent as the zeolite dose to the system. It was suspected that the zeolite may decompose during the incineration step of the VSS test, but this was disproved by a thermogravimetric analysis (TGA) test.

The Experimental system also showed higher DSVI during zeolite dosing than the Control. According to the bulking theories of Casey *et al.*, (1992), filamentous bulking in the MUCT system can be associated with high nitrite concentrations leaving the second anoxic zone. When these nitrite concentrations were compared with the DSVI trends, (cf section 3.5.8.4), it became clear that there was an association between the 2 parameters. Because of this association, the difference in DSVI between the Control and Experimental systems during the zeolite dosing period cannot be attributed to the presence of zeolite in the Experimental system.

For the Experimental system with zeolite dosing, the data shows improved phosphate release in the second anaerobic reactor, lower effluent phosphate concentration and higher overall removal than the Control system. This implies that zeolite has a positive influence on the biological phosphorus removal process; if the effect was chemical, the improved P removal would not be associated with higher P release. The magnitude of difference in P removal is ±1.4 mgP/l compared with the average influent P concentration of 19.7 mgP/l during the zeolite dosing period.

### iii. HSA Calcite Dosing Period

The presence of HSA calcite in the Experimental system had no effect on the VSS, effluent TKN, effluent COD, pH, phosphate release, uptake and removal and nitrate concentrations.

Since HSA calcite is an inorganic solid, the inorganic solids increased in the Experimental system but not in the same quantity of the dose to the system (cf section 3.5.5). This is because a portion of the HSA calcite dissolved in the sludge and the remainder decomposed partially in the incineration step of the VSS test.

The DSVI of the Experimental system when dosed with HSA calcite showed a sharp decrease relative to the Control. During this period, the effluent nitrite concentration from the second anoxic reactors of both Control and Experimental systems were low; consequently no correlation can be drawn between the DSVI and incomplete denitrification in the second anoxic zone, and the decrease in the DSVI of the Experimental system can be attributed

# CHAPTER 4

# CONCLUSIONS

## 4.1 BACKGROUND AND MOTIVATION FOR RESEARCH

The issue of a banning or regulating detergent phosphate in South Africa has been investigated by the Department of Water Affairs (Heynike and Wiechers, 1986). In their investigation, which included interviews with the detergent manufacturing industry, it was recommended not to impose a ban on detergent phosphate. Their reasoning was that BEPR technology exists; at the time of the study no alternative builder was available; the high cost of replacement and the reduction in phosphorus discharge would not be sufficient to eliminate eutrophication in sensitive catchments.

In spite of the recommendation by the Department of Water Affairs not to ban phosphate in detergents, South African consumers have become increasingly aware of environmental issues in the past few years, and recently, attention has been focused on the environmental impact of phosphate as a builder in detergents. By consumer pressure, detergent manufacturers may need to replace phosphate builders with alternative builders, such as zeolite or high surface area (HSA) calcite. Although most research efforts indicate that the use of zeolite is environmentally safe and does not adversely affect conventional activated sludge systems, the potential impact of these ingredients on the behaviour of nitrification denitrification biological excess phosphorus removal (NDBEPR) systems is not known. Thus as an environmental responsibility, Lever Brothers (South Africa) has supported a research programme at the University of Cape Town to investigate these effects.

## 4.2 RESEARCH METHODOLOGY

In this thesis, the research was limited to two potential alternative detergent builders; zeolite A and high surface area (HSA) calcite. Two laboratory MUCT NDBEPR systems, one Experimental and one Control, were operated at a long sludge age (20 days), a temperature of 20°C and were fed with real unsettled sewage. The Experimental system was supplemented separately with a quantity of zeolite and then HSA calcite, while the Control system was fed normal sewage. The periods of zeolite and HSA calcite dosing (first with zeolite and then with HSA calcite) were preceded and succeeded with 'baseline' periods when normal sewage was fed to both Control and Experimental systems. The purpose of the baseline period was firstly to ensure that both systems exhibited statistically similar behaviour with no supplement added to the Experimental system and secondly to assess the response of the system to builder dosing as well as cessation of dosing.

A new batch of sewage sometimes had very different characteristics from the preceding batch and the systems would take a few days to reach a new steady state. For this reason, in addition to the dosing/baseline periods, the investigation period was further divided into 9 steady state periods. To confirm correct operation of the systems and accurate laboratory results, COD and nitrogen mass balances were performed over the 9 steady state periods.

The data for each measured parameter was analyzed for any trends and small differences which may be attributed to the addition of adding zeolite or HSA calcite to the Experimental system. To confirm the effects of the presence of zeolite or HSA calcite in the influent sewage, a statistical analysis (using a t-distribution approximation to the normal distribution) was performed over the dosing periods. The same analysis was performed over the baseline periods to confirm no significant differences between the systems when no supplement was added.

## 4.3 RESEARCH RESULTS AND DISCUSSION

### 4.3.1 Mass Balances

Reasonably good nitrogen balances were obtained on the Control and Experimental systems, with weighted averages of 89.7% and 89.3% respectively. These are similar to the balances obtained by Clayton *et al.*, (1989) and Musvoto *et al.*, (1992) both operating MUCT nutrient removal systems.

The COD balances were not as good as the N balances, with weighted averages of 84.5% and 84.1% respectively for the Control and Experimental systems. These are somewhat lower than the COD balance attained by Clayton *et al.*, (1989) and Musvoto *et al.*, (1992) both running MUCT N&P removal systems, who obtained balances of average 94% and the range of 82% to 120% respectively. It is possible that some of the assumptions made in the COD balance such as stoichiometric constants 4.57 mgO utilised/mgN denitrified and 2.86 mgO/mg$NO_3$-N denitrified and the COD/VSS ratio of 1.48 mgCOD/mgVSS were slightly different from the actual values in this investigation. It is also possible that the oxygen utilisation rate (OUR), taken ±16 hours after feeding, underestimates the true average OUR over the 24 hour period.

### 4.3.2 Carbonaceous Organic Material Degradation

Neither the filtered effluent COD concentration nor the carbonaceous oxygen demand showed any differences between the Control and Experimental systems. Further, no difference could be established statistically.

The influent unbiodegradable soluble COD fraction, $f_{us}$, is the ratio of the filtered effluent COD and the influent total COD concentrations. There was no difference between the $f_{us}$ of the Control and Experimental systems. The results varied in phase as the $f_{us}$ of the sewage batches varied and were fed to both systems.

### 4.3.3 Volatile Suspended Solids

#### 4.4.3.1 Unbiodegradable particulate COD fraction ($f_{up}$)

The unbiodegradable particulate COD fraction can be calculated by one of two methods. The first is the WRC, (1984) method, which does not take account of the poly-P organisms. The second is the kinetic model of Wentzel *et al.*, (1990) which is specifically suited to the NDBEPR process and takes account of the poly-P organism growth in NDBEPR systems.

The values of the unbiodegradable particulate COD fractions (calculated by the NDBEPR method of Wentzel *et al.*, 1990), varied between 0.161 and 0.252 for the 9 steady state periods. However, the values obtained from the Control and Experimental systems during the same steady state periods showed only very small differences, indicating that it was the differences in the sewage batches that caused the differences in $f_{up}$ rather than zeolite or HSA calcite. A statistical analysis could not establish a significant difference between the $f_{up}$ values of the Control and Experimental systems.

#### 4.3.3.2 Active and Endogenous Fractions

Once $f_{us}$ and $f_{up}$ values were established, the non poly-P organism heterotrophic active mass was calculated with the aid of the model of Wentzel *et al.*, (1990). The active mass divided by the volatile solids mass gave the actual fraction of the VSS mass. The active fraction was required to calculate specific denitrification rates in terms of $mgNO_3$-N/(mgAVSS.d).

### 4.3.4 Inorganic Solids

When the inorganic suspended solids concnetrations of the Experimental and Control systems were compared by statistical analysis, significant differences were confirmed during the zeolite and HSA calcite dosing periods.

Because zeolite is an inorganic insoluble solid it was expected that when zeolite was dosed to the Experimental system, the inorganic suspended solids concentration of the Experimental system would increase relative to the Control by the same amount as the mass dry zeolite dosed. This increase, however was found to be only 180mg/l compared with the 320mg/l zeolite expected. Because zeolite is insoluble, the loss of zeolite may have arisen in the incineration step of the VSS test. In order to check the stability of zeolite at elevated temperatures, a thermogravimetric analysis (TGA) test was carried out from 30 to 700°C. The zeolite itself appeared stable, losing only its water of hydration between the temperatures of 30 and 460°C. No reason could be advanced for the discrepancy measured in ISS.

HSA calcite is also an inorganic solid dosed to the Experimental system. The increase in ISS of the Experimental system over the Control system was only 65mg/l of mixed liquor compared with the expected 200mg/l. (The concentration of dosed HSA calcite with respect to the influent was 20mg/l, but if it remains in the solid phase, its expected concentration with respect to the sludge is 200mg/l). The influent wastewater was found to be under-saturated with respect to calcium by 10 to 20 mg/l and so it can be concluded that a portion of the HSA calcite dissolved in the wastewater. A TGA test on HSA calcite showed a steady mass loss of 15% from 30 to 700°C. This confirms that the calcite decomposes in the incineration step of the VSS test. Because of the combination of dissolution and decomposition of HSA calcite, it seems reasonable that only 33% of the dosed HSA calcite was recovered.

### 4.3.5 Nitrification

Complete nitrification, resulting in low effluent TKN concentrations, were attained continuously in both systems by maintaining the dissolved oxygen concentration in the aerobic reactor between 2 and 3 mg/l. The addition of zeolite and HSA calcite had no inhibitory effect on nitrification and there was no difference between the filtered effluent TKN concentrations of the Control and Experimental systems (weighted averages 4.62 and 4.56 mgTKN-N/l respectively). Further, no statistically significant differences in effluent TKN concentrations could be confirmed by statistical analysis.

Nitrification capacity is the total mass per day of nitrate and nitrite ($NO_3^- + NO_2^- = NO_x$) generated by nitrification. It was calculated via the nitrogen balance as the sum of the effluent $NO_x$ and the $NO_x$ denitrified. The nitrification capacity of the Control and Experimental system were similar (weighted averages 531mgN/d and 525mgN/d respectively) except during steady state periods 5 and 6 (intermediate baseline period), when the nitrification capacity of the Control system was higher than the Experimental system. This was the result of a poor N mass balance over the Experimental system during these steady state periods.

### 4.3.6 Denitrification

Musvoto *et al.*, (1992) and Clayton *et al.*, (1989) concluded that unlike the nitrification-denitrification systems, only a single denitrification rate can be identified in the anoxic reactors of the MUCT system. They determined the average nitrate denitrification rate to be 0.296 $mgNO_3$-N/mgAVSS.d and 0.224 $mgNO_3$-N/mgAVSS.d respectively.

In this investigation, it was important to keep the second anoxic reactor underloaded with respect to nitrate, because it has been established previously (Casey *et al.*, 1992) that AA (low F/M) filament sludge bulking can be associated with incomplete denitrification in the second anoxic reactor. The first anoxic reactor was designed to be underloaded with respect to nitrate because any nitrate leaving this reactor could interfere with the BEPR process. The second anoxic reactor was designed to be underloaded with respect to nitrate so that AA filament bulking and its adverse effect on the DSVI would be absent in the Experimental and Control systems. Because both the first and second anoxic reactors were generally underloaded with respect to nitrate, it was not possible to measure the denitrification rates. Nevertheless, apparent rates were determined from the mass of nitrate denitrified, noting that this was not the real rate because the anoxic reactors were underloaded with nitrate. The apparent rates varied from 0.024 mg$NO_3$-N/mgAVSS.d to 0.109 mg$NO_3$-N/mgAVSS.d and were always significantly lower than the actual rate. The apparent rate depended more on the influent TKN and the a-recycle than on denitrification kinetics because these two parameters governed the nitrate load on the anoxic reactors.

### 4.3.7 DSVI and AA Filament Bulking

One of the major problems in operating MUCT systems is the tendency of AA filaments in the sludge to dominate over the floc formers, leading to sludge bulking and poor settleability. Consequently, it is important to investigate the impact of zeolite and HSA calcite on the settling behaviour of the activated sludge.

Filament identifications were carried out approximately every 4-5 weeks. The filament population did not change much over the investigation period, indicating that the changes in DSVI were more affected by changes in numbers of filaments present than by changes in types of filaments.

#### 4.3.7.1 Zeolite

It was observed that during zeolite dosing, the DSVI of both the Control and Experimental systems was increasing (from 100 to 150 ml/g), showing signs of AA filament bulking. The statistical analysis confirmed a differnce between the DSVI of the two systems, with more severe bulking in the Experimental system. Thus at first sight, it appeared that zeolite may have had a detrimental effect on the settleability of the sludge. However it was observed that incomplete denitrification in the second anoxic reactor preceded these periods of bulking. Because it has been established (Casey *et al.*, 1992) that incomplete denitrification in the second anoxic reactor can lead to AA bulking, the high DSVI of the Experimental system during zeolite dosing could not be attributed to the addition of zeolite. Bulking is more likely the consequence of the incomplete denitrfication than of the presence of zeolite.

### 4.3.7.2 HSA Calcite

It was observed that the Experimental system showed a sharp decrease relative to the Control system when HSA calcite was dosed to the Experimental system (ie DSVI decrease from 150ml/g to 100ml/g). This observation was strongly confirmed by the statistical analysis (99.9% confidence interval). Because the decrease in DSVI was not preceded by a period of incomplete denitrification in the second anoxic reactor in either the Experimental or Control systems, it can be concluded that the decrease in DSVI of ±50 ml/g is attributable to the presence of 20mg/l HSA calcite in the Experimental system influent sewage feed.

### 4.3.7.3 Correlation with MLVSS Concentration

Musvoto *et al.*, (1992), investigating nutrient removal MUCT systems, confirmed a correlation between the volatile suspended solids mass in the system, $MX_v$ and the DSVI, finding that the DSVI increased as $MX_v$ decreased when denitrification in the second anoxic reactor was incomplete. A statistical correlation was carried out on the DSVI and $MX_v$ data observed in this investigation. However, no trend between the DSVI and the MLVSS was discernable. This result was expected because denitrification in the second anoxic reactor was complete for the greater part of the investigation.

### 4.3.8 Phosphate Removal

#### 4.3.8.1 Actual vs Theoretical P Removal

For most of the investigation, the actual P removal (±12mgP/l) in both the Control and Experimental systems was only 60% of the P removal predicted theoretically (±20mgP/l). Other MUCT systems operating in the laboratory also showed similarly poor phosphorus removal, suggesting that the poor P removal was unlikely to be a result of experimental error or zeolite and HSA calcite dosing. No assignable cause for the poor P removal in the laboratory systems could be identified. Nevertheless, a comparison between the Control and Experimental systems is valid because both systems were shown statistically to be similar with respect to P removal during the baseline periods.

#### 4.3.8.2 Effect of Zeolite on P Removal

During zeolite dosing to the Experimental system, the Experimental system showed P removal 1.24 mg-P /l higher than the Control (removals 13.8mgP/l and 12.4mgP/l respectively). This difference was confirmed to be significant by the statistical analysis of the data.

The reason for this increase in P removal could be either chemical or biological. A chemical mechanism would involve adsorption of calcium by the zeolite particle, thus providing a heterogeneous surface for the formation of calcium-phosphate. However a biological mechanism was indicated because there was a higher P release in the anaerobic zone and higher uptake in the aerobic zone of the Experimental system. No assignable cause for the increased P removal could be identified.

#### 4.3.8.3 Effect of HSA Calcite on P Removal

During HSA calcite dosing to the Experimental system, there was statistically no significant difference between the P removal of the Control and Experimental systems. There was also no statistically significant difference between the P uptake and release of the Control and Experimental systems. Therefore it can be concluded that no phosphate was precipitated by the HSA calcite.

## 4.4 Closure

From the above observations, it would appear that the substitution of phosphates in detergent formulations with zeolite or HSA calcite will not have any adverse effects on the biological excess phosphorus removal sewage treatment process. No effect of zeolite or HSA calcite could be established on COD removal, nitrification, volatile solids production, pH and denitrification. This is in accordance with the conclusions of the literature review (cf. section 2.6.2). The mass of sludge production would increase (which is to be expected from the addition of inorganic material to the sewage), but this increase is likely to be very small - only 56% and 32% of the respective zeolite and HSA calcite dose was recovered in the sludge.

The presence of zeolite and HSA calcite are not likely to adversely affect sludge settleability -indeed it appeared that HSA calcite may have a small beneficial effect. This is also in accordance with the observations made by previous researchers (cf 2.6.3). Zeolite also appears to improve biological phosphate removal, but the reason for this is unclear. Previous researchers investigating the effect of zeolite in chemical P removal also found zeolite to have a positive effect.

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# APPENDIX 1:

## EXPERIMENTAL INVESTIGATION - PHASE 1 (1991)

### A1.1 PART 1: SINGLE SYSTEM TESTING

At the start of the project in March 1991, only one MUCT laboratory system was operated for this thesis. This system was made from second hand equipment already available in the laboratory. The University workshops were meanwhile commissioned by Lever Brothers to manufacture two new MUCT systems for comparative work later on. The purpose of running the first single system was to become familiar with and master the daily laboratory tests until reliable, accurate results could be attained.

### A1.2 PART 2: DUAL SYSTEM BASELINE

The second MUCT system was built in June 1991, and this was started up using waste sludge from the first system. Thus reasonably similar results could be expected. The purpose of this phase was to run 2 units on the same sewage and attempt to obtain similarity on the two sets of results. The results obtained from running the systems on identical sewage would provide a baseline of data for future comparison between the two systems.

### A1.3 PART 3: DETERGENT SUPPLEMENTATION

In the third part, detergent was mixed into the raw sewage influent which was then fed to the units.

### A1.3.1 Nature of Detergent Supplement

There was some discussion at the start of the project as to whether to single out a few detergent ingredients and measure their individual effects on the activated sludge system, or add the whole formulation. The decision reached was to dose the whole detergent formulation to the sewage influent. This decision was based on the following rationale:

1. It more closely represents the real situation, where a consumer uses a product and disposes of it via the sewage system.

2. One would assume that even if only one or two ingredients in the detergent formulation had any effect on the MUCT system, the MUCT system would still show these effects when the whole detergent formulation was dosed. The individual component responsible for the behaviour could be confirmed by isolating this component and dosing separately to the MUCT system at a later stage (phase 2 - see chapter 3).

### A1.3.2 Quantity of Detergent Supplement

For an ideal comparison of the effects of phosphate-based detergents and zeolite based detergents in the sewage system, one would need two sources of household sewage, one source using phosphate based detergent from normal household use, and it is not possible to remove this to replace with a zeolite-based detergent. One way to observe the effects of phosphate and zeolite based detergents would be to add a portion of these to the detergent fraction already existing in the Mitchell's Plain sewage from normal household use. It was decided to dose phosphate-based detergent to the Control system, and a zeolite-based detergent to the Experimental system. It is well documented (Heynike and Wiechers, 1986) that the average phosphate contribution in sewage that originates from detergents is approximately 40% of the total phosphorus in the sewage.

On the basis of the above information, the following control/experimental set up was decided on:

| | |
|---|---|
| Control: | Municipal sewage supplemented with phosphate-based OMO (P-OMO) to raise the phosphate content of the mix by 40%. ie. 10 litres/d Mitchell's Plain sewage supplemented with 1.22g/d of phosphate-based OMO. |
| Experiment: | Municipal sewage supplemented with zeolite-based OMO (Z-OMO) of same mass as the P-OMO above. ie. 10 litres/d Mitchell's Plain sewage supplemented with 1.22g/d of Z-OMO. |

The detergent formulation was added from a stock solution of 20 g/l detergent in water.

## A1.4 RESULTS OF DETERGENT DOSING PERIOD

The data showed high variability with time which masked the difference between the two systems. Although the two systems had variable results, they followed similar trends with time. Thus it was decided to use paired observations for the statistical analysis. This involved finding the difference between the two systems for each day and determining whether the statistical difference over the time period is significant or not.

### A1.4.1 Sludge bulking

When the detergent was supplemented to the feed of both systems, the sludges exhibited severe bulking (DSVI > 300ml/g), although this was less severe in the Experimental system (dosed with zeolite based detergent) than the Control (dosed with phosphate based detergent). As a result of this bulking, the settlers became overloaded and some system modifications were required to contain the sludge in the system. This poor settleability was thought to be due to the unusually high concentration of detergent in the influent sewage.

### A1.4.2 Detergent "Wetting"

Under actual conditions in the wash process, the form of the detergent is modified. In an effort to simulate this modification and as an attempt to alleviate the bulking problem, it was decided to "wet" the detergent in the sewage feed for 24 hours before dosing. This strategy led to a decrease in DSVI from >300 ml/g to between 220 to 260 ml/g.

### A1.4.3 Zero Effluent Phosphate

Until this stage, the two systems had been run on a comparative basis, with emphasis being placed on phosphorus removal, not on effluent phosphate concentration. The effluent phosphate concentration, however is the parameter normally used overseas as a measure of environmental acceptability. If the two systems could be run to produce near zero effluent phosphate concentration, the effect of a phosphate replacement would be interpreted as follows: If the Control system could not produce an effluent of phosphate concentration below 1 mg-P/l and Experimental system (with reduced influent phosphate and dosed with zeolite-based detergent) could achieve an effluent of phosphate concentration <1 mg-P/l, one may conclude that the replacement of phosphate in detergents by zeolite is beneficial in enabling a sewage treatment system to produce an effluent of < 1mg-P/l phosphate. This may be due to either the reduced influent phosphate concentration, or it may be an enhanced phosphate uptake effect caused by the presence of zeolite in the system. Most likely the cause would be a combination of these factors, but the advantage of zeolite replacement would be clear.

Both systems were already receiving phosphate from the normal household detergent usage in Mitchell's Plain. Neither the control system (receiving extra phosphate in the form of a detergent supplement) nor the Experimental system were able to remove sufficient phosphate to achieve an effluent with phosphate concentration below 1 mg-P/1/. In order to achieve this effluent phosphate requirement, an acetate solution was fed to the anaerobic zone to augment the phosphate removal by stimulating the growth of the poly-P organisms responsible for excess phosphorus removal.

### A1.4.4 Acetate Dosing

During this acetate dosing period, both systems showed signs of failure. Excessive foaming in the aerobic zone accompanied very low solids concentration, poor COD removal, poor clarification and failure of the nitrification and phosphate removal processes. These effects were most likely the result of an acetate overdose and oxygen entrainment in the anaerobic zones. The organisms were unable to sequester all the acetate in the anaerobic zones, with consequent acetate "leakage" into the aerobic zone. This can lead to the dominance of organisms such as Nocardia, which typically causes foaming problems (Jenkins *et al.,* 1990). However it is also likely that there was a single event in the history of the experiment that caused a change in the organism population and the system had been unable to recover from that event. This event could have been the addition of detergent formulation to the influent feed in August 1991. A further point of concern was that even before the unit failure, the systems were not removing sufficient phosphate to conform with theoretical expectations. This may have been due to oxygen being entrained in the anaerobic sufficient phosphate to conform with theoretical expectations. This may have been due to oxygen being entrained in the anaerobic zone and this possibility had to be eliminated. The sludge was discarded and the systems were thoroughly cleaned of all traces of organisms.

Once the laboratory units were emptied and thoroughly cleaned, it was clear from inspection that they needed to be modified to ensure that:

1. Both systems were identical in every respect.
2. No air could be entrained into the anaerobic and anoxic zones.
3. Effective mixing was achieved in all reactors to avoid the possibility of the zeolite settling out in the reactors.
4. Connecting tubing should be of the soft type so that they can be easily squeezed by hand thus reducing the likelihood of tube blockages and sludge wall growths.
5. Reactor supports should be arranged to give identical head differences for gravity flow between the reactors in both systems.
6. The influent containers of the two systems were kept at the same temperature, had the same influent pipe length and the same mixing intensity.
7. Inter-reactor connecting tubing cut to identical lengths.

These modifications were completed by the end of March 1992, and new sludge was collected from the Mitchell's Plain sewage works

## A1.5 DOSING OF ISOLATED BUILDERS

Because of the problems with adding the full detergent formulation (discussed above) which doubled the detergent component of the sewage and because the main purpose of the research is to determine the effect of the alternative builders on the nutrient removal activated sludge system, it was decided to isolate these builders and add them separately to the influent.

Although the direction of the research changed (from using a full formulation to using isolated builders), the results obtained during 1991 are useful to see the overall effect of using a zeolite-based detergent to replace the phosphate-based detergent and to confirm that the use of a zeolite based detergent will not have a drastic effect on the sewage treatment process.

## A1.6 DISCUSSION OF PHASE 1 RESULTS

The results from the two systems from the start of phase 1 to the beginning of acetate addition are plotted in Figures A.1 to A.8. The Control system was dosed with phosphate based detergent and the Experimental system was dosed with zeolite based detergent. The following trends can be observed from the graphs:

### A1.6.1 Solids fractions

From the plot of VSS concentration (Figure A.1), no difference can be observed between the Control and Experimental systems. This is expected since both the phosphate and zeolite based detergent formulation contain the same amounts of organic material.

From the plot of TSS concentration (Figure A.2), it appears that the Experimental system has a slightly higher TSS than the Control system. This is due to the presence of zeolite, which is an insoluble inorganic material, in the Experimental system

From the plot of VSS/TSS ratio (Figure A.3), the Experimental system shows a consistently lower VSS/TSS ratio than the Control. This is because the TSS concentration has been increased by the presence of zeolite.

### A1.6.2 Organic Material Degradation

From the plot of influent and effluent COD concentration (Figure A.4), there is no apparent difference between the effluent COD concentration of the Control and Experimental systems. This is expected since the same amount of detergent was added to both the Control and Experimental systems. The effluent COD thus represents only the unbiodegradable soluble COD, which is a characteristic of the influent sewage fed to both systems.

### A1.6.3 Nitrification

The influent and effluent TKN concentration for both the Control and Experimental systems are plotted in Figure A.5. No difference between the two systems is observed. In Figure A.6, the effluent nitrate concentration for the two systems are plotted. The Control and Experimental systems follow the same trends and no difference between them can be observed.

### A1.6.4 DSVI and Sludge Bulking

The DSVI of both the Control and Experimental systems are plotted in Figure A.7. It appears that the DSVI of the Experimental system (dosed with zeolite detergent) has a lower DSVI than the Control. However this is largely due to bulking of the Control system and not a drop in the DSVI of the Experimental system.

## A1.11

## GUIDE TO 1991 DATA:

For each variable, Control system data is listed first, then Experimental

| **PAGE NO.** | **DATE RANGE** |
|---|---|
| DSVI, TSS concentration, VSS concentration, VSS/TSS ratio, Influent and effluent COD concentration | |
| A21 | 27/06/91-29/09/91 |
| A22 | 30/09/91-3/12/91 |
| A23 | 4/12/91-22/02/92 |
| A24 | 24/02/92-8/03/92 |
| Influent & effluent TKN concentration, Phosphate concentration in influent, each reactor and effluent. | |
| A25 | 27/06/91-29/09/91 |
| A26 | 30/09/91-3/12/91 |
| A27 | 4/12/91-22/02/92 |
| A28 | 24/02/92-8/03/92 |
| Remaining phosphate concentration data, Phosphate removal, Nitrate concentration in reactors of Control system | |
| A29 | 27/06/91-29/09/91 |
| A30 | 30/09/91-3/12/91 |
| A31 | 4/12/91-22/02/92 |
| A32 | 24/02/92 |

## A1.12

Nitrate concentration data for Experimental system, Nitrite concentration for Control system

| | |
|---|---|
| A33 | 27/06/91-29/09/91 |
| A34 | 30/09/91-3/12/91 |
| A35 | 4/12/91-22/02/91 |

Nitrite concentration data for Experimental system

| | |
|---|---|
| A36 | 27/06/91-29/09/91 |
| A37 | 30/09/91-3/12/91 |
| A38 | 4/12/91-22/02/92 |

Note:

- In this first phase of experiments, the reactors are numbered as follows:

  C: Control, E: Experiment

  | | |
  |---|---|
  | C1, C11<br>E1, E11 | First and second anaerobic reactors respectively |
  | C2, E2 | 1st anoxic reactor |
  | C3, E3 | 2nd anoxic reactor |
  | C4, E4 | Aerobic reactor |

- The influent and effluent are named as IC, IE and EC, EE respectively.

- DSVI, MLSS, VSS and ISS were measured on samples taken from the aerobic reactor

* Next to date indicates day on which a new sewage batch was commenced

FIGURE A1.1: VOLATILE SUSPENDED SOLIDS CONCENTRATION (1991 DATA)

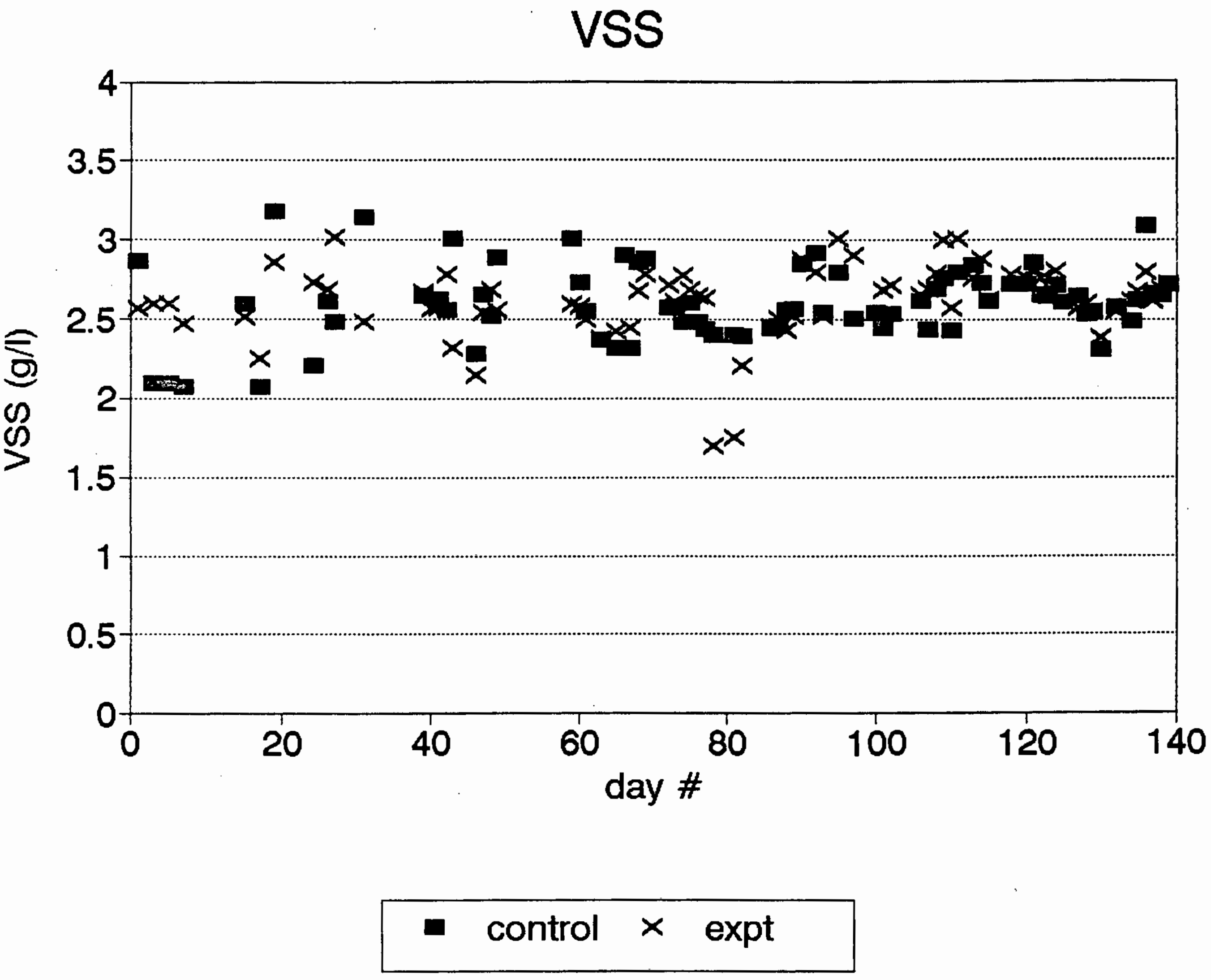


FIGURE A1.2: TOTAL SUSPENDED SOLIDS CONCENTRATION (1991 DATA)

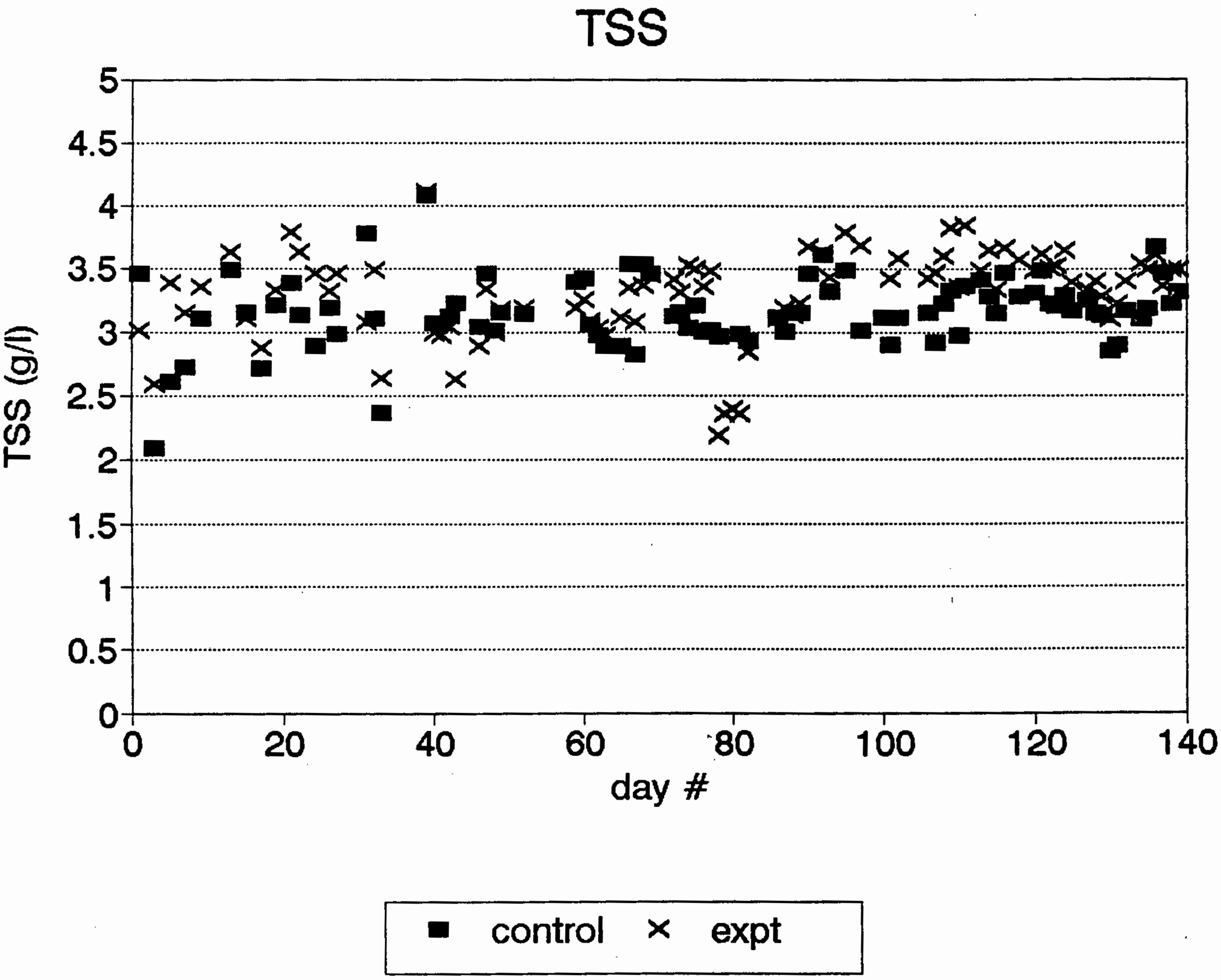


FIGURE A1.3: VSS/TSS RATIO (1991 DATA)

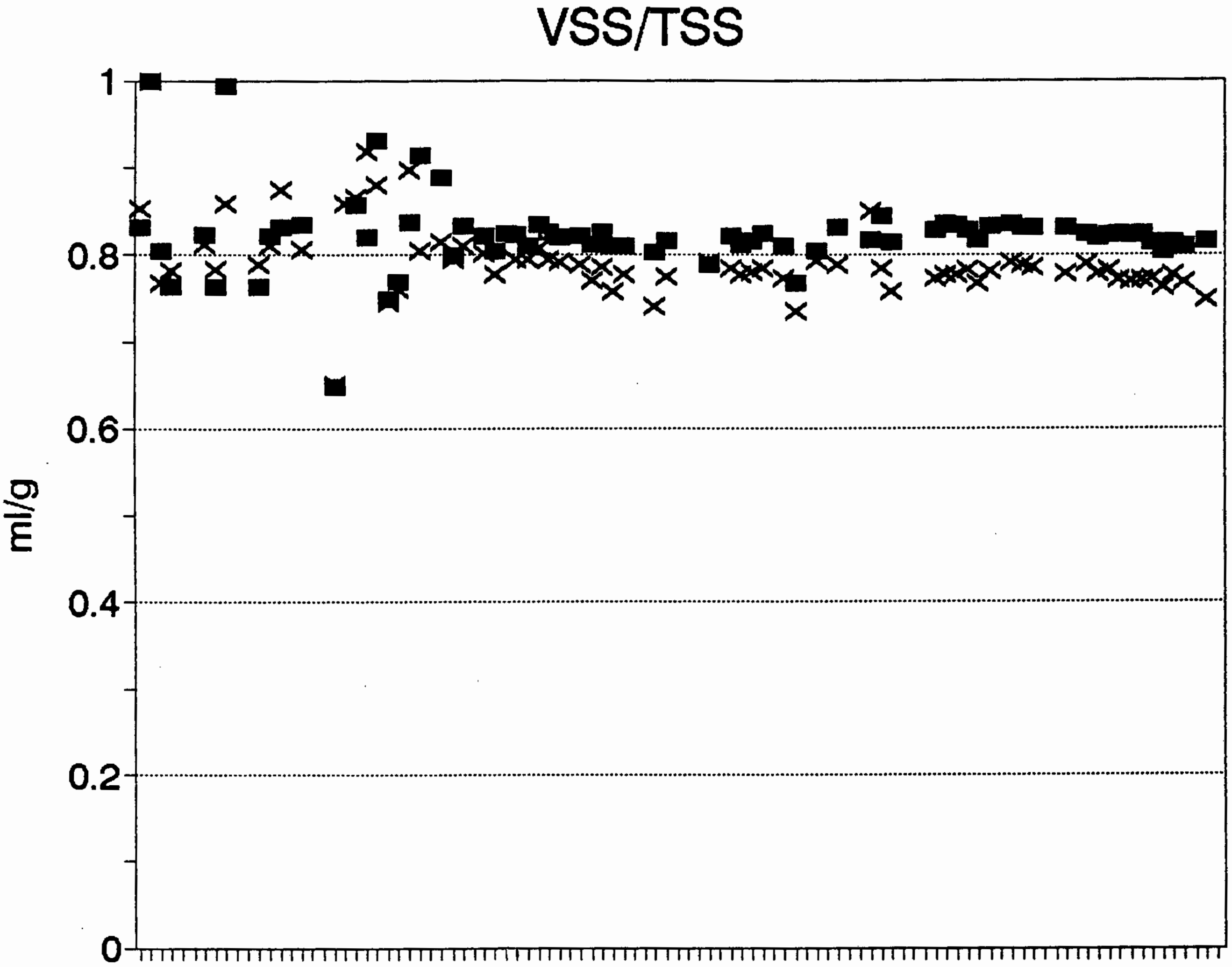


FIGURE A1.4: INFLUENT AND EFFLUENT COD CONCENTRATION (1991)

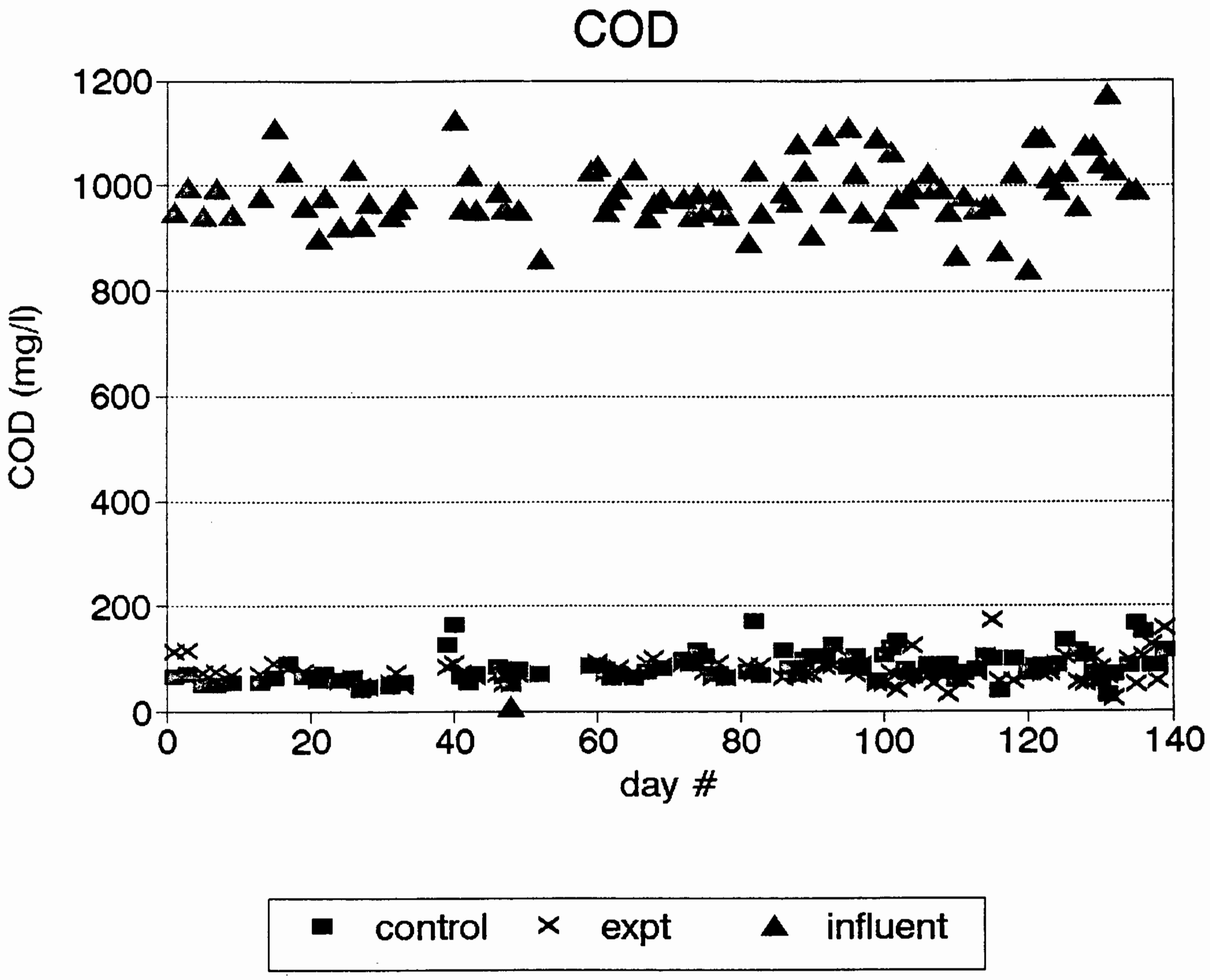


FIGURE A1.5: INFLUENT AND EFFLUENT TKN CONCENTRATION (1991)

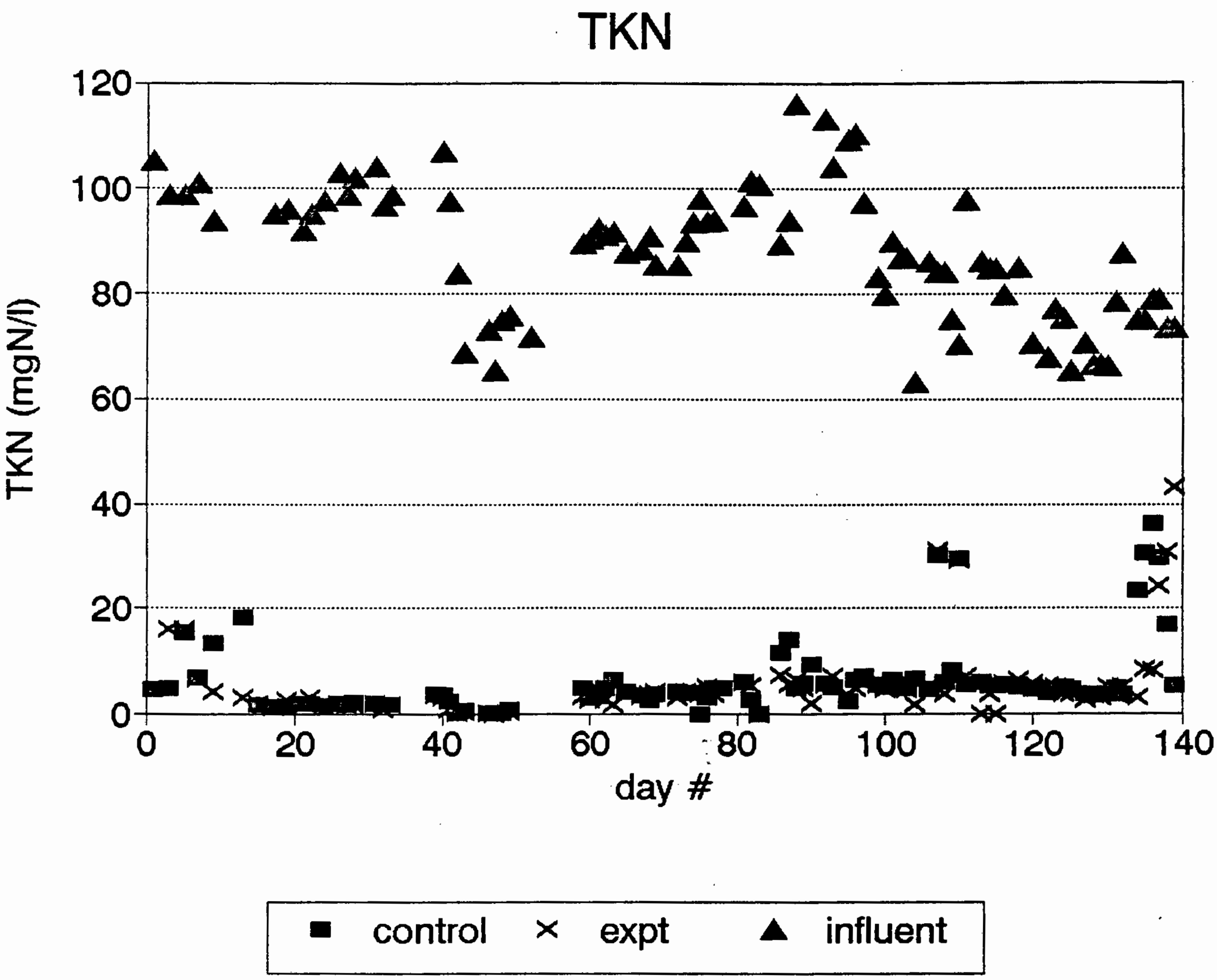


FIGURE A1.6: EFFLUENT NITRATE CONCENTRATION (1991 DATA)

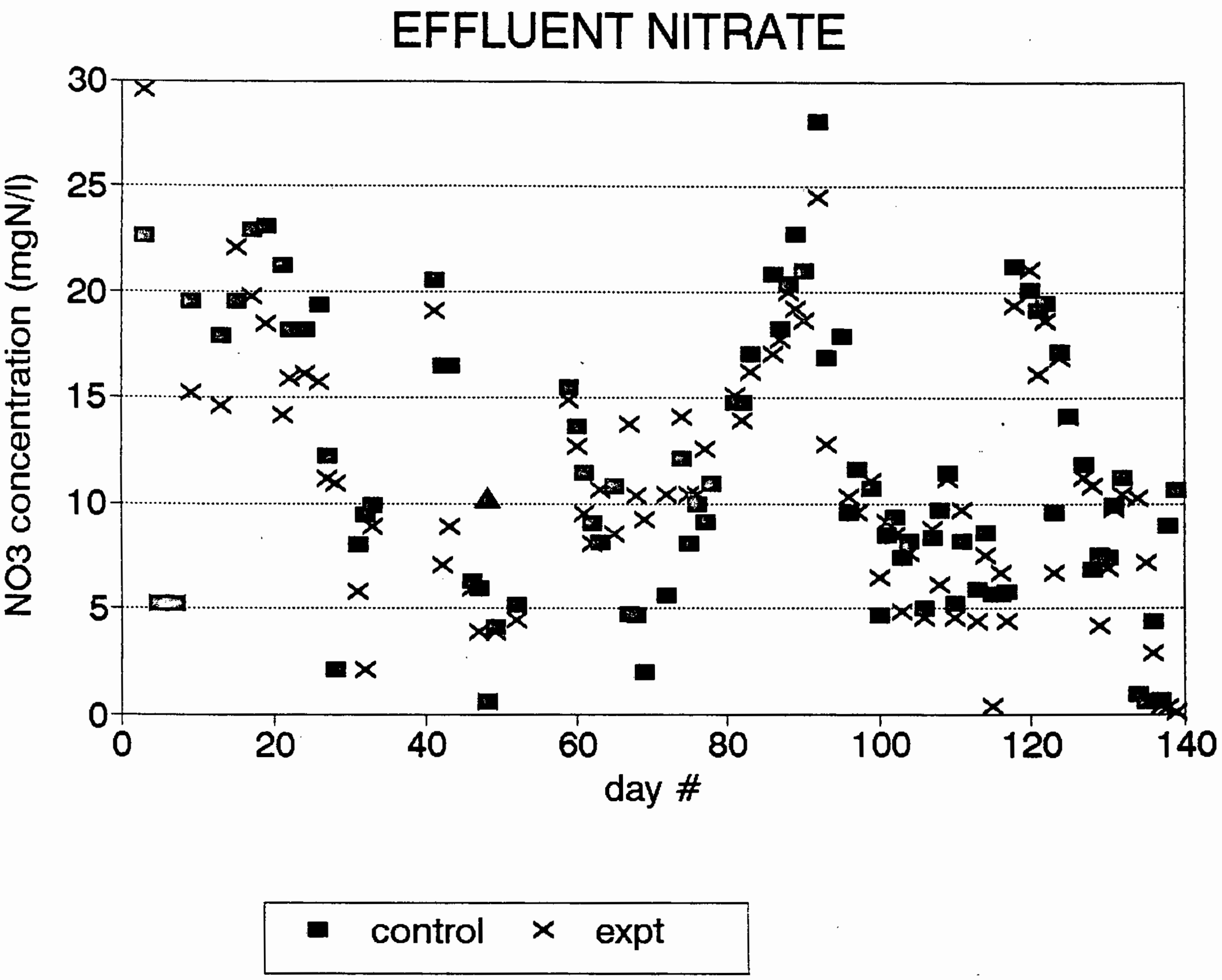


FIGURE A1.7: DSVI (1991 DATA)

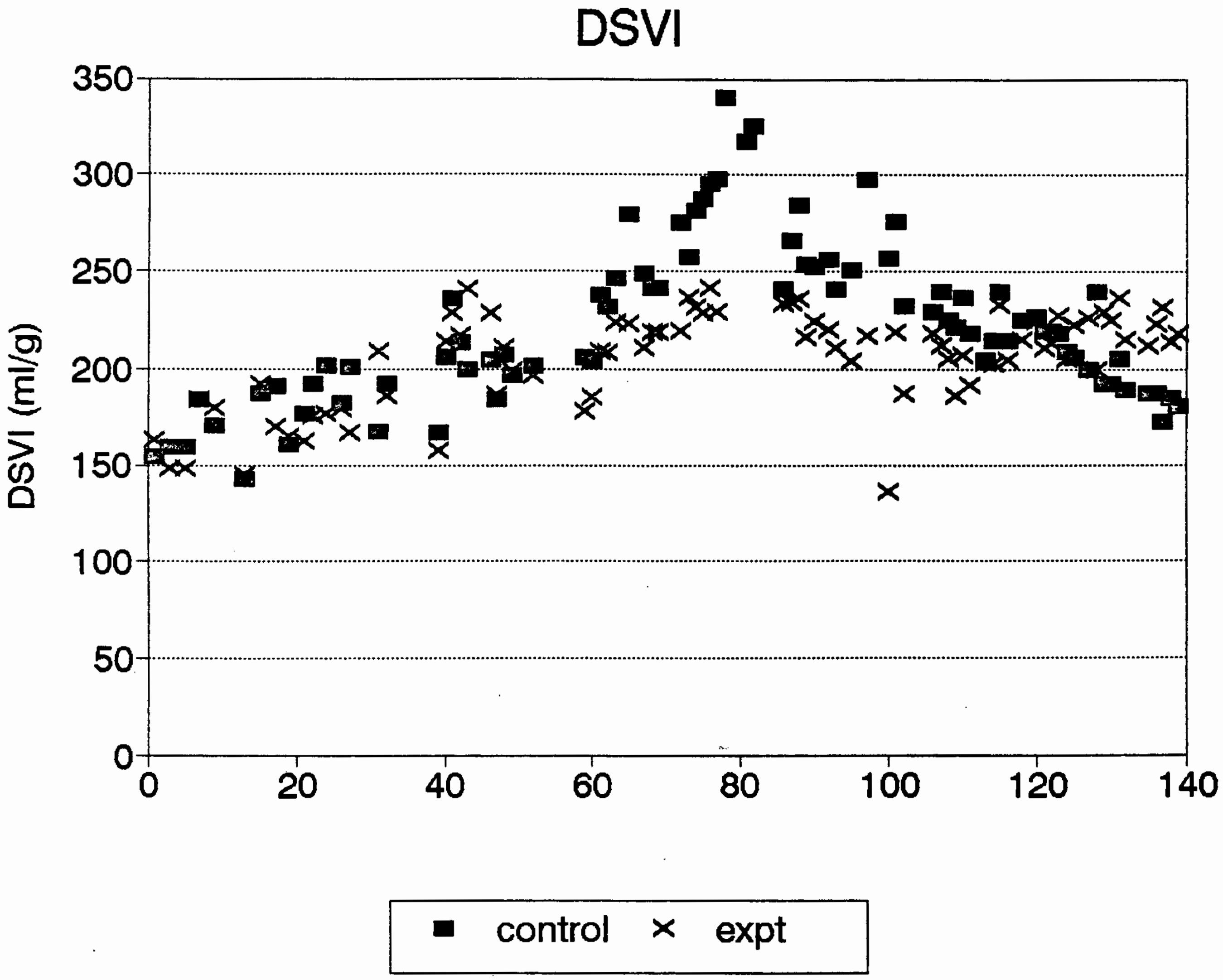
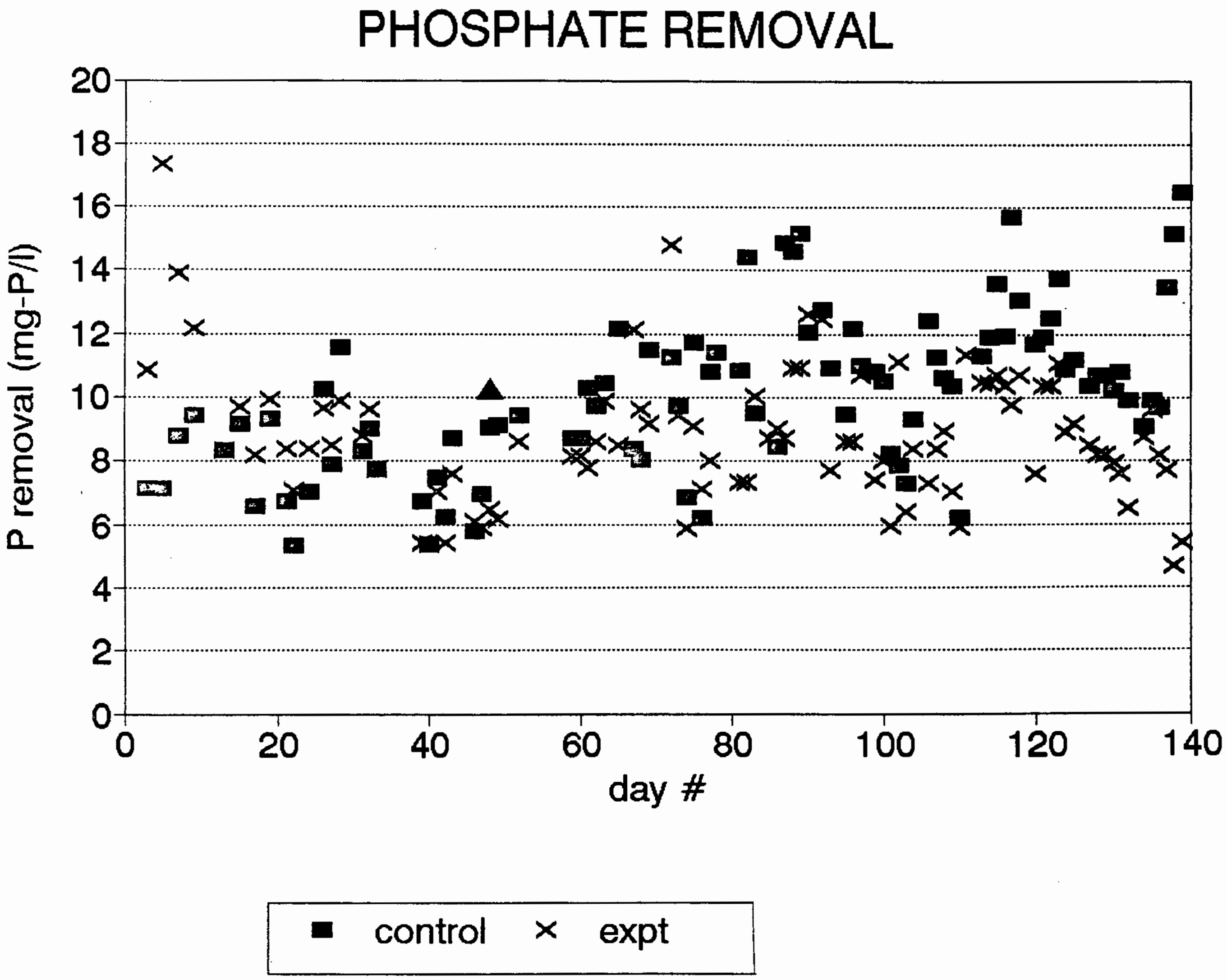


FIGURE A1.8: PHOSPHATE REMOVAL (1991 DATA)



| DATE | DSVI (mg/l) |  | MLSS (g/l) |  | VSS(g/l) |  | VSS/TSS |  | ISS |  | INFLUENT COD | EFFLUENT COD |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | C | E | C | E | C | E | C | E | C | E |  | C | E |
| 27-June * | 155 | 164 | 3.461 | 3.015 | 2.872 | 2.568 | 0.830 | 0.852 | 0.589 | 0.447 | 948 | 65 | 113 |
| 29-June | 160 | 149 | 2.098 | 2.598 | 2.098 | 2.598 | 1.000 | 1.000 | 0 | 0 | 996 | 71 | 115 |
| 30-June | 160 | 149 | 2.607 | 3.39 | 2.098 | 2.598 | 0.805 | 0.766 | 0.509 | 0.792 | 942 | 50 | 75 |
| 03-July | 184 | 184 | 2.723 | 3.164 | 2.081 | 2.472 | 0.764 | 0.781 | 0.642 | 0.692 | 994 | 51 | 76 |
| 07-July | 171 | 180 | 3.102 | 3.365 |  |  |  |  |  |  | 944 | 55 | 69 |
| 11-July | 143 | 146 | 3.497 | 3.629 |  |  |  |  |  |  | 978 | 57 | 72 |
| 13-July | 188 | 193 | 3.161 | 3.108 | 2.6 | 2.521 | 0.823 | 0.811 | 0.561 | 0.587 | 1108 | 64 | 92 |
| 15-July | 191 | 170 | 2.719 | 2.878 | 2.078 | 2.254 | 0.764 | 0.783 | 0.641 | 0.624 | 1026 | 92 | 82 |
| 17-July | 161 | 165 | 3.209 | 3.333 | 3.184 | 2.863 | 0.992 | 0.859 | 0.025 | 0.47 | 959 | 67 | 77 |
| 19-July | 177 | 163 | 3.381 | 3.796 |  |  |  |  |  |  | 898 | 61 | 61 |
| 20-July | 193 | 176 | 3.135 | 3.635 |  |  |  |  |  |  | 978 | 70 | 68 |
| 22-July | 202 | 177 | 2.893 | 3.463 | 2.211 | 2.731 | 0.764 | 0.789 | 0.682 | 0.732 | 922 | 62 | 58 |
| 24-July * | 183 | 179 | 3.186 | 3.318 | 2.614 | 2.687 | 0.820 | 0.810 | 0.572 | 0.631 | 1030 | 63 | 63 |
| 25-July | 201 | 167 | 2.991 | 3.456 | 2.483 | 3.019 | 0.830 | 0.874 | 0.508 | 0.437 | 924 | 43 | 49 |
| 26-July |  |  |  |  |  |  |  |  |  |  | 966 | 45 | 45 |
| 29-July | 168 | 209 | 3.78 | 3.081 | 3.152 | 2.482 | 0.834 | 0.806 | 0.628 | 0.599 | 942 | 49 | 57 |
| 30-July | 193 | 186 | 3.106 | 3.49 |  |  |  |  |  |  | 954 | 57 | 73 |
| 31-July |  |  | 2.375 | 2.639 |  |  |  |  |  |  | 976 | 57 | 49 |
| 06-Aug | 167 | 158 | 4.092 | 4.109 | 2.652 | 2.675 | 0.648 | 0.651 | 1.44 | 1.434 | 1258 | 128 | 84 |
| 07-Aug | 206 | 214 | 3.074 | 2.994 |  | 2.572 |  | 0.859 |  | 0.422 | 1124 | 164 | 92 |
| 08-Aug | 236 | 229 | 3.071 | 2.979 | 2.631 | 2.576 | 0.857 | 0.865 | 0.44 | 0.403 | 956 | 67 | 73 |
| 09-Aug | 213 | 217 | 3.127 | 3.036 | 2.564 | 2.784 | 0.820 | 0.917 | 0.563 | 0.252 | 1016 | 56 | 65 |
| 10-Aug | 200 | 241 | 3.238 | 2.632 | 3.014 | 2.317 | 0.931 | 0.880 | 0.224 | 0.315 | 952 | 71 | 65 |
| 13-Aug | 205 | 229 | 3.044 | 2.888 | 2.281 | 2.15 | 0.749 | 0.744 | 0.763 | 0.738 | 986 | 83 | 71 |
| 14-Aug | 184 | 187 | 3.459 | 3.338 | 2.66 | 2.54 | 0.769 | 0.761 | 0.799 | 0.798 | 956 | 65 | 54 |
| 15-Aug | 207 | 211 | 3.021 | 3 | 2.531 | 2.687 | 0.838 | 0.896 | 0.49 | 0.313 | 10.28 | 52 | 54 |
| 16-Aug | 197 | 199 | 3.158 | 3.18 | 2.889 | 2.56 | 0.915 | 0.805 | 0.269 | 0.62 | 952 | 78 | 72 |
| 19-Aug | 202 | 197 | 3.152 | 3.192 |  |  |  |  |  |  | 861 | 72 | 72 |
| 26-Aug * | 206 | 179 | 3.391 | 3.19 | 3.011 | 2.597 | 0.888 | 0.814 | 0.38 | 0.593 | 1028 | 86 | 88 |
| 27-Aug | 204 | 185 | 3.431 | 3.255 | 2.736 | 2.586 | 0.797 | 0.794 | 0.695 | 0.669 | 1034 | 86 | 94 |
| 28-Aug | 238 | 209 | 3.061 | 3.09 | 2.549 | 2.502 | 0.833 | 0.810 | 0.512 | 0.588 | 951 | 79 | 74 |
| 29-Aug | 232 | 208 | 2.971 | 3.027 |  |  |  |  |  |  | 973 | 64 | 70 |
| 30-Aug | 246 | 224 | 2.891 | 2.972 | 2.371 | 2.379 | 0.820 | 0.800 | 0.52 | 0.593 | 993 | 70 | 81 |
| 2-Sept | 279 | 223 | 2.887 | 3.117 | 2.323 | 2.421 | 0.805 | 0.777 | 0.564 | 0.696 | 1030 | 62 | 74 |
| 3-Sept |  |  | 3.534 | 3.352 | 2.91 |  | 0.823 | 0.000 | 0.624 | 3.352 |  |  |  |
| 4-Sept | 248 | 211 | 2.82 | 3.081 | 2.32 | 2.446 | 0.823 | 0.794 | 0.5 | 0.635 | 940 | 77 | 93 |
| 5-Sept | 242 | 219 | 3.538 | 3.378 | 2.866 | 2.686 | 0.810 | 0.795 | 0.672 | 0.692 | 965 | 81 | 101 |
| 6-Sept | 241 | 219 | 3.458 | 3.448 | 2.881 | 2.783 | 0.833 | 0.807 | 0.577 | 0.665 | 977 | 82 | 86 |
| 9-Sept | 276 | 220 | 3.121 | 3.416 | 2.578 | 2.716 | 0.826 | 0.795 | 0.543 | 0.7 | 975 | 98 | 92 |
| 10-Sept | 258 | 237 | 3.158 | 3.307 | 2.588 | 2.616 | 0.820 | 0.791 | 0.57 | 0.691 | 942 | 91 | 91 |
| NEW SEWAGE |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 11-Sept * | 281 | 231 | 3.024 | 3.522 | 2.484 | 2.775 | 0.821 | 0.788 | 0.54 | 0.747 | 983 | 115 | 95 |
| 12-Sept | 288 | 229 | 3.216 | 3.499 | 2.606 | 2.694 | 0.810 | 0.770 | 0.61 | 0.805 | 951 | 104 | 75 |
| 13-Sept | 295 | 242 | 3.007 | 3.364 | 2.484 | 2.646 | 0.826 | 0.787 | 0.523 | 0.718 | 975 | 71 | 63 |
| 14-Sept | 298 | 230 | 3.018 | 3.483 | 2.442 | 2.638 | 0.809 | 0.757 | 0.576 | 0.845 | 973 | 72 | 91 |
| 16-Sept | 340 | ERR | 2.968 | 2.191 | 2.402 | 1.7 | 0.809 | 0.776 | 0.566 | 0.491 | 945 | 64 | 64 |
| 17-Sept |  |  |  | 2.36 |  |  |  |  |  |  |  |  |  |
| 18-Sept |  |  |  | 2.388 |  |  |  |  |  |  |  |  |  |
| 19-Sept | 318 |  | 2.99 | 2.362 | 2.402 | 1.748 | 0.803 | 0.740 | 0.588 | 0.614 | 894 | 75 | 86 |
| 20-Sept | 325 | ERR | 2.936 | 2.842 | 2.394 | 2.204 | 0.815 | 0.776 | 0.542 | 0.638 | 1028 | 171 | 73 |
| 21-Sept |  |  |  |  |  |  |  |  |  |  | 947 | 69 | 86 |
| 22-Sept |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 23-Sept |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 24-Sept | 241 | 234 | 3.111 | 3.103 | 2.45 | 2.456 | 0.788 | 0.791 | 0.661 | 0.647 | 986 | 116 | 62 |
| NEW SEWAGE |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 25-Sept * | 266 | 235 | 3.008 | 3.196 | 2.468 | 2.506 | 0.820 | 0.784 | 0.54 | 0.69 | 967 | 82 | 78 |
| 26 Sept | 285 | 236 | 3.161 | 3.136 | 2.562 | 2.433 | 0.811 | 0.776 | 0.599 | 0.703 | 1080 | 72 | 68 |
| 27-Sept | 253 | 216 | 3.156 | 3.236 | 2.573 | 2.523 | 0.815 | 0.780 | 0.583 | 0.713 | 1028 | 98 | 71 |
| 28-Sept | 253 | 225 | 3.462 | 3.674 | 2.851 | 2.883 | 0.824 | 0.785 | 0.611 | 0.791 | 907 | 106 | 71 |
| 29-Sept |  |  |  |  |  |  |  |  |  |  |  |  |  |

**A1.22**

| DATE | DSVI (mg/l) | | MLSS (g/l) | | VSS(g/l) | | VSS/TSS | | ISS | | INFLUENT | EFFLUENT COD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | C | E | C | E | C | E | C | E | C | E | COD | C | E |
| 30-Sept | 256 | 220 | 3.607 | 3.633 | 2.922 | 2.807 | 0.810 | 0.773 | 0.685 | 0.826 | 1094 | 104 | 83 |
| 01-Oct | 241 | 211 | 3.323 | 3.44 | 2.546 | 2.525 | 0.766 | 0.734 | 0.777 | 0.915 | 965 | 129 | 87 |
| 02-Oct | | | | | | | | | | | | | |
| 03-Oct | 251 | 204 | 3.491 | 3.793 | 2.806 | 3.008 | 0.804 | 0.793 | 0.685 | 0.785 | 1111 | 85 | 102 |
| 04_oct | | | | | | | | | | | 1023 | 104 | 71 |
| 05-Oct | 298 | 217 | 3.021 | 3.691 | 2.511 | 2.907 | 0.831 | 0.788 | 0.51 | 0.784 | 948 | 81 | 89 |
| 06-Oct | | | | | | | | | | | | | |
| 07-Oct | | | | | | | | | | | 1090 | 58 | 54 |
| 08-Oct | 257 | 137 | 3.114 | 5.484 | 2.544 | 4.664 | 0.817 | 0.850 | 0.57 | 0.82 | 932 | 108 | 54 |
| 09-Oct | 276 | 219 | 2.899 | 3.428 | 2.445 | 2.69 | 0.843 | 0.785 | 0.454 | 0.738 | 1065 | 121 | 75 |
| 10-Oct * | 232 | 188 | 3.119 | 3.589 | 2.538 | 2.716 | 0.814 | 0.757 | 0.581 | 0.873 | 975 | 133 | 42 |
| 11-Oct | | | | | | | | | | | 975 | 78 | 60 |
| 12-Oct | | | | | | | | | | | 994 | 65 | 126 |
| 13-Oct | | | | | | | | | | | | | |
| 14-Oct | 230 | 218 | 3.159 | 3.434 | 2.618 | 2.657 | 0.829 | 0.774 | 0.541 | 0.777 | 1022 | 90 | 67 |
| 15-Oct | 239 | 212 | 2.926 | 3.472 | 2.443 | 2.698 | 0.835 | 0.777 | 0.483 | 0.774 | 994 | 86 | 53 |
| 16-Oct | 225 | 206 | 3.238 | 3.598 | 2.699 | 2.793 | 0.834 | 0.776 | 0.539 | 0.805 | 994 | 77 | 75 |
| 17-Oct | 221 | 187 | 3.33 | 3.832 | 2.758 | 2.998 | 0.828 | 0.782 | 0.572 | 0.834 | 951 | 91 | 34 |
| 18-Oct | 237 | 207 | 2.979 | 3.36 | 2.433 | 2.577 | 0.817 | 0.767 | 0.546 | 0.783 | 867 | 62 | 70 |
| 19-Oct | 218 | 192 | 3.371 | 3.848 | 2.805 | 3.008 | 0.832 | 0.782 | 0.566 | 0.84 | 980 | 74 | 58 |
| 20-Oct | | | | | | | | | | | | | |
| 21-Oct | 205 | 203 | 3.414 | 3.495 | 2.85 | 2.764 | 0.835 | 0.791 | 0.564 | 0.731 | 956 | 80 | 74 |
| 22-Oct | 215 | 203 | 3.291 | 3.658 | 2.735 | 2.885 | 0.831 | 0.789 | 0.556 | 0.773 | 964 | 106 | 104 |
| 23-Oct | 239 | 233 | 3.157 | 3.344 | 2.623 | 2.629 | 0.831 | 0.786 | 0.534 | 0.715 | 964 | 100 | 174 |
| 24-Oct | 215 | 205 | 3.471 | 3.662 | | | | | | | 878 | 39 | 59 |
| 25-Oct | ERR | ERR | 0 | 0 | 0 | 0 | | | | | | | |
| 26-Oct | 225 | 215 | 3.283 | 3.575 | 2.728 | 2.785 | 0.831 | 0.779 | 0.555 | 0.79 | 1022 | 101 | 59 |
| 27-Oct | | | | | | | | | | | | | |
| 28-Oct * | 227 | 225 | 3.307 | 3.496 | 2.725 | 2.759 | 0.824 | 0.789 | 0.582 | 0.737 | 842 | 73 | 75 |
| 29-Oct | 219 | 211 | 3.489 | 3.622 | 2.86 | 2.82 | 0.820 | 0.779 | 0.629 | 0.802 | 1090 | 84 | 84 |
| 30-Oct | 220 | 213 | 3.229 | 3.518 | 2.653 | 2.757 | 0.822 | 0.784 | 0.576 | 0.761 | 1090 | 86 | 72 |
| 31-Oct | 218 | 227 | 3.211 | 3.523 | 2.645 | 2.721 | 0.824 | 0.772 | 0.566 | 0.802 | 1016 | 82 | 74 |
| 01-Nov | 209 | 205 | 3.301 | 3.651 | 2.717 | 2.814 | 0.823 | 0.771 | 0.584 | 0.837 | 991 | 90 | 90 |
| 02-Nov | 206 | 222 | 3.174 | 3.397 | 2.615 | 2.623 | 0.824 | 0.772 | 0.559 | 0.774 | 1026 | 135 | 104 |
| 04-Nov | 200 | 226 | 3.252 | 3.341 | 2.646 | 2.583 | 0.814 | 0.773 | 0.606 | 0.758 | 961 | 114 | 55 |
| 05-Nov | 239 | 200 | 3.157 | 3.406 | 2.539 | 2.601 | 0.804 | 0.764 | 0.618 | 0.805 | 1075 | 108 | 52 |
| 06-Nov | 193 | 230 | 3.135 | 3.289 | 2.552 | 2.552 | 0.814 | 0.776 | 0.583 | 0.737 | 1075 | 73 | 101 |
| 07-Nov | 193 | 225 | 2.854 | 3.105 | 2.31 | 2.385 | 0.809 | 0.768 | 0.544 | 0.72 | 1040 | 61 | 82 |
| 08-Nov * | 205 | 237 | 2.901 | 3.234 | | | | | | | 1171 | 29 | 66 |
| 09-Nov | 189 | 215 | 3.168 | 3.412 | 2.584 | 2.556 | 0.816 | 0.749 | 0.584 | 0.856 | 1028 | 70 | 25 |
| 11-Nov | | | 3.1 | 3.548 | 2.492 | 2.624 | 0.804 | 0.740 | 0.608 | 0.924 | 991 | 88 | 96 |
| 12-Nov | 188 | 212 | 3.188 | 3.504 | 2.628 | 2.68 | 0.824 | 0.765 | 0.56 | 0.824 | 991 | 166 | 51 |
| 13-Nov | 188 | 223 | 3.672 | 3.616 | 3.096 | 2.8 | 0.843 | 0.774 | 0.576 | 0.816 | 1221 | 152 | 106 |
| 14-Nov | 172.8 | 231.5 | 3.468 | 3.38 | 2.668 | 2.624 | 0.769 | 0.776 | 0.8 | 0.756 | 1221 | 87.90 | 127.2 |
| 15-Nov | 185.2 | 213.6 | 3.236 | 3.508 | 2.66 | 2.7 | 0.822 | 0.770 | 0.576 | 0.808 | 1222 | 85.80 | 58.9 |
| 16-Nov | 180.8 | 218.3 | 3.316 | 3.508 | 2.728 | 2.728 | 0.823 | 0.778 | 0.588 | 0.78 | 1222 | 114.80 | 160.3 |
| 18-Nov | 180.0 | 212.8 | 3.516 | 3.6 | 2.916 | 2.82 | 0.829 | 0.783 | 0.6 | 0.78 | 1001 | 91.00 | 157.1 |
| 19-Nov | 193.6 | 228.3 | 3.268 | 3.72 | 2.66 | 2.68 | 0.814 | 0.720 | 0.608 | 1.04 | 1071 | 86.90 | 120 |
| 20-Nov * | 198.2 | 268.2 | 3.192 | 3.228 | 2.616 | 2.488 | 0.820 | 0.771 | 0.576 | 0.74 | 930.6 | 86.90 | 165.4 |
| 21-Nov | | | | | | | | | | | | | |
| 22-Nov | 272.3 | 200.3 | 2.996 | 2.992 | 1.732 | 2.432 | 0.578 | 0.813 | 1.264 | 0.56 | 1009 | 78.60 | 157 |
| 23-Nov | 196.4 | 273.3 | 3.136 | 2.924 | 2.568 | 2.26 | 0.819 | 0.773 | 0.568 | 0.664 | 943 | 74.50 | 95.1 |
| 25-Nov | 195.2 | 348.8 | 3.584 | 2.912 | 2.94 | 2.464 | 0.820 | 0.846 | 0.644 | 0.448 | 1381 | 70.30 | 215 |
| 26-Nov | 206.8 | 398.5 | 3.22 | 2.992 | 2.64 | 2.328 | 0.820 | 0.778 | 0.58 | 0.664 | 1025 | 74.40 | 161.3 |
| 27-Nov | 203.7 | 338.7 | 3.188 | 2.9 | 2.58 | 2.22 | 0.809 | 0.766 | 0.608 | 0.68 | 1100 | 85.80 | 110.6 |
| 28-Nov | 220.7 | 386.4 | 3.168 | 2.844 | 2.692 | 2.24 | 0.850 | 0.788 | 0.476 | 0.604 | 1100 | 85.80 | 114.8 |
| 29-Nov | 211.9 | 402.8 | 3.3 | 2.728 | | | | | | | 1100 | 77.60 | 106.5 |
| 30-Nov | 220.4 | 441 | 3.324 | 3.096 | 2.692 | 2.108 | 0.810 | 0.681 | 0.632 | 0.988 | 1054 | 51.70 | 55.8 |
| 2-Dec | 203.0 | 348.3 | 3.608 | 2.964 | 2.962 | 2.348 | 0.821 | 0.792 | 0.646 | 0.616 | 1034 | 107.00 | 66.7 |
| 3-Dec | 201.4 | 355.8 | 3.472 | 2.808 | 2.84 | 2.252 | 0.818 | 0.802 | 0.632 | 0.556 | 1034 | 94.90 | 167.7 |

| DATE | DSVI (mg/l) | | MLSS (g/l) | | VSS(g/l) | | VSS/TSS | | ISS | | INFLUENT | EFFLUENT COD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | C | E | C | E | C | E | C | E | C | E | COD | C | E |
| 4 Dec * | 201.9 | 333.5 | 3.464 | 2.896 | 2.824 | 2.252 | 0.815 | 0.778 | 0.64 | 0.644 | 949.4 | 66.70 | 66.7 |
| 5-Dec | 187.5 | 316.4 | 3.556 | 3.108 | 2.86 | 2.464 | 0.804 | 0.793 | 0.696 | 0.644 | 949.4 | 62.60 | 131.1 |
| 6-Dec | 178.6 | 274.6 | 3.356 | 3.032 | 2.764 | 2.46 | 0.824 | 0.811 | 0.592 | 0.572 | 1014 | 62.60 | 50.5 |
| 7-Dec | 172.4 | 267.7 | 3.476 | 3.172 | 2.812 | 2.536 | 0.809 | 0.799 | 0.664 | 0.636 | 1014 | 62.60 | 48.8 |
| 9-Dec | 147.1 | 202.8 | 3.848 | 3.284 | 3.112 | 2.648 | 0.809 | 0.806 | 0.736 | 0.636 | 860 | 64.60 | 46.5 |
| 10-Dec | 143.2 | 191.4 | 3.8 | 3.48 | 3.164 | 2.8 | 0.825 | 0.805 | 0.672 | 0.68 | 1018 | 86.90 | 109.1 |
| 11-Dec | 168.3 | 192 | 3.648 | 3.468 | 3.012 | 2.804 | 0.826 | 0.809 | 0.636 | 0.664 | 1018 | 68.70 | 52.5 |
| 12-Dec | 149.0 | 176.6 | 4.024 | 3.772 | 3.324 | 3.016 | 0.826 | 0.800 | 0.7 | 0.756 | 1042 | 64.60 | 48.5 |
| 13-Dec | 142.7 | 173.8 | 3.968 | 3.736 | 3.276 | 3.012 | 0.826 | 0.806 | 0.692 | 0.724 | 1042 | 52.50 | 54.5 |
| 14-Dec | 151.5 | 163.3 | 3.956 | 3.772 | 3.296 | 3.06 | 0.833 | 0.811 | 0.66 | 0.712 | | | |
| 17-Dec | 136.6 | 149.4 | 4.144 | 3.9 | 3.416 | 3.364 | 0.824 | 0.863 | 0.728 | 0.536 | 1113 | 89.70 | 104 |
| 18-Dec | 131.1 | 150.4 | 4.3 | 3.808 | 3.5 | 3.132 | 0.811 | 0.822 | 0.816 | 0.676 | 1113 | 73.40 | 83.6 |
| 19-Dec * | 136.1 | 143.5 | 4.16 | 3.828 | 3.42 | 3.104 | 0.822 | 0.811 | 0.74 | 0.724 | 1321 | 187.60 | 177.4 |
| 20-Dec | 134.9 | 135.2 | 4.072 | 3.94 | | | | | | | 1003 | 48.90 | 99.9 |
| 21-Dec | 153.2 | 137.9 | 3.696 | 3.864 | 3.096 | 3.164 | 0.838 | 0.819 | 0.6 | 0.7 | 1142 | 77.50 | 99.9 |
| 23-Dec | 143.0 | 124 | 3.96 | 3.492 | 3.296 | 2.916 | 0.832 | 0.835 | 0.664 | 0.576 | 995 | 77.50 | 65.2 |
| 02-Jan | 174.7 | 109.9 | 3.072 | 3.093 | 2.595 | 2.615 | 0.845 | 0.845 | 0.477 | 0.478 | 1229 | 56.30 | 59.1 |
| 03-Jan | 145.6 | 95.8 | 3.888 | 3.996 | 3.32 | 2.536 | 0.854 | 0.635 | 0.568 | 1.46 | 975 | 73.40 | 67.3 |
| 04-Jan | 141.4 | 124.3 | 3.296 | 2.812 | 2.736 | 2.356 | 0.830 | 0.838 | 0.56 | 0.456 | 1043 | 86.60 | 79.5 |
| 06-Jan | 151.7 | 118.6 | 3.956 | 2.952 | 3.32 | 2.508 | 0.839 | 0.850 | 0.636 | 0.444 | 962 | 48.90 | 54 |
| 07-Jan | 155.9 | 126.3 | 3.848 | 2.904 | 3.172 | 2.604 | 0.824 | 0.897 | 0.676 | 0.3 | 987 | 67.30 | 63.2 |
| 08-Jan * | 152.4 | 113.9 | 3.9 | 2.924 | 3.236 | 2.352 | 0.823 | 0.804 | 0.696 | 0.572 | 1108 | 74.40 | 78.5 |
| 09-Jan | 142.7 | 116.7 | 3.5 | 2.996 | 2.92 | 2.748 | 0.834 | 0.917 | 0.58 | 0.248 | 983 | 73.40 | 81.6 |
| 10-Jan | 146.1 | 123.3 | 3.648 | 2.7 | 3.028 | 2.28 | 0.830 | 0.844 | 0.62 | 0.42 | 1159 | 86.00 | 57.4 |
| 11-Jan | 145.5 | 137.7 | 3.892 | 2.84 | 3.216 | 2.412 | 0.826 | 0.849 | 0.676 | 0.428 | 1155 | 65.50 | 65.5 |
| 13-Jan | 142.4 | 112 | 3.508 | 2.976 | 2.988 | 2.532 | 0.852 | 0.851 | 0.52 | 0.444 | 987 | 69.30 | 77.5 |
| 14-Jan | 151.3 | 116.1 | 3.632 | 3.156 | 3.045 | 2.598 | 0.838 | 0.823 | 0.587 | 0.558 | 937.8 | 89.70 | 65.2 |
| 15-Jan | 134.3 | 126.8 | 3.348 | 3.676 | 2.762 | 2.924 | 0.825 | 0.795 | 0.586 | 0.752 | 995 | 85.60 | 61.2 |
| 16-Jan | 124.1 | 125.1 | 3.758 | 3.86 | 3.064 | 3.154 | 0.815 | 0.817 | 0.694 | 0.706 | | | |
| 17-Jan | 132.0 | 131.7 | 3.409 | 3.644 | 2.794 | 3 | 0.820 | 0.823 | 0.615 | 0.644 | 1077 | 73.70 | 73.73 |
| 18-Jan | 122.3 | 129 | 3.544 | 3.748 | 2.956 | 3.108 | 0.834 | 0.829 | 0.588 | 0.64 | 1020 | 83.97 | 63.49 |
| 20-Jan * | 130.1 | 137 | 3.84 | 3.888 | 3.188 | 3.236 | 0.830 | 0.832 | 0.652 | 0.652 | 1073.1 | 86.00 | 77.8 |
| 21-Jan | 135.8 | 144.94 | 3.8 | 3.676 | 3.16 | 3.052 | 0.832 | 0.830 | 0.64 | 0.624 | 1060 | 63.49 | 47.1 |
| 22-Jan | 128.6 | 141.1 | 3.9 | 3.776 | 3.176 | 3.094 | 0.818 | 0.819 | 0.708 | 0.682 | 1073 | 61.44 | 36.86 |
| 23-Jan | 132.1 | 155.69 | 3.78 | 3.636 | 3.128 | 3.004 | 0.828 | 0.826 | 0.652 | 0.632 | 1073 | 77.82 | 77.8 |
| 24-Jan | 127.6 | 140.72 | 3.916 | 3.665 | 3.276 | 2.99 | 0.837 | 0.816 | 0.64 | 0.675 | 1069 | 65.54 | 73.73 |
| 25-Jan | 134.0 | 139.79 | 3.78 | 3.696 | 3.1553 | 3.0492 | 0.835 | 0.825 | 0.6237 | 0.6468 | 1052 | 98.30 | 49.15 |
| 27-Jan | 137.8 | 145.12 | 4.111 | 3.675 | 3.4 | 3.051 | 0.827 | 0.830 | 0.711 | 0.624 | 1065 | 126.98 | 59.39 |
| 28-Jan | 135.4 | 139.9 | 3.94 | 3.812 | 3.256 | 3.196 | 0.826 | 0.838 | 0.684 | 0.616 | 1060 | 114.70 | 77.8 |
| 29-Jan | 133.6 | 125.8 | 3.988 | 3.972 | 3.268 | 3.318 | 0.819 | 0.835 | 0.72 | 0.654 | 983 | 147.50 | 53.2 |
| 30-Jan | 137.9 | 129.9 | 3.868 | 3.848 | 3.154 | 3.158 | 0.815 | 0.821 | 0.714 | 0.69 | 1114 | 127.00 | 49.2 |
| 31-Jan | 125.2 | 123.3 | 4.285 | 3.973 | 3.632 | 3.372 | 0.848 | 0.849 | 0.653 | 0.601 | 1156 | 132.90 | 62.8 |
| 01-Feb * | 137.6 | 143.8 | 3.828 | 3.87 | 3.236 | 3.286 | 0.845 | 0.849 | 0.592 | 0.584 | 1248 | 154.50 | 63.9 |
| 03-Feb | 135.5 | 137.9 | 3.716 | 3.698 | 3.08 | 3.088 | 0.829 | 0.835 | 0.636 | 0.61 | 966 | 50.50 | 42.2 |
| 04-Feb | 138.3 | 138.5 | 3.784 | 3.778 | 3.13 | 3.148 | 0.827 | 0.833 | 0.654 | 0.63 | 840 | 59.70 | 49.4 |
| 05-Feb | 138.7 | 129.5 | 3.604 | 3.836 | 2.968 | 3.182 | 0.824 | 0.830 | 0.636 | 0.654 | 1017 | 70.04 | 63.86 |
| 06-Feb | 148.4 | 138.2 | 3.706 | 3.69 | 3.064 | 3.084 | 0.827 | 0.836 | 0.642 | 0.606 | 948 | 47.38 | 51.5 |
| 07-Feb | 154.9 | 144.6 | 3.658 | 3.572 | 2.964 | 2.93 | 0.810 | 0.820 | 0.694 | 0.642 | 911 | 53.56 | 49.44 |
| 08-Feb | 144.7 | 140.4 | 3.686 | 3.586 | 3.046 | 2.968 | 0.826 | 0.828 | 0.64 | 0.618 | 960 | 55.60 | 55.6 |
| 10-Feb | 148.0 | 147.4 | 3.492 | 3.28 | 2.886 | 2.715 | 0.826 | 0.828 | 0.606 | 0.565 | 931 | 65.92 | 45.3 |
| 12-Feb | 152.2 | 150.6 | 3.394 | 3.21 | 2.806 | 2.664 | 0.827 | 0.830 | 0.588 | 0.546 | 908 | 56.65 | 56.65 |
| 13-Feb | 156.5 | 153.8 | 3.194 | 3.208 | 2.596 | 2.632 | 0.813 | 0.820 | 0.598 | 0.576 | 849 | 43.26 | 65.9 |
| 14-Feb | 156.0 | 149.7 | 3.206 | 3.252 | 2.626 | 2.692 | 0.819 | 0.828 | 0.58 | 0.56 | 833 | 43.01 | 40.96 |
| 15-Feb * | 156.5 | 150.9 | 2.982 | 3.18 | 2.456 | 2.652 | 0.824 | 0.834 | 0.526 | 0.528 | 1044 | 30.72 | 57.34 |
| 17-Feb | | | 3.504 | 3.182 | 2.914 | 2.67 | 0.832 | 0.839 | 0.59 | 0.512 | 956 | 55.30 | 61.4 |
| 18-Feb | 148.5 | 155.2 | 3.278 | 3.158 | 2.712 | 2.626 | 0.827 | 0.832 | 0.566 | 0.532 | 868 | 36.90 | 49.2 |
| 19-Feb | 153.1 | 155.1 | 3.2 | 3.116 | 2.652 | 2.61 | 0.821 | 0.838 | 0.58 | 0.506 | 922 | 59.40 | 77.8 |
| 20-Feb | 139.0 | 154.8 | 3.476 | 3.23 | 2.878 | 2.7 | 0.828 | 0.836 | 0.598 | 0.53 | 1124 | 60.40 | 93.2 |
| 21-Feb | 144.6 | 146.1 | 3.204 | 3.171 | 2.63 | 2.635 | 0.821 | 0.831 | 0.574 | 0.536 | 889 | 55.30 | 59.4 |
| 22-Feb | 143.8 | 151 | 3.222 | 3.112 | 2.636 | 2.57 | 0.818 | 0.826 | 0.586 | 0.542 | 1022 | 64.50 | 68.6 |

| DATE | DSVI (mg/l) | | MLSS (g/l) | | VSS(g/l) | | VSS/TSS | | ISS | | INFLUENT | EFFLUENT COD | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | C | E | C | E | C | E | C | E | C | E | COD | C | E |
| 24-Feb * | 136.9 | 148 | 3.312 | 3.154 | 2.688 | 2.58 | 0.812 | 0.818 | 0.624 | 0.574 | 872 | 55.30 | 53.2 |
| 25-Feb | 153.3 | 151.2 | 3.262 | 3.108 | 2.638 | 2.588 | 0.809 | 0.833 | 0.624 | 0.52 | 868 | 57.30 | 57.3 |
| 27-Feb | | | | | | | | | | | 974 | 83.97 | 81.9 |
| 28-Feb | 158.6 | 147.3 | 3.174 | 3.19 | 2.632 | 2.612 | 0.829 | 0.819 | 0.542 | 0.578 | 930 | 88.10 | 88.1 |
| 29-Feb | 154.1 | 142.8 | 3.266 | 3.292 | 2.686 | 2.754 | 0.822 | 0.837 | 0.58 | 0.538 | | | |
| 2-March | 160.9 | 154.1 | 3.466 | 2.964 | 2.86 | 2.506 | 0.825 | 0.845 | 0.606 | 0.458 | 930 | 71.70 | 77.8 |
| 3-March | 156.4 | 152.2 | 3.304 | 3.066 | 2.708 | 2.558 | 0.820 | 0.834 | 0.596 | 0.508 | 903 | 57.34 | 53.2 |
| 4-March | 137.7 | 165.8 | 3.39 | 3.216 | 2.81 | 2.688 | 0.829 | 0.836 | 0.58 | 0.528 | 823 | 45.60 | 51.2 |
| 5-March * | 152.2 | 143.1 | 3.394 | 3.214 | 2.772 | 2.66 | 0.817 | 0.828 | 0.622 | 0.554 | 983 | 75.30 | 59 |
| 6-March | 153.3 | 144.7 | 3.37 | 3.226 | 2.732 | 2.666 | 0.811 | 0.826 | 0.638 | 0.56 | 1044 | 37.70 | 47.8 |
| 7-Mar | 156.6 | 146.1 | 3.406 | 3.194 | 2.794 | 2.656 | 0.820 | 0.832 | 0.612 | 0.538 | 885 | 35.60 | 49.9 |
| 8-Mar | 150.1 | 150.8 | 3.554 | 3.094 | | | | | | | | | |
| 9-Mar | | | | | | | | | | | | 32.60 | 118.1 |
| 10-Mar | | | 3.320 | 3.161 | 2.723 | 2.627 | | | 0.597 | 0.534 | | | |

# A1.25

| DATE INFLUENT EFFLUENT TKN | | | | | | | PHOSPHATES | | (mg-P/l) | | | PHOSPHATE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TKN | I | CE | EE | IC | C1 | C11 | C2 | C3 | C4 | CE | IE | E1 | E11 |
| 27-June * | 105 | 4.55 | | | | | | | | | | | |
| 29-June | 98.5 | 4.7 | 16.1 | 17.4 | | 25.9 | 27.5 | 14.9 | 10.2 | 10.2 | 17.4 | | 20.8 |
| 30-June | 98.5 | 15.3 | 16.1 | 17.4 | | 25.9 | 27.5 | 14.9 | 10.2 | 10.2 | 17.4 | | 20.8 |
| 03-July | 101 | 6.9 | 6.6 | 17.6 | | 21.9 | 24.7 | 14.6 | 10.2 | 8.8 | 17.6 | | 21.4 |
| 07-July | 93.6 | 13.3 | 4.2 | 17.5 | | 19.3 | 21.2 | 12.3 | 8.8 | 8 | 17.5 | | 21.7 |
| 11-July | 127 | 18.3 | 3.1 | 18.0 | | 27.9 | 23.6 | 15.3 | 11.2 | 9.6 | 18.0 | | 25.8 |
| 13-July | 128 | 1.75 | 1.9 | 18.8 | | 21.2 | 15.5 | 11.8 | 10.4 | 9.6 | 18.8 | | 21.2 |
| 15-July | 95 | 1.26 | 1.26 | 16.2 | | 25.2 | 20.6 | 12.3 | 9.9 | 9.6 | 16.2 | | 22.8 |
| 17-July | 96 | 1.54 | 2.8 | 19.1 | | 21.6 | 15.8 | 12 | 10.6 | 9.8 | 19.1 | | 21.6 |
| 19-July | 92 | 2 | 2.17 | 16.5 | | 25.7 | 21 | 12.5 | 10.1 | 9.8 | 16.5 | | 23.2 |
| 20-July | 95 | 1.9 | 2.94 | 14.5 | | 23.1 | 17.2 | 11.8 | 9.3 | 9.1 | 14.5 | | 29.6 |
| 22-July | 97.5 | 1.33 | 1.33 | 15.8 | | 22.8 | 19.1 | 11.2 | 9.1 | 8.8 | 15.8 | | 21.5 |
| 24-July * | 103 | 1.93 | 1.96 | 18.2 | | 24.1 | 21.5 | 13 | 9.6 | 7.9 | 18.2 | | 24.7 |
| 25-July | 98.5 | 1.56 | 1.61 | 17.8 | | 24.7 | 22.7 | 13.6 | 9.9 | 9.9 | 17.8 | | 24.7 |
| 26-July | 102 | 2.14 | 1.79 | 19.4 | | 26.9 | 25.2 | 15.5 | 7.8 | 7.8 | 19.4 | | 25.5 |
| 29-July | 104 | 1.82 | 1.96 | 19.2 | | 27.5 | 28 | 23.2 | 13.2 | 10.9 | 19.2 | | 25.5 |
| 30-July | 96.5 | 1.72 | 0.88 | 19.6 | | 19.7 | 28.6 | 18.5 | 14.2 | 10.6 | 19.6 | | 27.7 |
| 31-July | 98.5 | 1.75 | 1.78 | 18.7 | | 25.9 | 28.6 | 24.3 | 15.5 | 10.9 | 18.7 | | 27.4 |
| 06-Aug | 121 | 3.85 | 3.5 | 14.9 | 23.3 | 23.6 | 22.2 | 14.4 | 11.2 | 8.2 | 14.9 | 23.6 | 24.9 |
| 07-Aug | 107 | 3.43 | 2.98 | 15.5 | 21.7 | 24.1 | 20.1 | 13.6 | 10.4 | 10.1 | 15.5 | 21.9 | 24.1 |
| 08-Aug | 97.58 | 2.38 | 0.98 | 15.7 | 22.1 | 23 | 21.6 | 13.2 | 8.7 | 8.2 | 15.7 | 21.3 | 21.6 |
| 09-Aug * | 83.72 | 0.06 | 0.07 | 14.4 | 22.4 | 24.4 | 22.1 | 13.5 | 9.8 | 8.2 | 14.4 | 20.2 | 23.2 |
| 10-Aug | 68.88 | 0.56 | 0.28 | 16.5 | 20.5 | 23 | 19.7 | 12.2 | 8.9 | 7.8 | 16.5 | 20.5 | 22.2 |
| 13-Aug | 72.94 | 0.03 | 0.04 | 15.8 | 21.9 | 21.6 | 17.6 | 14.1 | 10 | 10 | 15.8 | 21.9 | 23.2 |
| 14-Aug | 65.32 | | 0 | 15.4 | 19.7 | 21.3 | 20.7 | 13 | 9.2 | 8.4 | 15.4 | 20.7 | 22.9 |
| 15-Aug | 74.8 | 0.02 | | 16.4 | 19.9 | 21.8 | 19.7 | 13 | 7.4 | 7.4 | 16.4 | 18.6 | 22.9 |
| 16-Aug | 75.9 | 0.91 | 0.42 | 16.0 | 21.6 | 22.4 | 23.2 | 11.2 | 8.2 | 6.8 | 16.0 | 21.6 | 22.9 |
| 19-Aug | 71.7 | | | 16.2 | 20.2 | 21 | 19.6 | 11.2 | 7.6 | 6.8 | 16.2 | 20.7 | 23.2 |
| 26-Aug * | 89.60 | 4.83 | 3.36 | 20.3 | 21.9 | 27.3 | 28.1 | 17.7 | 13.0 | 11.6 | 15.8 | 24.2 | 26.1 |
| 27-Aug | 90.30 | 2.94 | 2.66 | 20.3 | 23.6 | 27.0 | 25.3 | 16.6 | 13.0 | 11.6 | 15.8 | 22.5 | 25.6 |
| 28-Aug | 92.40 | 3.26 | 4.45 | 20.2 | 25.29 | 28.51 | 27.95 | 17.65 | 11.80 | 9.85 | 15.7 | 24.61 | 26.56 |
| 29-Aug | 91.00 | 4.76 | 2.83 | 20.2 | 27.40 | 29.91 | 29.35 | 17.93 | 10.96 | 10.40 | 15.7 | 23.50 | 25.17 |
| 30-Aug | 91.56 | 6.48 | 1.68 | 19.4 | 27.3 | 27.6 | 27.0 | 16.6 | 9.5 | 8.9 | 15.4 | 22.5 | 24.5 |
| 2-Sept | 87.64 | 4.31 | 3.68 | 21.6 | 29.0 | 31.2 | 29.3 | 17.4 | 11.2 | 9.5 | 16.6 | 21.4 | 26.4 |
| 3-Sept | | | | | | | | | | | | | |
| 4-Sept | 88.34 | 3.57 | 3.36 | 19.7 | 28.3 | 31.1 | 30.2 | 18.4 | 11.6 | 11.3 | 16.6 | 25.2 | 28.3 |
| 5-Sept | 90.86 | 2.66 | 3.78 | 18.1 | | | | | | 10.0 | 14.7 | | |
| 6-Sept | 85.40 | 3.78 | 4.34 | 21.7 | 30.2 | 29.6 | 27.0 | 14.3 | 11.0 | 10.1 | 15.8 | 26.4 | 27.3 |
| 9-Sept | 85.40 | 4.20 | 3.01 | 22.5 | 29.1 | 31.7 | 28.2 | 14.9 | 11.9 | 11.3 | 21.1 | 24.0 | 28.2 |
| 10-Sept | 89.88 | 3.92 | 4.34 | 20.5 | | | | | | 10.7 | 16.0 | | |
| 11-Sept * | 93.38 | 4.03 | 4.34 | 18.0 | 26.0 | 28.1 | 22.0 | 16.9 | 13.1 | 11.1 | 11.9 | 18.6 | 22.6 |
| 12-Sept | 98.14 | 0.00 | 3.64 | 17.4 | | | | | | 5.7 | 11.7 | | |
| 13-Sept | 93.80 | 2.94 | 4.97 | 17.9 | 28.7 | 32.1 | 25.7 | 17.6 | 22.0 | 11.8 | 13.6 | 23.2 | 26.6 |
| 14-Sept | 94.08 | 4.76 | 3.78 | 20.4 | | | | | | 9.6 | 13.3 | | |
| 16-Sept | 131.04 | 4.90 | | 20.4 | 30.3 | 31.8 | 27.2 | 16.7 | 10.8 | 9.0 | | | |
| 17-Sept | | | | | | | | | | | | | |
| 18-Sept | | | | | | | | | | | | | |
| 19-Sept | 96.46 | 6.02 | 6.02 | 20.7 | | | | | | 9.8 | 14.5 | | |
| 20-Sept | 101.36 | 2.80 | 5.32 | 20.7 | | | | | | 6.3 | 13.6 | | |
| 21-Sept | 100.80 | 0.00 | 0.00 | 19.6 | | | | | | 10.1 | 16.1 | | |
| 22-Sept | | | | | | | | | | | | | |
| 23-Sept | | | | | | | | | | | 14.5 | | |
| 24-Sept | 89.60 | 11.48 | 7.28 | 17.0 | 25.4 | 29.0 | 25.4 | 14.4 | 8.5 | 8.5 | 13.0 | 21.7 | 20.3 |
| 25-Sept * | 94.08 | 14.14 | 5.53 | 22.6 | | | | | | 7.7 | 16.1 | | |
| 26 Sept | 115.92 | 4.83 | 6.23 | 23.7 | | | | | | 9.1 | 18.4 | | |
| 27-Sept | 120.40 | 5.95 | 4.69 | 24.5 | | | | | | 9.4 | 18.1 | | |
| 28-Sept | 123.20 | 9.38 | 1.96 | 20.9 | | | | | | 8.8 | 18.1 | | |
| 29-Sept | | | | | | | | | | | | | |

**A1.26**

| DATE | INFLUENT | EFFLUENT TKN | | | | | PHOSPHATES | | (mg-P/l) | | | PHOSPHATE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TKN I | CE | EE | IC | C1 | C11 | C2 | C3 | C4 | CE | IE | E1 | E11 |
| 30-Sept | 113.26 | 5.74 | 5.60 | 22.5 | 31.7 | 34.3 | 31.7 | 15.7 | 10.6 | 9.7 | 18.6 | 23.4 | 26.9 |
| 01-Oct | 104.16 | 5.11 | 7.00 | 20.7 | | | | | | 9.7 | 15.7 | | |
| 02-Oct | | | | | | | | | | | | | |
| 03-Oct | 109.20 | 2.52 | 3.50 | 20.4 | 29.9 | 34.7 | 29.9 | 16.0 | 12.1 | 10.9 | 15.7 | 24.9 | 27.2 |
| 04_oct | 110.32 | 6.30 | 4.90 | 24.0 | | | | | | 11.8 | 15.7 | | |
| 05-Oct | 97.30 | 7.14 | 5.88 | 21.3 | | | | | | 10.3 | 17.4 | | |
| 06-Oct | | | | | | | | | | | | | |
| 07-Oct | 83.16 | 5.60 | 5.60 | 21.9 | 27.6 | 29.9 | 28.7 | 17.9 | 11.9 | 11.08 | 15.1 | 20.8 | 23.6 |
| 08-Oct | 79.80 | 5.04 | 4.62 | 21.9 | | | | | | 11.4 | 15.9 | | |
| 09-Oct | 89.74 | 6.44 | 6.02 | 21.3 | 29.9 | 34.2 | 35.0 | 20.8 | 13.36 | 13.1 | 15.6 | 23.0 | 26.2 |
| 10-Oct * | 86.80 | 5.46 | 5.95 | 19.4 | | | | | | 11.51 | 15.0 | | |
| 11-Oct | 86.80 | 4.90 | 4.41 | 19.4 | 32.2 | 34.2 | 33.3 | 17.0 | 12.67 | 12.1 | 15.0 | 22.8 | 26.3 |
| 12-Oct | 63.00 | 6.72 | 1.68 | 20.5 | | | | | | 11.22 | 14.7 | | |
| 13-Oct | | | | | | | | | | | | | |
| 14-Oct | 86.24 | 4.62 | 5.32 | 20.5 | 31.0 | 33.3 | 28.4 | 16.5 | 12.1 | 8.1 | 14.7 | 20.2 | 22.4 |
| 15-Oct | 84.14 | 30.24 | 31.36 | 22.4 | | | | | | 11.1 | 16.8 | | |
| 16-Oct | 84.14 | 6.16 | 3.64 | 22.4 | 29.1 | 33.8 | 32.7 | 19.6 | 12.54 | 11.7 | 16.8 | 24.0 | 27.1 |
| 17-Oct | 75.04 | 8.26 | 6.72 | 21.5 | | | | | | 11.1 | 14.2 | | |
| 18-Oct | 70.28 | 29.68 | 29.40 | 17.3 | 27.4 | 30.2 | 31.9 | 17.6 | 11.1 | 11.1 | 12.0 | 19.0 | 21.2 |
| 19-Oct | 97.86 | 5.46 | 7.00 | 22.8 | | | | | | | 17.0 | | |
| 20-Oct | | | | | | | | | | | | | |
| 21-Oct | 86.24 | 6.02 | 0.00 | 21.3 | 33.2 | 35.2 | 35.8 | 19.3 | 11.7 | 10 | 16.4 | 22.5 | 24.5 |
| 22-Oct | 84.56 | 5.32 | 3.78 | 21.3 | | | | | | 9.4 | 15.8 | | |
| 23-Oct | 84.56 | 5.32 | 0.00 | 21.3 | 30.3 | 35.5 | 31.5 | 14.9 | 8.3 | 7.7 | 15.8 | 21.3 | 24.5 |
| 24-Oct | 79.80 | 5.60 | 5.74 | 20.7 | | | | | | 8.75 | 15.4 | | |
| 25-Oct | | | | 23.9 | 31.4 | 35.8 | 30.3 | 17.2 | 9 | 8.2 | 15.1 | 23.0 | 25.9 |
| 26-Oct | 84.84 | 5.11 | 6.30 | 21.3 | | | | | | 8.2 | 16.0 | | |
| 27-Oct | | | | | | | | | | | | | |
| 28-Oct * | 70.56 | 4.62 | 5.74 | 20.7 | | | | | | 9 | 14.0 | | |
| 29-Oct | | | | 20.7 | 30.6 | 35.2 | 32.3 | 18.3 | 18.1 | 8.8 | 15.7 | 21.8 | 24.7 |
| 30-Oct | 67.90 | 4.06 | 5.39 | 20.7 | | | | | | 8.2 | 15.7 | | |
| 31-Oct | 77.00 | 4.62 | 5.11 | 21.1 | 27.1 | 33.1 | 30.8 | 17.9 | 9.9 | 7.33 | 15.9 | 20.5 | 24.2 |
| 01-Nov | 75.32 | 4.97 | 3.64 | 19.1 | | | | | | 8.2 | 13.9 | | |
| 02-Nov | 65.52 | 4.62 | 3.85 | 19.7 | 33.1 | 35.1 | 30.0 | 16.5 | 9.3 | 8.5 | 14.2 | 24.2 | 31.4 |
| 04-Nov | 70.56 | 3.85 | 2.8 | 19.5 | 30.0 | 34.8 | 31.4 | 17.3 | 11.6 | 9.1 | 13.9 | 18.7 | 20.9 |
| 05-Nov | 66.36 | 3.5 | 3.5 | 19.5 | | | | | | 8.8 | 13.9 | | |
| 06-Nov | 66.36 | 3.78 | 3 | 19.5 | 30.3 | 34.8 | 30.3 | 16.7 | 10.2 | 8.8 | 13.9 | 19.0 | 20.9 |
| 07-Nov | 66.22 | 3.78 | 5.18 | 19.7 | 29.0 | 35.5 | 25.9 | 14.3 | 10.9 | 9.5 | 13.4 | 21.1 | 22.2 |
| 08-Nov * | 78.4 | 4.76 | 3.5 | 19.7 | 33.2 | 34.9 | | 16.0 | 10.6 | 8.9 | 13.4 | 22.8 | 23.9 |
| 09-Nov | 87.64 | 3.64 | 5.11 | 19.7 | 33.2 | 34.6 | 33.2 | 15.4 | 10.3 | 9.8 | 13.2 | 22.2 | 23.3 |
| 11-Nov | 75.04 | 23.48 | 3.01 | 19.7 | 34.9 | 36.9 | 37.5 | 28.1 | 10.6 | 10.6 | 14.0 | 24.2 | 25.3 |
| 12-Nov | 75.04 | 30.59 | 8.4 | 19.7 | 34.4 | 33.8 | 36.6 | 27.9 | 9.8 | 9.8 | 14.0 | 20.5 | 21.9 |
| 13-Nov | 78.82 | 36.4 | 8.12 | 19.3 | 36.3 | 35.7 | 35.2 | 26.4 | 10.5 | 9.6 | 13.5 | 24.6 | 25.8 |
| 14-Nov | 78.82 | 29.9 | 24.4 | 19.3 | 33.7 | 35.5 | 32.2 | 17.0 | 7.6 | 5.8 | 13.50 | 24.3 | 24.9 |
| 15-Nov | 73.6 | 17.1 | 31 | 19.3 | 33.7 | 36.6 | 30.2 | 11.7 | 4.4 | 4.1 | 11.70 | 24.0 | 25.8 |
| 16-Nov | 73.6 | 5.25 | 43.3 | 19.3 | 32.8 | 37.3 | 28.4 | 12.3 | 5.2 | 2.8 | 11.70 | 23.1 | 23.4 |
| 18-Nov | 72.5 | 4.5 | 49.6 | 21.1 | 34.0 | 37.5 | 32.8 | 8.4 | 5.2 | 5.2 | 15.50 | 20.2 | 19.9 |
| 19-Nov | 75.3 | 5.6 | 49.1 | 15.4 | 26.6 | 28.0 | 28.9 | 16.3 | 9.5 | 5.68 | 15.40 | 28.0 | 28.9 |
| 20-Nov * | 87.9 | 4.1 | 49.9 | 17.2 | 28.0 | 31.6 | 27.7 | 11.6 | 8.9 | 7.2 | 17.20 | 19.5 | 19.8 |
| 21-Nov | | | | | | | | | | | | | |
| 22-Nov | 71.1 | 4.7 | 48.1 | 16.3 | 31.50 | 28.9 | 26.3 | 13.9 | 9.5 | 6.3 | 16.3 | 17.2 | 18.7 |
| 23-Nov | 93.5 | 6.51 | 39.8 | 15.1 | 26.0 | 28.6 | 22.5 | 9.2 | 6.9 | 5.7 | 15.10 | 16.6 | 14.5 |
| 25-Nov | 87.6 | 4.1 | 29.5 | 15.1 | 29.5 | 31.3 | 24.5 | 14.8 | 9.5 | 4.5 | 15.10 | 16.0 | 15.7 |
| 26-Nov | 86.5 | 0 | 31.7 | 15.1 | 31.90 | 33.3 | 28.0 | 11.6 | 8 | 6.6 | 15.1 | 17.2 | 16.3 |
| 27-Nov | 86.5 | 6.51 | 23.8 | 14.1 | 28.1 | 29.1 | 25.7 | 10.5 | 7.3 | 5.8 | 14.10 | 13.6 | 13.8 |
| 28-Nov | 91.6 | 5 | 12.4 | 14.1 | 28.6 | 29.6 | 29.3 | 12.4 | 6.8 | 5.1 | 14.10 | 14.8 | 14.3 |
| 29-Nov | 91.6 | 7 | 5.3 | 14.1 | 29.0 | 31.3 | 25.6 | 9.3 | 5.57 | 4.1 | 14.10 | 25.6 | 15.3 |
| 30-Nov | 99.7 | 6.44 | 4.9 | 17.6 | 31.0 | 31.0 | 29.9 | 12.1 | 5.9 | 4.4 | 17.60 | 17.9 | 17.0 |
| 2-Dec | 91.3 | 5.6 | 3.6 | 18.0 | 35.5 | 36.4 | 34.6 | 13.9 | 6 | 3.4 | 18.00 | 20.3 | 20.3 |
| 3-Dec | 99.7 | 5.6 | 3.5 | 18.0 | 31.4 | 33.1 | 25.3 | 10.4 | 5.7 | 5.2 | 18.00 | 17.4 | 18.3 |

| DATE | INFLUENT | EFFLUENT TKN | | | | | PHOSPHATES | (mg-P/l) | | | | PHOSPHATE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TKN I | CE | EE | IC | C1 | C11 | C2 | C3 | C4 | CE | IE | E1 | E11 |
| 4-Dec * | 90.4 | 6.1 | 3.85 | 17.5 | 34.9 | 34.3 | 27.9 | 9.6 | 6.4 | 4.1 | 17.50 | 20.7 | 21.8 |
| 5-Dec | | | | 17.5 | 31.4 | 34.0 | 26.5 | 10.2 | 5.6 | 4.1 | 17.50 | 20.7 | 21.8 |
| 6-Dec | 79.9 | 1.4 | 0 | 18.1 | 33.1 | 33.4 | 28.4 | 13.4 | 6.3 | 4.9 | 18.10 | 20.4 | 21.6 |
| 7-Dec | 79.9 | 1.7 | 0 | 18.1 | 31.3 | 33.7 | 25.4 | 12.2 | 6.6 | 5.1 | 18.10 | 20.1 | 22.5 |
| 9-Dec | 82.9 | 3.4 | 2 | 17.9 | 31.6 | 33.6 | 27.4 | 13.4 | 8.6 | 6.7 | 17.90 | 21.2 | 21.8 |
| 10-Dec | 80.6 | 7.8 | 0.63 | 17.6 | 34.1 | 36.1 | 35.0 | 23.2 | 8.1 | 6.7 | 17.60 | 22.4 | 23.2 |
| 11-Dec | 80.6 | 4.4 | 6.44 | 17.6 | 27.7 | 29.7 | 23.7 | 11.4 | 7.7 | 7.1 | 17.60 | 19.1 | 22.3 |
| 12-Dec | 49 | 0 | 0 | 19.7 | 35.7 | 38.0 | 31.1 | 14.9 | 10.3 | 7.1 | 19.70 | 25.4 | 26.3 |
| 13-Dec | 49 | 0 | 0 | 19.7 | 36.30 | 38.5 | 32.9 | 18.0 | 11.6 | 10.2 | 19.7 | 23.5 | 26.8 |
| 14-Dec | 49.8 | 0 | 0 | 19.3 | 34.3 | 36.8 | 32.4 | 17.4 | 10.8 | 10.2 | 19.30 | 27.4 | 26.8 |
| 17-Dec | 66.9 | 0 | 0 | 20.8 | 34.8 | 35.6 | 31.2 | 17.2 | 10.3 | 9.8 | 20.80 | 26.3 | 27.9 |
| 18-Dec | 66.9 | 0 | 0 | 20.8 | 34.5 | 35.1 | 30.4 | 16.6 | 9.8 | 9 | 20.80 | 23.8 | 24.6 |
| 19-Dec * | 66.7 | 0 | 0 | 19.1 | 36.8 | 37.3 | 33.4 | 17.5 | 11 | 8.5 | 19.10 | 23.8 | 22.3 |
| 20-Dec | 85.5 | 4.9 | 4.3 | 19.4 | 37.6 | 36.5 | 31.4 | 18.1 | 9.6 | 9.6 | 19.40 | 25.2 | 23.5 |
| 21-Dec | 84 | 2.5 | 0.6 | 19.6 | 34.7 | 36.0 | 33.0 | 19.4 | 11.2 | 10.4 | 19.6 | 24 | 24.0 |
| 23-Dec | 106.4 | 5.4 | 4.5 | 16.90 | 32.8 | 34.1 | 25.9 | 16.4 | 10.4 | 10.4 | 16.90 | 21.3 | 21.3 |
| 02-Jan | 110.2 | 4.34 | 3.57 | 18.0 | 29.3 | 32.9 | 28.1 | 16.5 | 12.3 | 10.5 | 18.0 | 22.4 | 19.5 |
| 03-Jan | 93.8 | 5.11 | 5.53 | 16.2 | 27.5 | 31.1 | 26.6 | 14.7 | 11.1 | 9.6 | 16.2 | 17.4 | 18.0 |
| 04-Jan | 103.6 | 12.6 | 7.14 | 21.4 | 32.8 | 32.8 | 36.1 | 25.8 | 15.6 | 13.5 | 21.4 | 21.4 | 21.4 |
| 06-Jan | 112 | 4.9 | 3.26 | 18.1 | 26.4 | 27.0 | 21.4 | 13.5 | 10.6 | 10.6 | 18.2 | 20.6 | 21.7 |
| 07-Jan | 78.1 | 5.15 | 5.46 | 18.1 | 27.4 | 29.3 | 23.4 | 13.6 | 11.1 | 10.2 | 18.1 | 20.3 | 20.6 |
| 08-Jan * | 71.1 | 8.82 | 5.39 | 16.4 | 27.4 | 29.3 | 23.7 | 13.6 | 11.1 | 11.1 | 16.4 | 18.7 | 19.5 |
| 09-Jan | 88.48 | 4.62 | 2.87 | 16.4 | 28.7 | 30.7 | 27.8 | 16.1 | 11.8 | 10.3 | 16.4 | 20.4 | 19.2 |
| 10-Jan | 94.92 | 3.92 | 2.94 | 18.1 | 27.5 | 30.4 | 27.8 | 20.9 | 12.3 | 9.2 | 18.1 | 20.1 | 20.7 |
| 11-Jan | 91.84 | 5.18 | 1.61 | 19.0 | 33.0 | 34.9 | 32.1 | 19.4 | 12.1 | 12.1 | 19.0 | 21.9 | 25.1 |
| 13-Jan | 85.1 | 10.22 | 9.94 | 20.6 | | | | | | 18.1 | 20.6 | | |
| 14-Jan | 98.6 | 7.42 | 8.68 | 17.1 | 27.5 | 28.1 | 25.1 | 13.8 | 7.3 | 7.3 | 17.1 | 18.0 | 18.6 |
| 15-Jan | 96.6 | 8.05 | 6.9 | 19.8 | 32.0 | 34.0 | 28.7 | 15.3 | 10.8 | 9.6 | 19.8 | 31.3 | 34.0 |
| 16-Jan | 99 | 4.55 | 5.95 | 18.4 | 33.7 | 34.6 | 31.1 | 18.1 | 15.9 | 11.7 | 18.4 | 30.8 | 34.9 |
| 17-Jan | 82 | 3.71 | 4.2 | 16.2 | 30.9 | 37.8 | 39.6 | 23.5 | 11.9 | 9.2 | 16.2 | 31.2 | 38.1 |
| 18-Jan | 108 | 13.2 | 10.8 | 21.4 | 38.4 | | 40.1 | 26.5 | 13.1 | 10.4 | 21.4 | 33.0 | 39.0 |
| 20-Jan * | 99 | 6.02 | 5.67 | 22.2 | 38.4 | 41.0 | 35.4 | 18.3 | 10.6 | 8.9 | 22.2 | 34.5 | 37.5 |
| 21-Jan | 118 | 5.39 | 5.74 | 21.9 | 38.4 | 40.1 | 33.4 | 15.7 | 8.6 | 8.6 | 21.9 | 34.2 | 37.5 |
| 22-Jan | 99 | 7.3 | 6.6 | 21.1 | 35.2 | 38.3 | 33.3 | 16.3 | 7.3 | 7.3 | 21.1 | 34.90 | 36.9 |
| 23-Jan | 100 | 2.8 | 5.2 | 18.0 | 36.6 | 36.9 | 37.5 | 16.3 | 9.8 | 6.7 | 18.0 | 33.2 | 35.5 |
| 24-Jan | 81 | 6.4 | 4.34 | 19.4 | 37.1 | 39.8 | 36.1 | 17.6 | | | 19.4 | 32.1 | 36.7 |
| 25-Jan | 99.4 | 2.9 | 5.2 | 19.7 | 37.7 | 41.4 | 37.7 | 17.9 | 7.6 | 5.2 | 19.7 | 33.3 | 37.4 |
| 27-Jan | 98 | 1.7 | 4.6 | 19.7 | 33.8 | 41.6 | 38.4 | 20.5 | 9.2 | 7.2 | 19.7 | 26.6 | 39.0 |
| 28-Jan | 104 | 6.86 | 4.9 | 19.6 | 41.6 | 43.6 | 35.1 | 14.0 | 7.5 | 7.5 | | 36.1 | 40.3 |
| 29-Jan | 101 | 4.62 | 3.47 | 19.5 | 37.0 | 42.8 | 33.8 | 14.7 | 8.3 | 7.0 | 19.5 | 36.4 | 39.9 |
| 30-Jan | 87 | 5.39 | 4.13 | 18.8 | 36.4 | 41.5 | 35.4 | 14.7 | 10.2 | 7.3 | 18.8 | 35.4 | 29 |
| 31-Jan | 93 | 3.99 | 5.04 | 20.6 | 35.4 | 44.2 | 39.9 | 18.9 | 8.6 | 5.6 | 20.6 | 34.9 | 42.0 |
| 01-Feb * | 88 | 4.2 | 5.04 | 20.6 | 36.6 | 43.2 | 35.2 | 16.9 | 8.6 | 6.2 | 20.6 | 34.2 | 39.9 |
| 03-Feb | 75 | 3.43 | 3.99 | 18.9 | 39.2 | 41.2 | 40.5 | 22.2 | 9.9 | 7.3 | 18.9 | 33.9 | 36.2 |
| 04-Feb | 67 | 3.22 | 4.2 | 17.6 | 31.5 | 38.5 | 34.5 | 17.9 | 8.9 | 6.6 | 17.6 | 32.2 | 36.2 |
| 05-Feb | 69 | 6.3 | 2.59 | 15.8 | 37.0 | 38.5 | 39.7 | 26.9 | 9.6 | 4.2 | 15.8 | 28.4 | 32.5 |
| 06-Feb | 73 | 5.3 | 4.34 | 16.4 | 30.4 | 38.80 | 35.5 | 21.2 | 10.1 | 5.7 | 16.4 | 27.5 | 33.1 |
| 07-Feb | 72 | 3.78 | 4.48 | 17.4 | 30.1 | 39.30 | 40.0 | 23.4 | 11.40 | 7.5 | 17.4 | 31.5 | 31.5 |
| 08-Feb | 71 | 5.74 | 4.2 | 17.7 | 31.9 | 41.8 | 36.5 | 20.90 | 8.9 | 8.2 | 17.7 | 33.6 | 35.8 |
| 10-Feb | 68 | 3.78 | 2.94 | 18.1 | 32.3 | 37.6 | 34.8 | 18.40 | 8.6 | 6.7 | 18.1 | 24.7 | 27.2 |
| 12-Feb | 67.2 | 4.48 | 4.13 | 17.1 | 32.6 | 34.8 | 37.3 | 18.10 | 7.7 | 7.7 | 17.1 | 27.9 | 34.5 |
| 13-Feb | 62.7 | 2.94 | 3.22 | 18.7 | | 41.5 | 42.5 | 21.3 | 8.39 | 4.4 | 18.7 | 35.2 | 34.5 |
| 14-Feb | 63 | 4.69 | 2.8 | 18.3 | 35.9 | 39.5 | 34.2 | 18.70 | 8.1 | 3.8 | 18.3 | 27.6 | 34.2 |
| 15-Feb * | 72.2 | 4.9 | 5.04 | 17.0 | 32.9 | 37.5 | 43.4 | 20.10 | 10.7 | 4.5 | 17.0 | 29.9 | 33.7 |
| 17-Feb | 65.5 | 4.27 | 5.04 | 16.7 | 33.20 | 38.4 | 47.8 | 30.9 | 15.50 | 2.7 | 16.7 | 31.0 | 31.9 |
| 18-Feb | 71.7 | 4.55 | 4.2 | 13.9 | 32.80 | 38.5 | 45.1 | 22.10 | 6.6 | 1.8 | 13.9 | 31.0 | 29.4 |
| 19-Feb | 68.9 | 3.85 | 3.99 | 16.1 | 34.30 | 37.3 | 42.4 | 20.60 | 7.5 | 2.1 | 16.1 | 28.7 | 32.2 |
| 20-Feb | 72.2 | 3.99 | 5.04 | 21.7 | 33.90 | 39.9 | 40.1 | 18.40 | 7.1 | 1.8 | 21.7 | 28.2 | 33.9 |
| 21-Feb | 63.8 | 4.55 | 3.36 | 16.3 | 35.40 | 40.1 | 44.9 | 21.30 | 5.3 | 1.2 | 16.3 | 28.8 | 33.0 |
| 22-Feb | 76.2 | 3.99 | 3.78 | 15.3 | 34.20 | 40.3 | 41.2 | 24.1 | 8.00 | 1.6 | 15.3 | 29.3 | 30.9 |

| DATE | INFLUENT | EFFLUENT TKN | | | | | PHOSPHATES | | (mg-P/l) | | | PHOSPHATE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TKN I | CE | EE | IC | C1 | C11 | C2 | C3 | C4 | CE | IE | E1 | E11 |
| 24-Feb | 56.60 | * 2.1 | 4.2 | 17.1 | 39.10 | 43.0 | 45.2 | 23.80 | 7.1 | 1.9 | 17.1 | 33.0 | 37.3 |
| 25-Feb | 64.40 | 4.41 | 4.62 | 16.0 | 28.50 | 41.2 | 48.5 | 25.60 | 6.7 | 2.4 | 16.0 | 19.0 | 35.7 |
| 27-Feb | 62.70 | 4.62 | 4.41 | 16.3 | 31.60 | 36.6 | 44.1 | 21.20 | 9.3 | 5.0 | 16.3 | 25.6 | 27.8 |
| 28-Feb | 64.40 | 4.34 | 5.04 | 17.7 | 41.50 | 48.1 | 52.4 | 28.00 | 11.1 | 3.5 | 17.7 | 35.9 | 39.8 |
| 29-Feb | | | | | | | | | | | | | |
| 2-March | 68.30 | 4.2 | 4.27 | | | | | | | | | | |
| 3-March | 71.12 | 4.55 | 4.2 | | | | | | | | | | |
| 4-March | 64.96 | 2.66 | 4.62 | | | | | | | | | | |

# A1.29

| DATE | PHOSPHATES | | (mg-P/l) | | | | NITRATES (mg-N/l) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E2 | E3 | E4 | EE | delC | delE | C1 | C11 | C2 | C3 | C4 | CE | E1 | E11 |
| 27-June * | | | | | | | | | | | | | | |
| 29-June | 21.4 | 14.9 | 6.5 | 6.5 | 7.2 | 10.9 | | 0.680 | 0.540 | 2.330 | 32.480 | 22.640 | | 2.390 |
| 30-June | 21.4 | 6.5 | 6.5 | | 7.2 | 17.4 | | 1.480 | 1.610 | 1.320 | 5.270 | 5.270 | | 1.230 |
| 03-July | 16.6 | 9.6 | 4.6 | 3.7 | 8.8 | 13.9 | | 1.520 | 1.590 | 1.320 | 5.270 | 5.270 | | 1.100 |
| 07-July | 18.8 | 10.4 | 5.9 | 5.3 | 9.5 | 12.2 | | 0.300 | 0.190 | 0.630 | 19.560 | 19.560 | | 1.270 |
| 11-July | 22 | 14.5 | 10.7 | 9.6 | 8.4 | 8.4 | | 1.320 | 0.260 | 0.530 | 18.110 | 17.900 | | 0.250 |
| 13-July | 15.5 | 11.2 | 8.5 | 9.1 | 9.2 | 9.7 | | 0.730 | 0.330 | 0.610 | 19.350 | 19.560 | | 1.450 |
| 15-July | 18.5 | 11.8 | 8.8 | 8 | 6.6 | 8.2 | | 1.740 | 0.490 | 0.610 | 22.260 | 22.880 | | 1.610 |
| 17-July | 15.8 | 11.4 | 8.7 | 9.2 | 9.3 | 9.9 | | 1.450 | 0.950 | 1.390 | 19.350 | 23.090 | | 2.410 |
| 19-July | 18.8 | 12 | 9 | 8.1 | 6.7 | 8.4 | | 1.410 | 1.040 | 1.670 | 26.410 | 21.220 | | 2.570 |
| 20-July | 18.2 | 12 | 8.2 | 7.4 | 5.4 | 7.1 | | 1.180 | 0.480 | 0.400 | 17.760 | 18.180 | | 1.160 |
| 22-July | 19.1 | 11.2 | 8.5 | 7.4 | 7.0 | 8.4 | | 1.370 | 0.280 | 0.420 | 14.870 | 18.180 | | 1.500 |
| 24-July * | 19 | | | 8.5 | 10.3 | 9.7 | | 0.690 | 0.250 | 0.240 | 14.050 | 19.420 | | 1.550 |
| 25-July | 23 | 13.6 | 10.2 | 9.3 | 7.9 | 8.5 | | 0.930 | 0.350 | 0.240 | 11.990 | 12.190 | | 0.930 |
| 26-July | 21.5 | 14.1 | 10.4 | 9.5 | 11.6 | 9.9 | | 0.330 | 0.250 | 0.610 | 12.810 | 2.080 | | 1.020 |
| 29-July | 28 | 23.5 | 15.2 | 10.4 | 8.3 | 8.8 | 0.32 | 0.260 | 0.210 | 0.910 | 7.340 | 8.060 | 0.640 | 0.270 |
| 30-July | 30.1 | 25.2 | 15.8 | 10 | 9.0 | 9.6 | 1.01 | 0.350 | 0.200 | 0.220 | 8.890 | 9.510 | 0.810 | 0.330 |
| 31-July | 29.8 | 25.9 | 14.8 | 10.9 | 7.7 | 7.7 | 0.47 | 0.340 | 0.250 | 0.220 | 9.510 | 9.320 | 0.990 | 0.930 |
| 06-Aug | 21.4 | 13.9 | 10.6 | 9.5 | 6.7 | 5.4 | | | | | | | | |
| 07-Aug | 20.9 | 13 | 10.1 | 10.1 | 5.4 | 5.4 | | | | | | | | |
| 08-Aug | 20.2 | 12.6 | 8.7 | 8.7 | 7.5 | 7.0 | 0.95 | 0.260 | 0.140 | 0.130 | 13.910 | 20.560 | 1.090 | 0.220 |
| 09-Aug * | 21 | 12.1 | 9.3 | 9 | 6.2 | 5.4 | 1.1 | 0.240 | 0.120 | 0.110 | 9.010 | 16.500 | 1.090 | 0.240 |
| 10-Aug | 19.7 | 13 | 9.7 | 8.9 | 8.7 | 7.6 | 0.91 | 0.250 | 0.200 | 0.150 | 10.960 | 16.500 | 1.180 | 0.260 |
| 13-Aug | 22.7 | 15.7 | 11.1 | 9.7 | 5.8 | 6.1 | 0.68 | 0.220 | 0.120 | 0.160 | 5.230 | 6.340 | 0.030 | 0.030 |
| 14-Aug | 20.7 | 14.3 | 9.5 | 9.5 | 7.0 | 5.9 | 0.60 | 0.180 | 0.120 | 0.090 | 5.600 | 5.970 | 0.450 | 0.160 |
| 15-Aug | 21.3 | 14.3 | 11.1 | 10 | 9.0 | 6.4 | 0.53 | 0.190 | 0.130 | 0.150 | 5.230 | 0.610 | 0.440 | 0.150 |
| 16-Aug | 21.3 | 12.8 | 10.4 | 9.8 | 9.2 | 6.2 | 0.94 | 0.300 | 0.150 | 0.090 | 0.610 | 4.120 | 0.100 | 0.100 |
| 19-Aug | 21 | 13.1 | 8.7 | 7.6 | 9.4 | 8.6 | 0.35 | 0.150 | 0.110 | 0.100 | 4.490 | 5.230 | 0.410 | 0.150 |
| 26-Aug * | 23.6 | 13.8 | 8.5 | 7.6 | 8.7 | 8.1 | 0.48 | 0.180 | 0.370 | 0.420 | 13.250 | 15.530 | 1.240 | 0.240 |
| 27-Aug | 23.9 | 15.2 | 9.0 | 7.6 | 8.7 | 8.1 | 0.22 | 0.095 | 0.070 | 0.060 | 12.812 | 13.629 | 0.975 | 0.180 |
| 28-Aug | 22.94 | 14.30 | 8.45 | 7.90 | 10.3 | 7.8 | 0.24 | 0.120 | 0.100 | 0.075 | 9.051 | 11.423 | 1.110 | 0.860 |
| 29-Aug | 23.78 | 11.80 | 7.62 | 7.06 | 9.8 | 8.6 | 0.87 | 0.155 | 0.078 | 0.035 | 8.084 | 9.100 | 0.110 | 0.080 |
| 30-Aug | 22.8 | 10.3 | 6.7 | 5.5 | 10.4 | 9.9 | 0.13 | 0.093 | 0.068 | 0.040 | 7.280 | 8.225 | 0.732 | 0.146 |
| 2-Sept | 23.0 | 17.7 | 9.5 | 8.1 | 12.1 | 8.5 | 0.18 | 0.220 | 0.180 | 0.150 | 10.460 | 10.860 | 1.050 | 0.240 |
| 3-Sept | | | | | | | | | | | | | | |
| 4-Sept | 24.9 | 12.5 | 6.0 | 4.4 | 8.4 | 12.1 | 0.108 | 0.091 | 0.046 | 0.015 | 6.500 | 4.760 | 0.647 | 0.106 |
| 5-Sept | | | | 5.1 | 8.1 | 9.6 | | | | | | 4.720 | | |
| 6-Sept | 23.4 | 12.8 | 6.6 | 6.6 | 11.5 | 9.2 | | | | | 6.630 | 1.960 | | |
| 9-Sept | 22.8 | 12.5 | 6.9 | 6.3 | 11.2 | 14.8 | | | | | 6.090 | 5.670 | | |
| 10-Sept | | | | 6.6 | 9.8 | 9.5 | | | | | | | | |
| 11-Sept * | 19.6 | 10.9 | 6.0 | 6.0 | 6.9 | 5.9 | 0.779 | 0.321 | 0.235 | 0.257 | 16.000 | 12.160 | 1.322 | 0.438 |
| 12-Sept | | | | 2.6 | 11.7 | 9.1 | | | | | | 8.120 | | |
| 13-Sept | 19.5 | 12.1 | 7.1 | 6.5 | 6.2 | 7.1 | 0.512 | 0.331 | 0.321 | 0.321 | 14.290 | 10.030 | 1.194 | 0.374 |
| 14-Sept | | | | 5.3 | 10.8 | 8.0 | | | | | | 9.180 | | |
| 16-Sept | | | | | 11.4 | 0.0 | 1.173 | 0.651 | 0.459 | 0.416 | 11.520 | 10.890 | | |
| 17-Sept | | | | | | | | | | | | | | |
| 18-Sept | | | | | | | | | | | | | | |
| 19-Sept | | | | 7.1 | 10.9 | 7.3 | | | | | | 14.720 | | |
| 20-Sept | | | | 6.3 | 14.4 | 7.3 | | | | | | 14.720 | | |
| 21-Sept | | | | 6.0 | 9.5 | 10.0 | 1 | 0.587 | 0.555 | 0.534 | 13.020 | 17.060 | | |
| 22-Sept | | | | | | | | | | | | | | |
| 23-Sept | | | | 5.8 | | 8.7 | | | | | | | | |
| 24-Sept | 14.2 | 7.4 | 5.2 | 4.0 | 8.5 | 9.0 | | | 0.236 | 0.530 | 21.980 | 20.800 | 1.070 | 0.324 |
| 25-Sept * | | | | 7.4 | 14.9 | 8.7 | | | | | | 18.260 | | |
| 26 Sept | | | | 7.4 | 14.6 | 11.0 | | | | | | 20.400 | | |
| 27-Sept | | | | 7.1 | 15.2 | 11.0 | | | | | | 22.800 | | |
| 28-Sept | | | | 5.5 | 12.1 | 12.6 | | | | | | 21.000 | | |
| 29-Sept | | | | | | | | | | | | | | |

# A1.30

| DATE | PHOSPHATES | (mg-P/l) | | | | | NITRATES (mg-N/l) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E2 | E3 | E4 | EE | delC | delE | C1 | C11 | C2 | C3 | C4 | CE | E1 | E11 |
| 30-Sept | 18.3 | 8.6 | 8.3 | 6.2 | 12.7 | 12.4 | | 0.403 | 0.177 | 0.138 | 21.000 | 28.100 | 1.890 | 0.304 |
| 01-Oct | | | | 8.0 | 11.0 | 7.7 | | | | | | 16.900 | | |
| 02-Oct | | | | | | | | | | | | | | |
| 03-Oct | 22.2 | 12.4 | 8.5 | 7.06 | 9.5 | 8.6 | 1.86 | | 1.030 | | 15.700 | 17.900 | | |
| 04_oct | | | | 7.06 | 12.2 | 8.6 | | | | | | 9.610 | | |
| 05-Oct | | | | 6.77 | 11.0 | 10.7 | | | | | | 11.620 | | |
| 06-Oct | | | | | | | | | | | | | | |
| 07-Oct | 19.9 | 11.9 | 9.08 | 7.66 | 10.8 | 7.4 | 0.756 | 0.344 | 0.160 | 0.142 | 10.710 | 10.710 | 0.985 | 0.390 |
| 08-Oct | | | | 7.9 | 10.5 | 8.0 | | | | | | 4.670 | | |
| 09-Oct | 23.3 | 14.5 | 9.66 | 9.66 | 8.2 | 5.9 | 0.664 | 0.152 | 0.133 | 0.124 | 9.790 | 8.510 | | |
| 10-Oct * | | | | 3.87 | 7.9 | 11.1 | | | | | | 9.360 | | |
| 11-Oct | 22.8 | 13.0 | 9 | 8.6 | 7.3 | 6.4 | 0.652 | 0.274 | 0.207 | 0.376 | 5.030 | 7.470 | 0.345 | 0.431 |
| 12-Oct | | | | 6.28 | 9.3 | 9.4 | | | | | | 8.260 | | |
| 13-Oct | | | | | | | | | | | | | | |
| 14-Oct | 17.3 | 10.6 | 7.44 | 7.44 | 12.4 | 7.3 | 0.175 | 0.321 | 0.286 | 0.305 | 3.930 | 5.030 | 0.400 | 0.164 |
| 15-Oct | | | | 9.34 | 11.3 | 8.4 | | | | | | 8.380 | | |
| 16-Oct | 21.8 | 12.3 | 7.78 | 7.78 | 10.7 | 9.0 | 0.841 | 0.190 | 0.128 | 0.073 | 5.730 | 9.710 | 0.642 | 0.114 |
| 17-Oct | | | | 7.22 | 10.4 | 7.0 | | | | | | 11.420 | | |
| 18-Oct | 19.3 | 12.0 | 6.1 | 6.1 | 6.2 | 5.9 | 0.553 | 0.690 | 0.114 | 0.059 | 4.740 | 5.250 | 0.560 | 0.128 |
| 19-Oct | | | | 5.65 | | 11.4 | | | | | | 8.270 | | |
| 20-Oct | | | | | | | | | | | | | | |
| 21-Oct | 20.4 | 11.2 | 6.8 | 5.94 | 11.3 | 10.5 | 0.512 | 0.190 | 0.090 | 0.070 | 6.080 | 5.940 | 0.621 | 0.162 |
| 22-Oct | | | | 5.36 | 11.9 | 10.4 | | | | | | 8.680 | | |
| 23-Oct | 20.7 | 10.3 | 5.9 | 5.1 | 13.6 | 10.7 | 0.724 | 0.203 | 0.118 | 0.347 | 5.460 | 5.730 | 0.375 | 0.114 |
| 24-Oct | | | | 5 | 12.0 | 10.4 | | | | | | 5.730 | | |
| 25-Oct | 21.5 | 10.8 | 5.6 | 5.3 | 15.7 | 9.8 | 0.642 | 0.135 | 0.114 | 0.087 | 6.210 | 5.800 | 0.423 | 0.107 |
| 26-Oct | | | | 5.3 | 13.1 | 10.7 | | | | | | 21.200 | | |
| 27-Oct | | | | | | | | | | | | | | |
| 28-Oct * | | | | 6.4 | 11.7 | 7.6 | | | | | | 20.100 | | |
| 29-Oct | 21.5 | 13.1 | 6.1 | 5.3 | 11.9 | 10.4 | 0.95 | 0.101 | 0.021 | 0.084 | 12.346 | 19.117 | 1.204 | 0.161 |
| 30-Oct | | | | 5.3 | 12.5 | 10.4 | | | | | | 19.500 | | |
| 31-Oct | 20.5 | 12.8 | 7 | 4.8 | 13.8 | 11.1 | 0.999 | 0.216 | 0.074 | 0.057 | 6.304 | 9.626 | 0.977 | 0.146 |
| 01-Nov | | | | 5 | 10.9 | 8.9 | | | | | | 17.200 | | |
| 02-Nov | 23.7 | 11.1 | 7.6 | 5 | 11.2 | 9.2 | 0.0557 | 0.027 | 0.044 | 0.269 | 14.709 | 14.150 | 0.260 | 0.144 |
| 04-Nov | 18.7 | 10.5 | 8.2 | 5.4 | 10.4 | 8.5 | 1.881 | 0.464 | 0.154 | 0.120 | 12.099 | 11.828 | 1.113 | 0.989 |
| 05-Nov | | | | 5.7 | 10.7 | 8.2 | | | | | | 6.911 | | |
| 06-Nov | 18.7 | 9.6 | 6.2 | 5.7 | 10.7 | 8.2 | 1.651 | 0.306 | 0.107 | 0.059 | 3.977 | 7.571 | 1.800 | 0.182 |
| 07-Nov | 18.0 | 10.3 | 8.4 | 5.5 | 10.2 | 7.9 | 0.814 | 0.315 | 0.668 | 2.750 | 10.500 | 7.470 | 0.327 | 0.156 |
| 08-Nov * | 19.7 | 10.9 | 7.2 | 5.8 | 10.8 | 7.6 | 0.14 | 0.113 | 0.111 | 1.350 | 12.517 | 9.722 | 0.110 | 0.082 |
| 09-Nov | 18.0 | 13.8 | 6.7 | 6.7 | 9.9 | 6.5 | 0.2425 | 0.113 | 0.092 | 10.543 | 10.642 | 10.843 | 0.141 | 0.286 |
| 11-Nov | 19.7 | 10.6 | 6.7 | 5.25 | 9.1 | 8.8 | 0.175 | 0.147 | 0.091 | 0.253 | 1.246 | 0.914 | 0.405 | 0.315 |
| 12-Nov | 16.0 | 6.9 | 4.4 | 4.4 | 9.9 | 9.6 | 0.075 | 0.157 | 0.104 | 0.238 | 0.753 | 0.568 | 0.107 | 0.336 |
| 13-Nov | 25.5 | 15.5 | 7.3 | 5.3 | 9.7 | 8.2 | 0.1443 | 0.122 | 0.126 | 0.216 | 23.773 | 4.431 | 0.256 | 0.084 |
| 14-Nov | 22.3 | 15.2 | 9.1 | 5.8 | 13.5 | 7.7 | 0.0935 | 0.264 | 0.106 | 0.482 | 10.118 | 0.705 | 0.131 | 0.207 |
| 15-Nov | 24.0 | 16.7 | 8.8 | 7 | 15.2 | 4.7 | 0.1764 | 0.335 | 0.121 | 0.787 | 14.010 | 8.990 | 0.224 | 0.247 |
| 16-Nov | 22.0 | 16.7 | 8.4 | 6.3 | 16.5 | 5.4 | 0.1365 | 0.140 | 0.208 | 0.813 | 10.555 | 10.639 | 0.138 | 0.140 |
| 18-Nov | 18.7 | 14.0 | 9.3 | 6.7 | 15.9 | 8.8 | 0.1813 | 0.156 | 0.250 | 0.820 | 10.980 | 13.416 | 0.324 | 0.469 |
| 19-Nov | 25.7 | 23.3 | 18.9 | 11.3 | 9.7 | 4.1 | 0.0948 | 0.082 | 0.234 | 0.404 | 5.749 | 0.306 | 0.655 | 0.120 |
| 20-Nov * | 21.3 | 18.9 | 18.6 | 18.6 | 10.0 | -1.4 | 0.255 | 0.116 | 0.174 | 0.720 | 7.182 | 8.736 | 0.819 | 0.194 |
| 21-Nov | | | | | | | | | | | | | | |
| 22-Nov | 21.3 | 17.7 | 17.7 | 17.1 | 10.0 | -0.8 | 0.2951 | 0.243 | 0.022 | 0.626 | 6.097 | 25.626 | 0.476 | 0.132 |
| 23-Nov | 16.0 | 15.4 | 12.7 | 12.7 | 9.4 | 2.4 | 0.108 | 0.092 | 0.316 | 0.544 | 5.521 | 5.120 | 0.085 | 0.455 |
| 25-Nov | 15.1 | 13.6 | 11.3 | 11.3 | 10.6 | 3.8 | 0.111 | 0.099 | 0.153 | 0.877 | 6.924 | 5.864 | 0.136 | 0.093 |
| 26-Nov | 15.7 | 13.3 | 11 | 10.7 | 8.5 | 4.4 | 0.099 | 0.091 | 0.109 | 0.482 | 3.723 | 4.339 | 0.116 | 0.117 |
| 27-Nov | 13.8 | 10.9 | 10.9 | 9.7 | 8.3 | 4.4 | 0.194 | 0.218 | 0.238 | 0.666 | 4.884 | 3.887 | 0.160 | 0.194 |
| 28-Nov | 13.6 | 10.7 | 8.3 | 8.3 | 9.0 | 5.8 | 0.741 | 0.102 | 0.057 | 0.750 | 9.645 | 8.912 | 0.568 | 0.048 |
| 29-Nov | 13.3 | 10.1 | 7.9 | 7.3 | 10.0 | 6.8 | 0.145 | 0.145 | 0.195 | 0.884 | 7.387 | 4.677 | 0.940 | 0.269 |
| 30-Nov | 15.3 | 9.9 | 7.3 | 6.1 | 13.2 | 11.5 | | | | 0.561 | 6.337 | 4.440 | 0.000 | 0.000 |
| 2-Dec | 16.8 | 12.2 | 8.1 | 5.7 | 14.6 | 12.3 | 0 | 0.000 | 0.013 | 0.236 | 4.785 | 4.063 | 0.016 | 0.019 |
| 3-Dec | 13.9 | 9.0 | 8.1 | 6 | 12.8 | 12.0 | 0.002 | 0.000 | 0.000 | 0.250 | 3.948 | 4.015 | 0.000 | 0.001 |

| DATE | PHOSPHATES |  | (mg-P/l) |  |  |  |  | NITRATES (mg-N/l) |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | E2 | E3 | E4 | EE | delC | delE |  | C1 | C11 | C2 | C3 | C4 | CE | E1 | E11 |
| 4-Dec * | 16.6 | 10.2 | 8.75 | 7.6 | 13.4 | 9.9 |  | 0 | 0.000 | 0.000 | 0.270 | 3.750 | 3.395 | 0.000 | 0.000 |
| 5-Dec | 16.3 | 10.5 | 8.2 | 7.6 | 13.4 | 9.9 |  | 0 | 0.000 | 0.000 | 0.225 | 3.731 | 3.379 | 0.089 | 0.213 |
| 6-Dec | 19.3 | 12.8 | 9.3 | 7.5 | 13.2 | 10.6 |  | 0.126 | 0.045 | 0.278 | 0.043 | 9.205 | 14.079 | 0.131 | 0.081 |
| 7-Dec | 16.3 | 9.3 | 6.9 | 6.9 | 13.0 | 11.2 |  | 0.095 | 0.092 | 0.045 | 0.147 | 4.953 | 7.865 | 0.215 | 0.098 |
| 9-Dec | 15.6 | 10.0 | 6.9 | 6.9 | 11.2 | 11.0 |  | 0.257 | 0.260 | 0.169 | 0.279 | 4.190 | 4.740 | 0.161 | 0.172 |
| 10-Dec | 20.4 | 11.4 | 8.3 | 6.4 | 10.9 | 11.2 |  | 0.185 | 0.216 | 0.188 | 0.199 | 2.827 | 1.724 | 0.150 | 0.136 |
| 11-Dec | 16.0 | 8.3 | 6.6 | 6.6 | 10.5 | 11.0 |  | 0.245 | 0.169 | 0.089 | 0.349 | 4.423 | 4.070 | 0.150 | 0.089 |
| 12-Dec | 15.0 | 13.4 | 8.6 | 6.9 | 12.6 | 12.8 |  | 0.125 | 0.109 | 0.092 | 0.481 | 5.276 | 5.202 | 0.349 | 0.092 |
| 13-Dec | 18.3 | 10.2 | 8.8 | 8.8 | 9.5 | 10.9 |  | 0.117 | 0.110 | 0.131 | 0.363 | 4.365 | 3.890 | 0.073 | 0.057 |
| 14-Dec | 23.5 | 14.7 | 9.7 | 8.3 | 9.1 | 11.0 |  |  |  |  |  |  |  |  |  |
| 17-Dec | 26.5 | 22.4 | 19.1 | 16.6 | 11.0 | 4.2 | Combined | 0.958 | 0.755 | 0.109 | 0.133 | 11.533 | 6.703 | 0.556 | 0.119 |
| 18-Dec | 23.5 | 19.4 | 18.6 | 18.6 | 11.8 | 2.2 | Exptal mu | 0.282 | 0.081 | 0.072 | 0.228 | 5.187 | 7.923 | 0.335 | 0.300 |
| 19-Dec * | 22.3 | 17.0 | 17.8 | 15.3 | 10.6 | 3.8 |  | 0.22 | 0.156 | 0.058 | 0.291 | 4.246 | 4.499 | 0.259 | 0.075 |
| 20-Dec | 22.9 | 17.3 | 14.2 | 11.9 | 9.8 | 7.5 |  | 0.438 | 0.357 | 0.454 | 0.706 | 5.432 | 5.351 | 0.413 | 0.438 |
| 21-Dec | 22.1 | 16.6 | 12.8 | 12.8 | 9.2 | 4.1 |  | 0.316 | 0.235 | 0.235 | 0.608 | 4.945 | 4.950 | 0.227 | 0.235 |
| 23-Dec | 20.7 | 14.2 | 10.4 | 10.4 | 6.5 | 6.5 |  | 1.328 | 0.085 | 0.094 | 0.303 | 9.957 | 12.001 | 1.356 | 0.218 |
| 02-Jan | 17.1 | 14.1 | 10.2 | 10.2 | 7.5 | 7.8 |  | 0.335 | 0.068 | 0.014 | 0.000 | 5.945 | 13.414 | 0.978 | 0.164 |
| 03-Jan | 17.1 | 11.7 | 9.3 | 9.3 | 6.56 | 6.9 |  | 0.13 | 0.083 | 0.039 | 0.317 | 5.887 | 9.657 | 0.198 | 0.066 |
| 04-Jan | 17.3 | 13.8 | 12.4 | 11.8 | 7.9 | 9.6 |  | 0.161 | 0.088 | 0.019 | 0.001 | 4.241 | 2.156 | 0.249 | 0.052 |
| 06-Jan | 18.2 | 13 | 13 | 12.1 | 7.5 | 6.1 |  | 0.124 | 0.059 | 0.041 | 0.336 | 4.722 | 5.480 | 0.106 | 0.039 |
| 07-Jan | 20.3 | 14.2 | 12.2 | 11.6 | 7.9 | 6.5 |  | 0.265 | 0.150 | 0.232 | 1.070 | 11.394 | 12.049 | 0.150 | 0.037 |
| 08-Jan | 16.7 | 12.8 | 12.5 | 11.1 | 5.3 | 5.3 |  | 0.159 | 0.215 | 0.248 | 1.002 | 7.822 | 7.768 | 0.167 | 0.059 |
| 09-Jan | 20.1 | 14.4 | 11.5 | 10.9 | 6.1 | 5.5 |  | 0.182 | 0.042 | 0.070 | 0.476 | 6.093 | 4.858 | 0.095 | 0.007 |
| 10-Jan | 18.9 | 13.5 | 10.9 | 10.3 | 8.9 | 7.8 |  | 0 | 0.000 | 0.000 | 0.000 | 7.794 | 5.285 | 0.000 | 0.000 |
| 11-Jan | 22.9 | 16.8 | 14.6 | 13 | 6.9 | 6 |  | 0.036 | 0.017 | 0.017 | 0.458 | 5.600 | 5.028 | 0.033 | 0.000 |
| 13-Jan |  |  |  | 14.3 | 2.5 | 6.3 |  |  |  |  |  |  |  |  |  |
| 14-Jan | 15.6 | 10.8 | 7.3 | 6.07 | 9.8 | 11.03 |  | 0.734 | 0.123 | 0.068 | 0.067 | 8.037 | 9.919 | -0.163 | 0.120 |
| 15-Jan | 26 | 16.5 | 11.1 | 9.3 | 10.2 | 10.5 |  | 0.242 | 0.114 | 0.133 | 0.282 | 7.067 | 6.641 | 0.299 | 0.148 |
| 16-Jan | 28.3 | 18.7 | 12.4 | 10.8 | 6.7 | 7.6 |  | 0.262 | 0.195 | 0.088 | 2.756 | 5.108 | 6.523 | 1.030 | 0.177 |
| 17-Jan | 35.7 | 20.8 | 31.4 | 10.7 | 7 | 5.5 |  | 0.427 | 0.074 | 0.091 | 0.076 | 2.609 | 3.456 | 0.467 | 0.149 |
| 18-Jan | 32.1 | 29.4 | 14.6 | 10.7 | 11 | ERR |  | 0.181 | 0.107 | 0.113 | 0.146 | 0.996 | 1.395 | 0.136 | 0.106 |
| 20-Jan * | 29.8 | 18.3 | 11.2 | 9.5 | 13.3 | 12.7 |  | 0.086 | 0.126 | 0.081 | 0.295 | 3.968 | 3.648 | 0.123 | 0.070 |
| 21-Jan | 28.9 | 16.8 | 10.1 | 8.6 | 13.3 | 13.3 |  | 1.381 | 0.265 | 0.222 | 0.488 | 6.176 | 5.020 | 0.193 | 0.115 |
| 22-Jan | 27.0 | 14.3 | 10.1 | 9.2 | 13.8 | 11.9 |  | 0.105 | 0.079 | 0.024 | 0.447 | 5.463 | 4.551 | 0.175 | 0.096 |
| 23-Jan | 27.01 | 14.3 | 10.3 | 8.4 | 11.3 | 9.6 |  | 0.09 | 0.120 | 0.081 | 0.401 | 5.619 | 4.457 | 0.151 | 0.190 |
| 24-Jan | 28.4 | 15.7 | 9.5 | 8.6 |  | 10.8 |  | 0.141 | 0.143 | 0.117 | 0.356 | 4.678 | 3.931 | 0.131 | 0.118 |
| 25-Jan | 27.2 | 14.1 | 8.6 | 7.33 | 14.5 | 12.37 |  | 0.108 | 0.081 | 0.084 | 0.058 | 5.372 | 4.246 | 0.066 | 0.075 |
| 27-Jan | 29 | 17.9 | 9.8 | 8.5 | 12.5 | 11.2 |  | 0.389 | 0.153 | 0.106 | 0.075 | 4.341 | 4.457 | 0.414 | 0.143 |
| 28-Jan | 31.9 | 17.6 | 10.5 | 9.5 | 12.1 |  |  | 1.013 | 0.136 | 0.090 | 0.226 | 11.200 | 10.530 | 0.347 | 0.167 |
| 29-Jan | 24.3 | 17.2 | 8.6 | 7.7 | 12.5 | 11.8 |  | 0.243 | 0.092 | 0.133 | 0.383 | 6.404 | 9.880 | 0.411 | 0.174 |
| 30-Jan | 15.6 | 15.6 | 10.9 | 7 | 11.5 | 11.8 |  | 0.326 | 0.228 | 0.281 | 0.598 | 6.626 | 7.360 | 0.420 | 0.343 |
| 31-Jan | 40.9 | 23.2 | 8.6 | 5.9 | 15 | 14.7 |  | 0.834 | 0.395 | 0.185 | 0.129 | 2.316 | 4.070 | 0.943 | 0.333 |
| 01-Feb * | 34.9 | 19.9 | 9.6 | 7.6 | 14.4 | 13 |  | 1.723 | 0.575 | 0.273 | 0.187 | 10.760 | 8.870 | 0.890 | 0.337 |
| 03-Feb | 33.9 | 19.2 | 8.3 | 7.9 | 11.6 | 11 |  | 0.239 | 0.149 | 0.159 | 0.353 | 5.910 | 5.360 | 0.169 | 0.139 |
| 04-Feb | 33.5 | 19.6 | 8.3 | 5.6 | 11 | 12 |  | 0.558 | 0.215 | 0.122 | 0.097 |  | 2.610 | 0.414 | 0.152 |
| 05-Feb | 31.9 | 17.6 | 6.9 | 4.2 | 11.6 | 11.6 |  | 0.13 | 0.110 | 0.112 | 0.102 | 0.089 | 5.392 | 0.222 | 0.167 |
| 06-Feb | 34.0 | 19.7 | 11.6 | 6.9 | 10.7 | 9.5 |  | 0.062 | 0.059 | 0.060 | 0.089 | 5.392 | 4.440 | 0.407 | 0.198 |
| 07-Feb | 29.4 | 19.9 | 11.0 | 7.1 | 9.9 | 10.3 |  | 0.306 | 0.735 | 0.235 | 0.025 | 8.862 | 8.363 | 0.224 | 0.753 |
| 08-Feb | 27.6 | 14.9 | 8.6 | 7.8 | 9.5 | 9.9 |  | 0.472 | 0.239 | 0.108 | 0.043 | 4.632 | 5.387 | 0.184 | 0.156 |
| 10-Feb | 24.1 | 15.2 | 9.6 | 8.0 | 11.38 | 10.1 |  | 1.292 | 0.303 | 0.156 | 0.130 | 4.967 | 5.288 | 0.188 | 0.120 |
| 12-Feb | 32.3 | 19.3 | 10.8 | 9.6 | 9.43 | 7.54 |  | 0.597 | 0.290 | 0.154 | 0.116 | 5.187 | 4.872 | 0.144 | 0.119 |
| 13-Feb | 33.9 | 22.0 | 13.0 | 10.0 | 14.28 | 8.7 |  | 0.665 | 0.205 | 0.135 | 0.144 | 1.972 | 4.432 | 0.096 | 0.458 |
| 14-Feb | 31.6 | 19.0 | 11.4 | 9.7 | 14.5 | 8.6 |  | 0.459 | 0.193 | 0.000 | 0.098 | 4.670 | 4.193 | 0.112 | 0.061 |
| 15-Feb * | 36.4 | 20.7 | 8.9 | 8.0 | 12.52 | 9 |  | 0.125 | 0.067 | 0.060 | 0.070 | 4.417 | 2.930 | 0.126 | 0.078 |
| 17-Feb | 40.7 | 27.0 | 12.4 | 6.5 | 14 | 10.2 |  | 0.081 | 0.111 | 0.243 | 0.114 | 4.461 | 4.013 | 0.085 | 0.056 |
| 18-Feb | 36.1 | 19.4 | 8.1 | 4.2 | 12.1 | 9.7 |  | 0.08 | 0.083 | 0.102 | 0.082 | 4.427 | 3.207 | 0.092 | 0.071 |
| 19-Feb | 34.6 | 18.8 | 7.8 | 4.2 | 14 | 11.9 |  | 0.105 | 0.282 | 0.194 | 0.150 | 3.992 | 3.198 | 0.040 | 0.070 |
| 20-Feb | 31.5 | 16.3 | 6.2 | 3.2 | 19.9 | 18.5 |  | 0.105 | 0.128 | 0.110 | 0.043 | 3.866 | 3.350 | 0.085 | 0.099 |
| 21-Feb | 34.5 | 17.2 | 5.6 | 2.1 | 15.1 | 14.2 |  | 2.278 | 0.673 | 0.191 | 0.121 | 7.105 | 6.704 | 0.079 | 0.051 |
| 22-Feb | 36 | 20.8 | 7.7 | 3.1 | 13.7 | 12.2 |  | 0.503 | 0.223 | 0.112 | 2.578 | 5.664 | 5.445 |  |  |

| DATE | PHOSPHATES (mg-P/l) | | | | | | NITRATES (mg-N/l) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E2 | E3 | E4 | EE | delC | delE | C1 | C11 | C2 | C3 | C4 | CE | E1 | E11 |
| 24-Feb | 42.7 | 23.5 | 11.0 | 3.7 | 15.2 | 13.4 | | | | | | | | |

| DATE | NITRATES (mg-N/l) | | | | | | NITRITES (mg-N/l) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E11 | E2 | E3 | E4 | EE | C1 | C11 | C2 | C3 | C4 | CE |
| 27-June * | | | | | | | | 0.110 | 0.080 | 0.160 | 0.100 | 2.070 |
| 29-June | | 2.390 | 0.700 | 2.040 | 8.170 | 29.580 | | 0.160 | 0.090 | 0.210 | 0.340 | 2.100 |
| 30-June | | 1.230 | 1.610 | 1.320 | 5.270 | 5.270 | | 0.080 | 0.070 | 0.060 | 0.040 | 0.020 |
| 03-July | | 1.100 | 1.280 | 1.320 | 5.270 | 5.270 | | 0.110 | 0.070 | 0.060 | 0.270 | 0.020 |
| 07-July | | 1.270 | 0.240 | 0.640 | 13.120 | 15.200 | | 0.070 | 0.080 | 0.060 | 0.050 | 0.020 |
| 11-July | | 0.250 | 0.280 | 0.690 | 14.580 | 14.580 | | 0.370 | 0.180 | 0.150 | 0.470 | 0.230 |
| 13-July | | 1.450 | 0.300 | 0.630 | 15.720 | 22.050 | | 0.260 | 0.190 | 0.100 | 0.100 | 0.050 |
| 15-July | | 1.610 | 0.290 | 0.610 | 17.690 | 19.770 | | 0.440 | 0.210 | 0.240 | 0.200 | 0.520 |
| 17-July | | 2.410 | 0.920 | 1.310 | 16.240 | 18.520 | | 0.500 | 0.220 | 2.330 | 0.440 | 0.550 |
| 19-July | | 2.570 | 0.940 | 1.620 | 28.080 | 14.160 | | 0.890 | 0.290 | 1.000 | 0.170 | 0.680 |
| 20-July | | 1.160 | 0.260 | 0.150 | 10.330 | 15.910 | | 0.140 | 0.070 | 0.100 | 0.090 | 0.240 |
| 22-July | | 1.500 | 0.310 | 0.190 | 11.570 | 16.110 | | 0.160 | 0.140 | 0.380 | 0.140 | 0.550 |
| 24-July * | | 1.550 | 0.380 | 0.220 | 11.160 | 15.700 | | 0.210 | 0.140 | 0.150 | 0.130 | 0.430 |
| 25-July | | 0.930 | 0.190 | 0.240 | 10.540 | 11.160 | | 0.120 | 0.100 | 0.230 | 0.100 | 0.240 |
| 26-July | | 1.020 | 0.320 | 0.240 | 10.130 | 10.950 | | | | | | |
| 29-July | 0.640 | 0.270 | 0.220 | 0.200 | 6.830 | 5.790 | | | | | | |
| 30-July | 0.810 | 0.330 | 0.230 | 0.380 | 8.060 | 2.080 | 0.140 | 0.120 | 0.120 | 0.120 | 1.010 | 0.080 |
| 31-July | 0.990 | 0.930 | 0.340 | 0.220 | 8.270 | 8.890 | | | | | | |
| 06-Aug | | | | | | | | | | | | |
| 07-Aug | | | | | | | | | | | | |
| 08-Aug | 1.090 | 0.220 | 0.120 | 0.120 | 11.510 | 19.090 | | | | | | |
| 09-Aug * | 1.090 | 0.240 | 0.130 | 0.100 | 7.070 | 7.070 | | | | | | |
| 10-Aug | 1.180 | 0.260 | 0.150 | 0.170 | 5.600 | 8.920 | | | | | | |
| 13-Aug | 0.030 | 0.030 | 0.030 | 0.230 | 4.670 | 5.970 | 0.140 | 0.110 | 0.110 | 0.180 | 0.340 | 0.350 |
| 14-Aug | 0.450 | 0.160 | 0.120 | 0.100 | 3.750 | 3.930 | 0.140 | 0.090 | 0.080 | 0.080 | 0.140 | 0.140 |
| 15-Aug | 0.440 | 0.150 | 0.130 | 0.090 | 3.930 | 0.610 | 0.120 | 0.110 | 0.110 | 0.140 | 0.370 | 0.370 |
| 16-Aug | 0.100 | 0.100 | 0.100 | 0.370 | 3.930 | 3.930 | 0.850 | 0.230 | 0.130 | 0.070 | 0.080 | 0.340 |
| 19-Aug | 0.410 | 0.150 | 0.110 | 0.090 | 4.120 | 4.490 | 0.140 | 0.150 | 0.140 | 0.140 | 0.110 | 0.230 |
| 26-Aug * | 1.240 | 0.240 | 0.120 | 0.070 | 8.260 | 14.850 | 0.720 | 0.120 | 0.150 | 0.105 | 0.194 | 0.288 |
| 27-Aug | 0.975 | 0.180 | 0.115 | 0.000 | 8.320 | 12.686 | 0.115 | 0.095 | 0.070 | 0.070 | 0.228 | 0.401 |
| 28-Aug | 1.110 | 0.860 | 0.133 | 0.100 | 7.147 | 9.570 | 0.159 | 0.100 | 0.070 | 0.085 | 0.219 | 0.827 |
| 29-Aug | 0.110 | 0.080 | 0.093 | 0.060 | 6.888 | 8.116 | 0.174 | 0.095 | 0.092 | 0.075 | 0.996 | 0.970 |
| 30-Aug | 0.732 | 0.146 | 0.090 | 0.050 | 6.270 | 10.660 | 0.110 | 0.097 | 0.092 | 0.100 | 1.200 | 1.045 |
| 2-Sept | 1.050 | 0.240 | 0.170 | 0.130 | 7.670 | 8.580 | | | | | | 3.250 |
| 3-Sept | | | | | | | | | | | | |
| 4-Sept | 0.647 | 0.106 | 0.065 | 0.000 | 15.250 | 13.800 | 0.362 | 0.149 | 0.124 | 0.115 | 4.160 | 5.110 |
| 5-Sept | | | | | | 10.420 | | | | | | 5.740 |
| 6-Sept | | | | | 5.210 | 9.260 | 0.124 | 0.149 | 0.496 | 0.209 | 5.110 | 6.580 |
| 9-Sept | | | | | 8.760 | 10.450 | 0.243 | 0.095 | 0.070 | 0.139 | 4.370 | 4.790 |
| 10-Sept | | | | | | | | | | | | 7.610 |
| 11-Sept * | 1.322 | 0.438 | 0.267 | 0.267 | 12.800 | 14.080 | | | 0.209 | 0.276 | 2.660 | 8.030 |
| 12-Sept | | | | | | 10.460 | | | | | | 5.600 |
| 13-Sept | 1.194 | 0.374 | 0.267 | 0.235 | 11.300 | 10.460 | | | | | | |
| 14-Sept | | | | | | 12.590 | | | | | | 3.750 |
| 16-Sept | | | | | | | 0.745 | | | 9.760 | 4.290 | 2.100 |
| 17-Sept | | | | | | | | | | | | |
| 18-Sept | | | | | | | | | | | | |
| 19-Sept | | | | | | 15.150 | | | | | | 0.416 |
| 20-Sept | | | | | | 13.870 | | | | | | 0.163 |
| 21-Sept | | | | | | 16.210 | 0.859 | 0.168 | 0.135 | 0.240 | 5.300 | 0.058 |
| 22-Sept | | | | | | | | | | | | |
| 23-Sept | | | | | | | | | | | | |
| 24-Sept | 1.070 | 0.324 | 0.265 | 0.295 | 17.700 | 17.100 | 0.063 | 0.050 | 0.046 | 0.269 | 1.680 | 8.250 |
| 25-Sept * | | | | | | 17.700 | | | | | | 1.380 |
| 26 Sept | | | | | | 20.000 | | | | | | 0.926 |
| 27-Sept | | | | | | 19.200 | | | | | | |
| 28-Sept | | | | | | 18.600 | | | | | | 6.650 |
| 29-Sept | | | | | | | | | | | | |

| DATE | NITRATES (mg-N/l) | | | | | | NITRITES (mg-N/I) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E11 | E2 | E3 | E4 | EE | C1 | C11 | C2 | C3 | C4 | CE |
| 30-Sept | 1.890 | 0.304 | 0.197 | 0.648 | 16.900 | 24.500 | 0.033 | 0.029 | 0.029 | 0.021 | 0.584 | 0.921 |
| 01-Oct | | | | | | 12.800 | | | | | | 0.416 |
| 02-Oct | | | | | | | | | | | | |
| 03-Oct | | | | | | | 0.050 | 0.038 | 0.021 | 0.021 | 0.028 | 0.584 |
| 04_oct | | | | | | 10.340 | | | | | | 1.700 |
| 05-Oct | | | | | | 9.610 | | | | | | 0.921 |
| 06-Oct | | | | | | | | | | | | |
| 07-Oct | 0.985 | 0.390 | 0.160 | 0.124 | 6.320 | 11.070 | 0.088 | 0.047 | 0.028 | 0.033 | 0.302 | 0.462 |
| 08-Oct | | | | | | 6.500 | | | | | | 0.382 |
| 09-Oct | | | | | | 9.160 | 0.070 | 0.051 | 0.056 | 0.038 | 0.211 | 0.337 |
| 10-Oct * | | | | | | 8.530 | | | | | | 0.417 |
| 11-Oct | 0.345 | 0.431 | 0.313 | 0.179 | 2.830 | 4.910 | 0.038 | 0.033 | 0.038 | 0.033 | 0.073 | 0.485 |
| 12-Oct | | | | | | 7.710 | | | | | | 0.371 |
| 13-Oct | | | | | | | | | | | | |
| 14-Oct | 0.400 | 0.164 | 0.069 | 0.219 | 3.160 | 4.600 | 0.038 | 0.033 | 0.033 | 0.038 | 0.051 | 0.061 |
| 15-Oct | | | | | | 8.770 | | | | | | 0.371 |
| 16-Oct | 0.642 | 0.114 | 0.059 | 0.059 | 2.990 | 6.210 | 0.087 | 0.061 | 0.054 | 0.039 | 0.039 | 0.291 |
| 17-Oct | | | | | | 11.150 | | | | | | 0.291 |
| 18-Oct | 0.560 | 0.128 | 0.073 | 0.053 | 2.990 | 4.600 | 0.015 | 0.096 | 0.057 | 0.044 | 0.044 | 0.204 |
| 19-Oct | | | | | | 9.680 | | | | | | 0.209 |
| 20-Oct | | | | | | | | | | | | |
| 21-Oct | 0.621 | 0.162 | 0.087 | 0.059 | 3.680 | 4.430 | 0.109 | 0.100 | 0.048 | 0.044 | 0.035 | 0.339 |
| 22-Oct | | | | | | 7.520 | | | | | | 0.213 |
| 23-Oct | 0.375 | 0.114 | 0.087 | 0.007 | 3.200 | 0.354 | 0.117 | 0.113 | 0.065 | 0.104 | 0.044 | 0.126 |
| 24-Oct | | | | | | 6.720 | | | | | | 0.191 |
| 25-Oct | 0.423 | 0.107 | 0.087 | 0.066 | 0.040 | 4.430 | 0.096 | 0.057 | 0.050 | 0.039 | 0.387 | 0.680 |
| 26-Oct | | | | | | 19.400 | | | | | | 0.472 |
| 27-Oct | | | | | | | | | | | | |
| 28-Oct * | | | | | | 21.100 | | | | | | 0.236 |
| 29-Oct | 1.204 | 0.161 | 0.036 | 0.022 | 6.977 | 16.112 | 0.193 | 0.107 | 0.081 | | 0.354 | 0.183 |
| 30-Oct | | | | | | 18.600 | | | | | | 0.183 |
| 31-Oct | 0.977 | 0.146 | 0.013 | 0.007 | 3.560 | 6.682 | 0.161 | 0.107 | 0.094 | 0.081 | 0.736 | 0.344 |
| 01-Nov | | | | | | 16.900 | | | | | | 0.413 |
| 02-Nov | 0.260 | 0.144 | 0.146 | 0.032 | 6.987 | 14.100 | 0.099 | 0.110 | 0.102 | 0.123 | 0.131 | 0.550 |
| 04-Nov | 1.113 | 0.989 | 0.221 | 0.130 | 9.458 | 11.245 | 0.588 | 0.187 | 0.200 | 0.180 | 0.131 | 1.272 |
| 05-Nov | | | | | | 10.836 | | | | | | 1.364 |
| 06-Nov | 1.800 | 0.182 | 0.045 | 0.072 | 1.763 | 4.182 | 0.544 | 0.217 | 0.193 | 0.180 | 0.199 | 1.315 |
| 07-Nov | 0.327 | 0.156 | 0.068 | 0.135 | 7.800 | 6.940 | 0.137 | 0.097 | 0.097 | 0.134 | 0.122 | 0.591 |
| 08-Nov * | 0.110 | 0.082 | 0.057 | 0.143 | 9.304 | 9.626 | 0.067 | 0.067 | 0.087 | 0.155 | 0.183 | 0.198 |
| 09-Nov | 0.141 | 0.286 | 0.113 | 0.570 | 8.295 | 10.378 | 0.067 | 0.067 | 0.087 | 0.157 | 0.208 | 0.377 |
| 11-Nov | 0.405 | 0.315 | 0.090 | 0.186 | 6.319 | 10.125 | 0.069 | 0.097 | 0.079 | 0.092 | 0.082 | 0.054 |
| 12-Nov | 0.107 | 0.336 | 0.088 | 0.105 | 5.465 | 7.096 | 0.253 | 0.087 | 0.084 | 0.087 | 0.059 | 0.059 |
| 13-Nov | 0.256 | 0.084 | 0.051 | 0.000 | 0.166 | 2.888 | 0.082 | 0.067 | 0.072 | 0.112 | 0.097 | 0.099 |
| 14-Nov | 0.131 | 0.207 | 0.365 | 0.212 | 0.327 | 0.361 | 0.067 | 0.082 | 0.092 | 0.246 | 1.282 | 0.505 |
| 15-Nov | 0.224 | 0.247 | 0.204 | 0.365 | 0.247 | 0.188 | 0.077 | 0.077 | 0.132 | 0.657 | | |
| 16-Nov | 0.138 | 0.140 | 0.102 | 0.099 | 0.160 | 0.113 | 0.062 | 0.077 | 0.092 | 0.147 | 0.858 | 3.750 |
| 18-Nov | 0.324 | 0.469 | 0.204 | 0.384 | 0.439 | 0.207 | 0.082 | 0.097 | 0.087 | 0.112 | 0.420 | 0.964 |
| 19-Nov | 0.655 | 0.120 | 0.073 | 0.065 | 0.009 | 5.353 | 0.084 | 0.097 | 0.112 | 0.119 | 0.271 | 0.505 |
| 20-Nov * | 0.819 | 0.194 | 0.066 | 0.107 | 0.279 | 0.529 | 0.114 | 0.114 | 0.137 | 0.147 | 0.288 | 0.677 |
| 21-Nov | | | | | | | | | | | | |
| 22-Nov | 0.476 | 0.132 | 0.118 | 0.034 | 0.000 | 0.198 | 0.074 | 0.117 | 0.126 | 0.192 | 0.533 | 0.084 |
| 23-Nov | 0.085 | 0.455 | 0.103 | 0.044 | 0.036 | 0.000 | 0.130 | 0.154 | 0.208 | 0.323 | 0.909 | 1.880 |
| 25-Nov | 0.136 | 0.093 | 0.083 | 0.075 | 0.000 | 0.245 | 0.117 | 0.139 | 0.143 | 0.334 | 1.050 | 0.918 |
| 26-Nov | 0.116 | 0.117 | 0.105 | 0.089 | 0.000 | 0.000 | 0.129 | 0.108 | 0.158 | 0.340 | 1.575 | 2.078 |
| 27-Nov | 0.160 | 0.194 | 0.247 | 1.420 | 12.200 | 12.353 | 0.142 | 0.181 | 0.184 | 0.354 | 1.940 | 0.318 |
| 28-Nov | 0.568 | 0.048 | 0.000 | 0.000 | 0.000 | 0.000 | 0.198 | 0.234 | 0.273 | 0.338 | 0.821 | 0.318 |
| 29-Nov | 0.940 | 0.269 | 0.115 | 0.109 | 12.067 | 5.786 | 0.176 | 0.170 | 0.204 | 0.323 | 1.050 | 0.237 |
| 30-Nov | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.226 | 0.239 | 0.231 | 0.260 | 0.818 | 0.281 |
| 2-Dec | 0.016 | 0.019 | 0.000 | 0.000 | 0.000 | 0.000 | 0.161 | 0.164 | 0.169 | 0.180 | 0.570 | 0.487 |
| 3-Dec | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.156 | 0.136 | 0.161 | 0.283 | 0.976 | 0.355 |

| DATE | NITRATES (mg-N/l) | | | | | | NITRITES (mg-N/l) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E1 | E11 | E2 | E3 | E4 | EE | C1 | C11 | C2 | C3 | C4 | CE |
| 4-Dec * | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.211 | 0.153 | 0.233 | 0.927 | 0.913 |
| 5-Dec | 0.089 | 0.213 | 0.430 | 0.087 | 4.290 | 4.900 | 0.147 | 0.156 | 0.156 | 0.216 | 0.700 | 0.683 |
| 6-Dec | 0.131 | 0.081 | 0.040 | 0.026 | 1.266 | 3.477 | 0.133 | 0.145 | 0.200 | 0.133 | 0.609 | 1.090 |
| 7-Dec | 0.215 | 0.098 | 0.072 | 0.027 | 3.510 | 0.000 | 0.150 | 0.153 | 0.145 | 0.194 | 0.747 | 0.783 |
| 9-Dec | 0.161 | 0.172 | 0.142 | 0.070 | 3.448 | 1.661 | 0.139 | 0.136 | 0.145 | 0.227 | 0.540 | 0.750 |
| 10-Dec | 0.150 | 0.136 | 0.070 | 0.062 | 1.500 | 1.720 | 0.156 | 0.125 | 0.153 | 0.156 | 0.313 | 0.996 |
| 11-Dec | 0.150 | 0.089 | 0.090 | 0.071 | 3.162 | 2.595 | 0.153 | 0.161 | 0.172 | 0.186 | 0.371 | 1.270 |
| 12-Dec | 0.349 | 0.092 | 0.012 | 0.000 | 3.713 | 3.478 | 0.150 | 0.139 | 0.156 | 0.164 | 0.274 | 0.208 |
| 13-Dec | 0.073 | 0.057 | 0.058 | 0.372 | 3.446 | 3.544 | 0.117 | 0.117 | 0.117 | 0.186 | 0.360 | 0.219 |
| 14-Dec | | | | | | | | | | | | |
| 17-Dec | 0.556 | 0.119 | 0.297 | 0.091 | 8.327 | 8.255 | 0.170 | 0.178 | 0.175 | 0.175 | 0.315 | 0.597 |
| 18-Dec | 0.335 | 0.300 | 0.073 | 0.272 | 4.614 | 7.629 | 0.229 | 0.170 | 0.106 | 0.120 | 0.245 | 0.352 |
| 19-Dec * | 0.259 | 0.075 | 0.104 | 0.274 | 4.244 | 4.741 | 0.128 | 0.128 | 0.128 | 0.122 | 0.212 | 0.609 |
| 20-Dec | 0.413 | 0.438 | 0.324 | 0.227 | 4.133 | 4.864 | 0.238 | 0.272 | 0.203 | 0.192 | 0.164 | 0.594 |
| 21-Dec | 0.227 | 0.235 | 0.194 | 0.389 | 3.646 | 3.808 | 0.118 | 0.109 | 0.084 | 0.138 | 0.246 | 0.483 |
| 23-Dec | 1.356 | 0.218 | 0.035 | 0.044 | 6.420 | 7.973 | 0.089 | 0.101 | 0.072 | 0.098 | 0.203 | 0.309 |
| 02-Jan | 0.978 | 0.164 | 0.041 | 0.008 | 7.987 | 8.608 | 0.266 | 0.118 | 0.072 | 0.058 | 0.069 | 0.106 |
| 03-Jan | 0.198 | 0.066 | 0.130 | 0.318 | 4.909 | 6.632 | 0.110 | 0.090 | 0.107 | 0.150 | 0.136 | 0.114 |
| 04-Jan | 0.249 | 0.052 | 0.053 | 0.360 | 3.901 | 5.126 | 0.092 | 0.085 | 0.074 | 0.065 | 0.309 | 0.253 |
| 06-Jan | 0.106 | 0.039 | 0.023 | 0.279 | 3.802 | 3.829 | 0.069 | 0.060 | 0.065 | 0.131 | 0.230 | 0.141 |
| 07-Jan | 0.150 | 0.037 | 0.014 | 0.001 | 6.562 | 7.659 | 0.101 | 0.065 | 0.065 | 0.130 | 0.036 | 0.141 |
| 08-Jan * | 0.167 | 0.059 | 0.121 | 0.912 | 6.772 | 8.056 | 0.083 | 0.069 | 0.098 | 0.094 | 0.168 | 0.910 |
| 09-Jan | 0.095 | 0.007 | 0.000 | 0.000 | 3.612 | 4.651 | 0.060 | 0.063 | 0.049 | 0.083 | 0.177 | 0.592 |
| 10-Jan | 0.000 | 0.000 | 0.000 | 0.268 | 4.329 | 3.504 | 0.096 | 0.114 | 0.076 | 0.101 | 0.056 | 0.297 |
| 11-Jan | 0.033 | 0.000 | 0.000 | 0.285 | 4.282 | 3.346 | 0.069 | 0.074 | 0.060 | 0.087 | 0.119 | 0.141 |
| 13-Jan | | | | | | | | | | | | 0.758 |
| 14-Jan | -0.163 | 0.120 | 0.083 | 0.147 | 4.233 | 1.648 | 0.067 | 0.049 | 0.049 | 0.043 | 0.043 | 0.821 |
| 15-Jan | 0.299 | 0.148 | 0.113 | 0.132 | 4.730 | 5.882 | 0.094 | 0.085 | 0.107 | 0.081 | 0.123 | 0.069 |
| 16-Jan | 1.030 | 0.177 | 0.093 | 0.059 | 3.301 | 4.707 | 0.074 | 0.086 | 0.090 | 0.137 | 0.162 | 0.257 |
| 17-Jan | 0.467 | 0.149 | 0.092 | 0.062 | 3.169 | 3.411 | 0.210 | 0.234 | 0.081 | 0.068 | 0.201 | 0.654 |
| 18-Jan | 0.136 | 0.106 | 0.084 | 0.090 | 0.713 | 1.641 | 0.086 | 0.106 | 0.086 | 0.108 | 0.374 | 0.595 |
| 20-Jan * | 0.123 | 0.070 | 0.004 | 0.070 | 3.450 | 2.626 | 0.140 | 0.155 | 0.214 | 0.137 | 0.212 | 0.532 |
| 21-Jan | 0.193 | 0.115 | 0.126 | 0.088 | 4.583 | 3.926 | 0.216 | 0.216 | 0.129 | 0.214 | 0.194 | 0.440 |
| 22-Jan | 0.175 | 0.096 | 0.049 | 0.099 | 4.820 | 4.647 | 0.221 | 0.221 | 0.327 | 0.255 | 0.257 | 1.039 |
| 23-Jan | 0.151 | 0.190 | 0.076 | 0.382 | 4.854 | 4.896 | 0.158 | 0.167 | 0.128 | 0.158 | 0.101 | 0.873 |
| 24-Jan | 0.131 | 0.118 | 0.109 | 0.074 | 4.579 | 4.382 | 0.081 | 0.079 | 0.079 | 0.099 | 0.392 | 0.879 |
| 25-Jan | 0.066 | 0.075 | 0.111 | 0.432 | 5.127 | 4.531 | 0.104 | 0.115 | 0.086 | 0.099 | 0.088 | 0.694 |
| 27-Jan | 0.414 | 0.143 | 0.111 | 0.077 | 3.986 | 4.298 | 0.079 | 0.081 | 0.077 | 0.095 | 1.249 | 0.613 |
| 28-Jan | 0.347 | 0.167 | 0.090 | 0.065 | 19.150 | 11.670 | 0.077 | 0.072 | 0.063 | 0.086 | 0.179 | 0.629 |
| 29-Jan | 0.411 | 0.174 | 0.104 | 0.083 | 4.250 | 6.350 | 0.070 | 0.067 | 0.081 | 0.123 | 0.186 | 1.009 |
| 30-Jan | 0.420 | 0.343 | 0.369 | 0.489 | 5.250 | 5.790 | 0.118 | 0.132 | 0.100 | 0.109 | 0.104 | 0.536 |
| 31-Jan | 0.943 | 0.333 | 0.187 | 0.145 | 6.350 | 5.980 | 0.088 | 0.125 | 0.044 | 0.044 | 0.044 | 0.638 |
| 01-Feb * | 0.890 | 0.337 | 0.203 | 0.167 | 6.870 | 6.370 | 0.239 | 0.125 | 0.053 | 0.049 | 0.144 | 0.489 |
| 03-Feb | 0.169 | 0.139 | 0.152 | 0.407 | 4.730 | 4.690 | 0.239 | 0.107 | 0.056 | 0.111 | 0.046 | 0.480 |
| 04-Feb | 0.414 | 0.152 | 0.202 | 0.097 | 3.680 | 4.440 | 0.239 | 0.152 | 0.100 | 0.090 | 0.048 | 0.425 |
| 05-Feb | 0.222 | 0.167 | 0.098 | 0.081 | 3.860 | 3.350 | 0.113 | 0.133 | 0.103 | 0.085 | 0.373 | 0.464 |
| 06-Feb | 0.407 | 0.198 | 0.145 | 0.131 | | | 0.083 | 0.093 | 0.058 | 0.140 | 0.088 | 0.554 |
| 07-Feb | 0.224 | 0.753 | 0.093 | 0.017 | 4.500 | 7.632 | 0.113 | 0.182 | 0.142 | 0.110 | 0.098 | 0.237 |
| 08-Feb | 0.184 | 0.156 | 0.073 | 0.056 | 7.112 | 8.043 | 0.068 | 0.088 | 0.098 | 0.142 | 0.058 | 0.083 |
| 10-Feb | 0.188 | 0.120 | 0.083 | 0.067 | 4.127 | 4.432 | 0.123 | 0.095 | 0.093 | 0.147 | 0.083 | 0.082 |
| 12-Feb | 0.144 | 0.119 | 0.113 | 0.067 | 4.737 | 5.137 | 0.306 | 0.172 | 0.137 | 0.133 | 0.073 | 0.038 |
| 13-Feb | 0.096 | 0.458 | 0.183 | 0.082 | 4.117 | 4.187 | 0.323 | 0.222 | 0.142 | 0.133 | 0.088 | 0.118 |
| 14-Feb | 0.112 | 0.061 | 0.073 | 0.058 | 3.764 | 3.740 | 0.266 | 0.177 | 0.142 | 0.137 | 0.066 | 0.147 |
| 15-Feb * | 0.126 | 0.078 | 0.092 | 0.072 | 4.142 | 3.647 | 0.088 | 0.118 | 0.118 | 0.108 | 0.063 | 0.410 |
| 17-Feb | 0.085 | 0.056 | 0.098 | 0.087 | 3.393 | 3.397 | 0.118 | 0.123 | 0.105 | 0.128 | 0.229 | 0.177 |
| 18-Feb | 0.092 | 0.071 | 0.059 | 0.071 | 3.149 | 2.764 | 0.261 | 0.137 | 0.118 | 0.103 | 0.053 | 0.133 |
| 19-Feb | 0.040 | 0.070 | 0.105 | 0.115 | 3.577 | 3.087 | 0.222 | 0.187 | 0.140 | 0.113 | 0.058 | 0.212 |
| 20-Feb | 0.085 | 0.099 | 0.103 | 0.020 | 3.583 | 2.835 | 0.137 | 0.121 | 0.097 | 0.135 | 0.044 | 0.130 |
| 21-Feb | 0.079 | 0.051 | 0.092 | 0.064 | 5.115 | 5.518 | 0.252 | 0.149 | 0.144 | 0.121 | 0.065 | 0.196 |
| 22-Feb | | | | | | | 0.359 | 0.112 | 0.117 | 0.072 | 0.056 | 0.205 |
| 24-Feb | | | | | | | 0.079 | 0.103 | 0.089 | 0.049 | 0.042 | 0.238 |

| DATE | NITRITES (mg-N/l) | | | | | |
|---|---|---|---|---|---|---|
| | E1 | E11 | E2 | E3 | E4 | EE |
| 27-June * | | 0.230 | 0.090 | 0.180 | 0.060 | 0.240 |
| 29-June | | 0.100 | 0.070 | 0.210 | 0.630 | 2.020 |
| 30-June | | 0.070 | 0.050 | 0.040 | 0.550 | 0.790 |
| 03-July | | 0.070 | 0.060 | 0.010 | 0.670 | 0.040 |
| 07-July | | 0.060 | 0.060 | 0.070 | 0.070 | 0.020 |
| 11-July | | 0.090 | 0.090 | 0.100 | 0.560 | 0.480 |
| 13-July | | 0.090 | 0.090 | 0.110 | 0.500 | 0.060 |
| 15-July | | 0.160 | 0.120 | 0.330 | 0.510 | 0.360 |
| 17-July | | 0.140 | 0.130 | 0.330 | 0.500 | 0.440 |
| 19-July | | 0.130 | 0.120 | 0.350 | 0.450 | 0.630 |
| 20-July | | 0.180 | 0.210 | 0.180 | 0.780 | 0.470 |
| 22-July | | 0.120 | 0.120 | 0.110 | 0.450 | 0.330 |
| 24-July * | | 0.100 | 0.120 | 0.110 | 0.500 | 0.330 |
| 25-July | | 0.130 | 0.130 | 0.110 | 0.490 | 0.460 |
| 26-July | | | | | | |
| 29-July | | | | | | |
| 30-July | 0.350 | 0.210 | 0.120 | 0.840 | 0.290 | 0.020 |
| 31-July | | | | | | |
| 06-Aug | | | | | | |
| 07-Aug | | | | | | |
| 08-Aug | | | | | | |
| 09-Aug * | | | | | | |
| 10-Aug | | | | | | |
| 13-Aug | 1.140 | 0.760 | 0.410 | 0.110 | 0.630 | 0.080 |
| 14-Aug | 0.060 | 0.070 | 0.080 | 0.070 | 0.400 | 0.070 |
| 15-Aug | 0.120 | 0.100 | 0.110 | 0.080 | 0.330 | 0.020 |
| 16-Aug | 0.070 | 0.070 | 0.100 | 0.070 | 0.420 | 0.070 |
| 19-Aug | 0.090 | 0.110 | 0.090 | 0.090 | 0.770 | 0.090 |
| 26-Aug * | 0.094 | 0.085 | 0.085 | 0.085 | 0.619 | 0.174 |
| 27-Aug | 0.085 | 0.070 | 0.075 | 0.750 | 0.560 | 0.154 |
| 28-Aug | 0.080 | 0.080 | 0.077 | 0.080 | 0.743 | 1.090 |
| 29-Aug | 0.090 | 0.090 | 0.077 | 0.080 | 0.802 | 0.164 |
| 30-Aug | 0.188 | 0.104 | 0.110 | 0.110 | 1.020 | |
| 2-Sept | 0.293 | 0.114 | 0.112 | 0.104 | 0.723 | 0.610 |
| 3-Sept | | | | | | |
| 4-Sept | 0.303 | 0.124 | 0.115 | 0.357 | 1.950 | 1.420 |
| 5-Sept | | | | | | 1.530 |
| 6-Sept | 0.095 | 0.122 | 0.174 | 0.214 | 1.840 | 2.260 |
| 9-Sept | 0.381 | 0.110 | 0.087 | 0.095 | 1.270 | 2.050 |
| 10-Sept | | | | | | 0.905 |
| 11-Sept * | 0.850 | | 0.590 | | 4.000 | 1.320 |
| 12-Sept | | | | | | 1.156 |
| 13-Sept | | | | | | |
| 14-Sept | | | | | | 1.490 |
| 16-Sept | | | | | | |
| 17-Sept | | | | | | |
| 18-Sept | | | | | | |
| 19-Sept | | | | | | 1.170 |
| 20-Sept | | | | | | 0.669 |
| 21-Sept | | | | | | 1.420 |
| 22-Sept | | | | | | |
| 23-Sept | | | | | | 1.148 |
| 24-Sept | 0.067 | 0.063 | 0.084 | 0.088 | 0.143 | 0.125 |
| 25-Sept * | | | | | | 0.152 |

| DATE | NITRITES (mg-N/l) | | | | | |
|---|---|---|---|---|---|---|
| | E1 | E11 | E2 | E3 | E4 | EE |
| 26 Sept | | | | | | 0.033 |
| 27-Sept | | | | | | |
| 28-Sept | | | | | | 0.033 |
| 29-Sept | | | | | | |
| 30-Sept | 0.071 | 0.029 | 0.029 | 0.442 | 0.088 | 0.024 |
| 01-Oct | | | | | | 0.047 |
| 02-Oct | | | | | | |
| 03-Oct | 0.017 | 0.012 | 0.017 | 0.712 | 0.921 | 0.058 |
| 04_oct | | | | | | 0.111 |
| 05-Oct | | | | | | 0.102 |
| 06-Oct | | | | | | |
| 07-Oct | 0.097 | 0.047 | 0.042 | 0.035 | 0.371 | 0.085 |
| 08-Oct | | | | | | 0.085 |
| 09-Oct | 0.042 | 0.049 | 0.042 | 0.047 | 0.256 | 0.096 |
| 10-Oct * | | | | | | 0.130 |
| 11-Oct | 0.033 | 0.033 | 0.033 | 0.028 | 0.051 | 0.188 |
| 12-Oct | | | | | | 0.051 |
| 13-Oct | | | | | | |
| 14-Oct | 0.049 | 0.031 | 0.038 | 0.028 | 0.074 | 0.394 |
| 15-Oct | | | | | | 0.097 |
| 16-Oct | 0.052 | 0.048 | 0.052 | 0.044 | 0.030 | 0.111 |
| 17-Oct | | | | | | 0.130 |
| 18-Oct | 0.048 | 0.057 | 0.061 | 0.054 | 0.539 | 0.052 |
| 19-Oct | | | | | | 0.059 |
| 20-Oct | | | | | | |
| 21-Oct | 0.122 | 0.083 | 0.057 | 0.044 | 0.115 | 0.057 |
| 22-Oct | | | | | | 0.243 |
| 23-Oct | 0.057 | 0.057 | 0.061 | 0.050 | 0.039 | 0.230 |
| 24-Oct | | | | | | 0.239 |
| 25-Oct | 0.143 | 0.070 | 0.048 | 0.044 | 0.117 | 0.472 |
| 26-Oct | | | | | | 0.384 |
| 27-Oct | | | | | | |
| 28-Oct * | | | | | | 0.274 |
| 29-Oct | 0.166 | 0.145 | 0.097 | 0.089 | 0.773 | 0.188 |
| 30-Oct | | | | | | 0.145 |
| 31-Oct | 0.193 | 0.097 | 0.094 | 0.091 | 1.130 | 0.188 |
| 01-Nov | | | | | | 0.169 |
| 02-Nov | 0.094 | 0.086 | 0.064 | 0.140 | 0.193 | |
| 04-Nov | 0.199 | 0.180 | 0.199 | 0.137 | 0.125 | 0.261 |
| | | | | | | 0.267 |
| 05-Nov | | | | | | |
| 06-Nov | 0.150 | 0.174 | 0.199 | 0.156 | 0.156 | 0.273 |
| 07-Nov | 0.084 | 0.079 | 0.074 | 0.074 | 0.077 | 0.198 |
| 08-Nov * | 0.069 | 0.069 | 0.067 | 0.067 | 0.067 | 0.104 |
| 09-Nov | 0.067 | | | 0.102 | 0.145 | 0.102 |
| 11-Nov | 0.072 | 0.069 | 0.062 | 0.062 | 0.072 | 0.172 |
| 12-Nov | 0.072 | 0.067 | 0.072 | 0.074 | 0.185 | 0.132 |
| 13-Nov | 0.072 | 0.049 | 0.072 | 0.220 | 0.087 | 0.155 |
| 14-Nov | 0.132 | 0.084 | 0.084 | 0.079 | 0.067 | 0.097 |
| 15-Nov | 0.122 | 0.072 | 0.087 | 0.084 | 0.137 | 0.117 |
| 16-Nov | 0.301 | 0.132 | 0.032 | 0.061 | 0.067 | 0.243 |
| 18-Nov | 0.097 | 0.082 | 0.077 | 0.074 | 0.077 | 0.125 |
| 19-Nov | 0.082 | 0.152 | 0.162 | 0.142 | 0.198 | 0.107 |
| 20-Nov * | 0.122 | 0.142 | 0.147 | 0.155 | 0.147 | 0.142 |
| 21-Nov | | | | | | |
| 22-Nov | 0.081 | 0.081 | 0.095 | 0.351 | 3.205 | 2.066 |
| 23-Nov | 0.079 | 0.159 | 0.086 | 0.227 | 2.310 | 3.933 |
| 25-Nov | 0.093 | 0.524 | 0.121 | 0.104 | 8.940 | 5.150 |
| 26-Nov | 0.078 | 0.072 | 0.060 | 0.090 | 11.070 | 7.720 |
| 27-Nov | 0.114 | 0.122 | 0.240 | 1.424 | 13.470 | 12.860 |
| 28-Nov | 0.181 | 0.159 | 0.150 | 0.212 | 14.591 | 6.491 |

## A1.38

| DATE | NITRITES (mg-N/l) E1 | E11 | E2 | E3 | E4 | EE |
|---|---|---|---|---|---|---|
| 30-Nov | 0.160 | 0.166 | 0.166 | 0.166 | 15.370 | 5.500 |
| 2-Dec | 0.142 | 0.120 | 0.103 | 0.103 | 12.000 | 5.220 |
| 3-Dec | 0.150 | 0.120 | 0.100 | 1.018 | 12.800 | 7.750 |
| 4-Dec * | 0.117 | 0.106 | 0.095 | 0.446 | 9.510 | 7.720 |
| 5-Dec | 0.183 | 0.128 | 0.117 | 0.117 | 7.450 | 6.560 |
| 6-Dec | 0.100 | 0.095 | 0.095 | 0.095 | 9.510 | 6.200 |
| 7-Dec | 0.139 | 0.133 | 0.111 | 0.122 | 0.951 | 8.270 |
| 9-Dec | 0.153 | 0.183 | 0.103 | 0.106 | 0.464 | 3.760 |
| 10-Dec | 0.109 | 0.109 | 0.106 | 0.100 | 5.060 | 2.190 |
| 11-Dec | 0.125 | 0.131 | 0.117 | 0.136 | 0.399 | 2.130 |
| 12-Dec | 0.131 | 0.142 | 0.167 | 0.153 | 0.533 | 0.289 |
| 13-Dec | 0.161 | 0.150 | 0.142 | 0.150 | 0.252 | 0.496 |
| 14-Dec | | | | | | |
| 17-Dec | 0.150 | 0.181 | 0.181 | 0.176 | 0.516 | 0.832 |
| 18-Dec | 0.095 | 0.097 | 0.089 | 0.125 | 0.494 | 0.402 |
| 19-Dec * | 0.106 | 0.111 | 0.123 | 0.156 | 0.539 | 1.016 |
| 20-Dec | 0.238 | 0.332 | 0.249 | 0.158 | 0.338 | 0.315 |
| 21-Dec | 0.069 | 0.061 | 0.052 | 0.089 | 0.494 | 1.322 |
| 23-Dec | 0.049 | 0.089 | 0.084 | 0.035 | 0.400 | 0.460 |
| 02-Jan | 0.052 | 0.049 | 0.052 | 0.044 | 0.044 | 0.092 |
| 03-Jan | 0.069 | 0.067 | 0.069 | 0.123 | 0.311 | 0.060 |
| 04-Jan | 0.058 | 0.054 | 0.060 | 0.128 | 0.382 | 0.364 |
| 06-Jan | 0.054 | 0.054 | 0.056 | 0.128 | 0.548 | 0.387 |
| 07-Jan | 0.065 | 0.054 | 0.049 | 0.049 | 0.121 | 0.056 |
| 08-Jan * | 0.096 | 0.087 | 0.094 | 0.060 | 0.186 | 0.347 |
| 09-Jan | 0.065 | 0.112 | 0.047 | 0.045 | 0.188 | 0.380 |
| 10-Jan | 0.092 | 0.103 | 0.107 | 0.098 | 0.152 | 0.083 |
| 11-Jan | 0.058 | 0.058 | 0.069 | 0.088 | 0.199 | 0.172 |
| 13-Jan | | | | | | 1.133 |
| 14-Jan | 0.403 | 0.038 | 0.034 | 0.038 | 0.087 | 0.072 |
| 15-Jan | 0.105 | 0.119 | 0.072 | 0.081 | 0.060 | 0.078 |
| 16-Jan | 0.086 | 0.077 | 0.079 | 0.072 | 0.189 | 0.153 |
| 17-Jan | 0.101 | 0.070 | 0.059 | 0.061 | 0.121 | 0.149 |
| 18-Jan | 0.090 | 0.079 | 0.074 | 0.068 | 0.047 | 0.419 |
| 20-Jan * | 0.144 | 0.149 | 0.162 | 0.088 | 0.040 | 0.374 |
| 21-Jan | 0.171 | 0.146 | 0.135 | 0.121 | 0.097 | 0.104 |
| 22-Jan | 0.189 | 0.178 | 0.185 | 0.110 | 0.250 | 0.423 |
| 23-Jan | 0.162 | 0.149 | 0.133 | 0.203 | 0.086 | 0.304 |
| 24-Jan | 0.065 | 0.065 | 0.061 | 0.070 | 0.361 | 0.298 |
| 25-Jan | 0.104 | 0.095 | 0.072 | 0.088 | 0.203 | 0.279 |
| 27-Jan | 0.223 | 0.092 | 0.072 | 0.106 | 0.564 | 0.252 |
| 28-Jan | 0.077 | 0.063 | 0.063 | 0.060 | 0.146 | 0.130 |
| 29-Jan | 0.067 | 0.070 | 0.063 | 0.056 | 0.327 | 0.244 |
| 30-Jan | 0.114 | 0.121 | 0.123 | 0.086 | 0.086 | 0.169 |
| 31-Jan | 0.070 | 0.125 | 0.049 | 0.049 | 0.443 | 0.401 |
| 01-Feb * | 0.088 | 0.155 | 0.067 | 0.063 | 0.130 | 0.353 |
| 03-Feb | 0.074 | 0.077 | 0.049 | 0.044 | 0.046 | 0.095 |
| 04-Feb | 0.113 | 0.118 | 0.068 | 0.118 | 0.135 | 0.137 |
| 05-Feb | 0.118 | 0.076 | 0.103 | 0.078 | 0.088 | 0.053 |
| 06-Feb | 0.113 | 0.142 | 0.098 | 0.098 | 0.137 | 0.093 |
| 07-Feb | 0.110 | 0.100 | 0.127 | 0.125 | 0.120 | 0.048 |
| 08-Feb | 0.093 | 0.093 | 0.133 | 0.115 | 0.068 | 0.207 |
| 10-Feb | 0.125 | 0.115 | 0.123 | 0.118 | 0.163 | 0.048 |
| 12-Feb | 0.147 | 0.172 | 0.157 | 0.132 | 0.093 | 0.623 |
| 13-Feb | 0.202 | 0.232 | 0.137 | 0.145 | 0.073 | 0.083 |
| 14-Feb | 0.137 | 0.145 | 0.133 | 0.162 | 0.076 | 0.100 |
| 15-Feb * | 0.172 | 0.157 | 0.157 | 0.113 | 0.048 | 0.123 |
| 17-Feb | 0.093 | 0.093 | 0.115 | 0.105 | 0.237 | 0.083 |
| 18-Feb | 0.100 | 0.113 | 0.118 | 0.100 | 0.051 | 0.076 |

# APPENDIX 2

## EXPERIMENTAL DATA - PHASE 2 (1992)

## (Dosing Isolated Builders to Control and Experimental Systems)

For each variable, Control system data is listed first, then Experimental

| **PAGE NO.** | **DAY NO.** |
|---|---|
| DSVI, TSS concentration, VSS concentration, VSS/TSS ratio | |
| A2.3 | 1 - 63 |
| A2.4 | 64 - 119 |
| A2.5 | 120 - 173 |
| A2.6 | 174 - 228 |
| A2.7 | 229 - 289 |
| Influent & effluent TKN concentration, Influent and efluent COD concentrations, pH, Oxygen utilisation rate. | |
| A2.8 | 1 - 62 |
| A2.9 | 64 - 119 |
| A2.10 | 120 - 173 |
| A2.11 | 174 - 228 |
| A2.12 | 229 - 289 |
| Phosphate concentration in influent, each reactor and effluent | |
| A2.13 | 1 - 63 |
| A2.14 | 64 - 119 |
| A2.15 | 120 - 173 |
| A2.16 | 174 - 228 |
| A2.17 | 229 - 289 |

Phosphate removal by Control and Experimental Systems

| | |
|---|---|
| A2.18 | 1 - 289 |

Nitrite concentrations in the reactors and effluent

| | |
|---|---|
| A2.19 | 1 - 63 |
| A2.20 | 64 - 119 |
| A2.21 | 120 - 173 |
| A2.22 | 174 - 228 |
| A2.23 | 229 - 289 |

Nitrate concentrations in the reactors and effluent

| | |
|---|---|
| A2.24 | 1 - 63 |
| A2.25 | 64 - 119 |
| A2.26 | 120 - 173 |
| A2.27 | 174 - 228 |
| A2.28 | 229 - 289 |

C: CONTROL SYSTEM E: EXPERIMENTAL SYSTEM

REACTOR NO 1: 1st ANAEROBIC
2: 2nd ANAEROBIC
3: 1st ANOXIC
4: 2nd ANOXIC
5: AEROBIC
E: EFFLUENT

Note: A * at day No. indicates day on which a new influent sewage feed batch was commenced

# A2.3

| | DSVI (mg/l) | | MLSS (g/l) | | MLVSS (g/l) | | ISS (g/l) | | VSS/TSS | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY # | C | E | C | E | C | E | C | E | C | E |
| 1 | 164.5 | 148.5 | 4.053 | 4.824 | 3.45 | 3.681 | 0.603 | 1.143 | 0.851 | 0.763 |
| 2 | | | 3.67 | 3.768 | 3.204 | 3.314 | 0.466 | 0.454 | 0.873 | 0.880 |
| 3 | 185.8 | 183.3 | 2.868 | 3.452 | 2.488 | 2.968 | 0.38 | 0.484 | 0.868 | 0.860 |
| 5 | 196.4 | 185.2 | 3.052 | 3.236 | 2.664 | 2.818 | 0.388 | 0.418 | 0.873 | 0.871 |
| 6 | 184 | 173.9 | 3.168 | 3.256 | 2.744 | 2.832 | 0.424 | 0.424 | 0.866 | 0.870 |
| 7 * | 178.7 | 160.5 | 3.168 | 3.32 | 2.736 | 2.848 | 0.432 | 0.472 | 0.864 | 0.858 |
| 8 | 174.3 | 166.9 | 3.152 | 3.192 | 2.74 | 2.952 | 0.412 | 0.24 | 0.869 | 0.925 |
| 9 | 173.7 | 181.2 | 3.068 | 3.124 | 2.644 | 2.696 | 0.424 | 0.428 | 0.862 | 0.863 |
| 10 | 160 | 167 | 3.334 | 3.384 | 2.89 | 2.908 | 0.444 | 0.476 | 0.867 | 0.859 |
| 12 | 177.8 | 173.8 | 3 | 3.452 | 2.536 | 2.932 | 0.464 | 0.52 | 0.845 | 0.849 |
| 13 | 174.3 | 175 | 3.346 | 3.238 | 2.926 | 2.816 | 0.42 | 0.422 | 0.874 | 0.870 |
| 14 | 168.1 | 169.7 | 3.372 | 3.496 | 2.9 | 2.972 | 0.472 | 0.524 | 0.860 | 0.850 |
| 15 | 158.2 | 190 | 3.368 | 2.98 | 2.886 | 2.528 | 0.482 | 0.452 | 0.857 | 0.848 |
| 16 | 186.3 | 162.6 | 2.86 | 3.38 | 2.452 | 2.872 | 0.408 | 0.508 | 0.857 | 0.850 |
| 17 | | | 3.348 | 3.708 | 3.004 | 3.204 | 0.344 | 0.504 | 0.897 | 0.864 |
| 19 | | | 3.186 | 3.158 | 2.712 | 2.672 | 0.474 | 0.486 | 0.851 | 0.846 |
| 20 | 136.1 | 126.6 | 3.306 | 3.29 | 2.838 | 2.794 | 0.468 | 0.496 | 0.858 | 0.849 |
| 21 | 138.6 | 137.7 | 3.126 | 3.268 | 2.672 | 2.782 | 0.454 | 0.486 | 0.855 | 0.851 |
| 22 * | 121.4 | 123.4 | 3.35 | 2.972 | 2.73 | 2.408 | 0.62 | 0.564 | 0.815 | 0.810 |
| 23 | 119 | 121.2 | 3.36 | 3.3 | 2.728 | 2.664 | 0.632 | 0.636 | 0.812 | 0.807 |
| 25 | 117.6 | 121.4 | 3.4 | 3.074 | 2.758 | 2.5 | 0.642 | 0.574 | 0.811 | 0.813 |
| 26 | 119.3 | 129.3 | 3.352 | 3.042 | 2.764 | 2.518 | 0.588 | 0.524 | 0.825 | 0.828 |
| 27 | 114.3 | 117.1 | 3.5 | 3.416 | 2.872 | 2.82 | 0.628 | 0.596 | 0.821 | 0.826 |
| 28 | 110.5 | 117.5 | 3.616 | 3.402 | 2.884 | 2.696 | 0.732 | 0.706 | 0.798 | 0.792 |
| 29 | 121.1 | 125.9 | 3.552 | 3.336 | 2.896 | 2.7 | 0.656 | 0.636 | 0.815 | 0.809 |
| 30 | 124.7 | 134 | 3.208 | 3.284 | 2.708 | 2.7 | 0.5 | 0.584 | 0.844 | 0.822 |
| 31 | 124.6 | 130.8 | 3.21 | 2.982 | 2.67 | 2.48 | 0.54 | 0.502 | 0.832 | 0.832 |
| 33 | 112.5 | 128.6 | 3.556 | 3.576 | 2.96 | 2.764 | 0.596 | 0.812 | 0.832 | 0.773 |
| 34 | 105.8 | 119.9 | 3.546 | 3.128 | 2.828 | 2.542 | 0.718 | 0.586 | 0.798 | 0.813 |
| 37 * | | | | | | | | | | |
| 38 | 123.1 | 125.6 | 2.742 | 2.608 | 2.27 | 2.126 | 0.472 | 0.482 | 0.828 | 0.815 |
| 40 | 113.6 | 115.1 | 2.906 | 2.998 | 2.446 | 2.49 | 0.46 | 0.508 | 0.842 | 0.831 |
| 41 | 105.3 | 110.1 | 3.32 | 3.024 | 2.804 | 2.512 | 0.516 | 0.512 | 0.845 | 0.831 |
| 42 | 118.3 | 123.6 | 3.044 | 2.912 | 2.636 | 2.456 | 0.408 | 0.456 | 0.866 | 0.843 |
| 43 | 116.5 | 115.9 | 2.854 | 2.976 | 2.378 | 2.468 | 0.476 | 0.508 | 0.833 | 0.829 |
| 44 | 112.5 | 130.8 | 3.12 | 2.676 | 2.628 | 2.6 | 0.492 | 0.076 | 0.842 | 0.972 |
| ADD ZEOLITE TO EXPERIMENTAL SYSTEM | | | | | | | | | | |
| 45 * | 115.3 | 113.5 | 3.056 | 3.084 | 2.572 | 2.57 | 0.484 | 0.514 | 0.842 | 0.833 |
| 47 | 115.6 | 116.1 | 3.136 | 2.994 | 2.61 | 2.432 | 0.526 | 0.562 | 0.832 | 0.812 |
| 48 | 112.9 | 106.9 | 3.122 | 3.088 | 2.724 | 2.644 | 0.398 | 0.444 | 0.873 | 0.856 |
| 49 | 111.8 | 102.7 | 3.22 | 3.504 | 2.774 | 2.94 | 0.446 | 0.564 | 0.861 | 0.839 |
| 50 | 124 | 120.7 | 3.064 | 3.148 | 2.72 | 2.764 | 0.344 | 0.384 | 0.888 | 0.878 |
| 51 | 119.8 | 113.9 | 2.922 | 3.028 | 2.586 | 2.622 | 0.336 | 0.406 | 0.885 | 0.866 |
| 52 | 106.1 | 111.2 | 3.58 | 3.236 | 2.888 | 2.624 | 0.692 | 0.612 | 0.807 | 0.811 |
| 55 * | | | | | | | | | | |
| 56 | | | | | | | | | | |
| 57 | 102.9 | 103.4 | 3.692 | 3.676 | 3.032 | 2.94 | 0.66 | 0.736 | 0.821 | 0.800 |
| 58 | 107.6 | 101.6 | 3.716 | 4.292 | 3.04 | 3.496 | 0.676 | 0.796 | 0.818 | 0.815 |
| 59 | 105.1 | 105.7 | 3.712 | 3.748 | 3.048 | 2.96 | 0.664 | 0.788 | 0.821 | 0.790 |
| 61 | 105.6 | 107.3 | 3.976 | 3.636 | 3.228 | 2.822 | 0.748 | 0.814 | 0.812 | 0.776 |
| 62 | 104.7 | 103 | 3.534 | 3.71 | 2.944 | 2.988 | 0.59 | 0.722 | 0.833 | 0.805 |
| 63 | 102.6 | 109.5 | 3.528 | 3.652 | 2.982 | 2.954 | 0.546 | 0.698 | 0.845 | 0.809 |

# A2.4

| | DSVI (mg/l) | | MLSS (g/l) | | MLVSS (g/l) | | ISS (g/l) | | VSS/TSS | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY # | C | E | C | E | C | E | C | E | C | E |
| 64 | 104.6 | 105.11 | 2.868 | 3.996 | 2.42 | 3.164 | 0.448 | 0.832 | 0.844 | 0.792 |
| 65 | 100.76 | 110.13 | 3.176 | 3.632 | 2.656 | 2.88 | 0.52 | 0.752 | 0.836 | 0.793 |
| 68 | 95.7 | 106.6 | 3.344 | 3.564 | 2.832 | 2.86 | 0.512 | 0.704 | 0.847 | 0.802 |
| 69 | 108 | 118.02 | 2.834 | 3.216 | 2.402 | 2.604 | 0.432 | 0.612 | 0.848 | 0.810 |
| 70 * | 106.8 | 115.4 | 2.978 | 3.294 | 2.382 | 2.51 | 0.596 | 0.784 | 0.800 | 0.762 |
| 71 | 97.9 | 134.8 | 3.146 | 2.82 | 2.588 | 2.44 | 0.558 | 0.38 | 0.823 | 0.865 |
| 72 | 107.7 | 111.9 | 3.156 | 3.576 | 2.656 | 2.832 | 0.5 | 0.744 | 0.842 | 0.792 |
| 74 | 101.7 | 112.7 | 3.148 | 3.548 | 2.576 | 2.736 | 0.572 | 0.812 | 0.818 | 0.771 |
| 75 | 102.7 | 111.5 | 3.312 | 3.588 | 2.744 | 2.844 | 0.568 | 0.744 | 0.829 | 0.793 |
| 76 | 111.5 | 122.2 | 3.14 | 3.6 | 2.616 | 2.84 | 0.524 | 0.76 | 0.833 | 0.789 |
| 77 | 110.7 | 115.4 | 3.344 | 3.812 | 2.734 | 2.94 | 0.61 | 0.872 | 0.818 | 0.771 |
| 78 | 111.18 | 124.58 | 3.328 | 3.532 | 2.784 | 2.8 | 0.544 | 0.732 | 0.837 | 0.793 |
| 79 | 119.05 | 130.51 | 3.024 | 3.448 | 2.564 | 2.72 | 0.46 | 0.728 | 0.848 | 0.789 |
| 80 | 122.85 | 127.35 | 3.024 | 3.612 | 2.56 | 2.864 | 0.464 | 0.748 | 0.847 | 0.793 |
| 81 * | 122.81 | 129.12 | 3.42 | 3.64 | 2.796 | 2.796 | 0.624 | 0.844 | 0.818 | 0.768 |
| 82 | 123.38 | 132.16 | 3.404 | 3.632 | 2.892 | 2.884 | 0.512 | 0.748 | 0.850 | 0.794 |
| 83 | 131.07 | 130.15 | 3.128 | 3.688 | 2.664 | 2.96 | 0.464 | 0.728 | 0.852 | 0.803 |
| 84 | 126.51 | 130.86 | 3.32 | 3.668 | 2.768 | 2.852 | 0.552 | 0.816 | 0.834 | 0.778 |
| 85 | 129.91 | 127.39 | 3.156 | 3.768 | 2.588 | 2.916 | 0.568 | 0.852 | 0.820 | 0.774 |
| 86 | 129.63 | 134.08 | 3.24 | 3.58 | 2.684 | 2.76 | 0.556 | 0.82 | 0.828 | 0.771 |
| 87 | 117.65 | 123.81 | 3.4 | 3.796 | 2.836 | 2.948 | 0.564 | 0.848 | 0.834 | 0.777 |
| 88 | 122.09 | 131.58 | 3.44 | 3.8 | 2.908 | 3.028 | 0.532 | 0.772 | 0.845 | 0.797 |
| 89 | 126.58 | 124.59 | 3.16 | 3.692 | 2.596 | 2.848 | 0.564 | 0.844 | 0.822 | 0.771 |
| 90 | 110 | 129.9 | 4.002 | 3.848 | 3.062 | 2.9 | 0.94 | 0.948 | 0.765 | 0.754 |
| 91 | 131.3 | 120.1 | 3.96 | 3.496 | 2.892 | 2.752 | 1.068 | 0.744 | 0.730 | 0.787 |
| 92 | 124.6 | 131 | 3.452 | 3.664 | 2.664 | 2.816 | 0.788 | 0.848 | 0.772 | 0.769 |
| 93 | 122.4 | 126.72 | 3.2 | 3.596 | 2.664 | 2.816 | 0.536 | 0.78 | 0.833 | 0.783 |
| 94 * | 122.4 | 126.72 | 3.268 | 3.788 | 2.696 | 2.936 | 0.572 | 0.852 | 0.825 | 0.775 |
| 95 | 117.8 | 124.9 | 3.396 | 3.684 | 2.788 | 2.84 | 0.608 | 0.844 | 0.821 | 0.771 |
| 96 | 113.6 | 123.7 | 3.696 | 3.88 | 3.184 | 3.164 | 0.512 | 0.716 | 0.861 | 0.815 |
| 97 | 123.9 | 130.3 | 3.104 | 3.374 | 2.632 | 2.648 | 0.472 | 0.726 | 0.848 | 0.785 |
| 98 | 106.7 | 145.2 | 3.748 | 3.168 | 2.728 | 2.624 | 1.02 | 0.544 | 0.728 | 0.828 |
| 99 | 114.6 | 137 | 3.316 | 3.284 | 2.78 | 2.54 | 0.536 | 0.744 | 0.838 | 0.773 |
| 100 | 137.4 | 131.7 | 2.62 | 3.188 | 2.168 | 2.452 | 0.452 | 0.736 | 0.827 | 0.769 |
| 101 | 123.9 | 137.3 | 3.228 | 3.204 | 2.636 | 2.428 | 0.592 | 0.776 | 0.817 | 0.758 |
| 102 | 112.8 | 147.4 | 3.368 | 3.12 | 2.682 | 2.29 | 0.686 | 0.83 | 0.796 | 0.734 |
| REMOVE ZEOLITE FROM EXPERIMENTAL SYSTEM | | | | | | | | | | |
| 105 * | 139.7 | 145.1 | 2.864 | 3.032 | 2.468 | 2.42 | 0.396 | 0.612 | 0.862 | 0.798 |
| 106 | 131.4 | 127.6 | 2.968 | 3.292 | | | | | | |
| 107 | 119.5 | 126.4 | 3.18 | 3.324 | 2.568 | 2.464 | 0.612 | 0.86 | 0.808 | 0.741 |
| 108 | 120.9 | 126.5 | 3.06 | 3.32 | 2.564 | 2.624 | 0.496 | 0.696 | 0.838 | 0.790 |
| 109 | 126.3 | 125.6 | 3.008 | 3.264 | 2.792 | 2.892 | 0.216 | 0.372 | 0.928 | 0.886 |
| 110 | | | | | | | | | | |
| 111 | 124.2 | 139.2 | 3.22 | 3.304 | 3.028 | 2.964 | 0.192 | 0.34 | 0.940 | 0.897 |
| 112 | 130.2 | 144.2 | 3.072 | 3.328 | 2.644 | 2.72 | 0.428 | 0.608 | 0.861 | 0.817 |
| 113 | 154.3 | 127.4 | 2.916 | 3.14 | 2.38 | 2.4 | 0.536 | 0.74 | 0.816 | 0.764 |
| 114 | | | 3.082 | 3.372 | 2.38 | 2.4 | 0.702 | 0.972 | 0.772 | 0.712 |
| 115 | 130.81 | 132.75 | 3.04 | 3.26 | 2.60 | 2.61 | 0.438111 | 0.6535 | 0.856 | 0.800 |
| 116 | | | | | | | | | | |
| 117 * | 124.9 | 135.3 | 3.284 | 3.4 | 2.756 | 2.744 | 0.528 | 0.656 | 0.839 | 0.807 |
| 118 | 137.1 | 147.4 | 2.844 | 3.052 | 2.352 | 2.456 | 0.492 | 0.596 | 0.827 | 0.805 |
| 119 | | | | | | | | | | |

# A2.5

| | | DSVI (mg/l) | | MLSS (g/l) | | MLVSS (g/l) | | ISS (g/l) | | VSS/TSS | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DAY # | | C | E | C | E | C | E | C | E | C | E |
| 120 | | 139.8 | 148.5 | 3.004 | 3.368 | 2.576 | 2.748 | 0.428 | 0.62 | 0.858 | 0.816 |
| 121 | | 133.4 | 150.5 | 3.148 | 3.256 | 2.644 | 2.636 | 0.504 | 0.62 | 0.840 | 0.810 |
| 122 | | 134.2 | 173.1 | 3.278 | 3.236 | 2.768 | 2.6 | 0.51 | 0.636 | 0.844 | 0.803 |
| 123 | | | | | | | | | | | |
| 124 | | | | | | | | | | | |
| 125 | | 147.1 | 171.7 | 2.72 | 3.028 | 2.612 | 2.432 | 0.108 | 0.596 | 0.960 | 0.803 |
| 126 | | 132.1 | 158.5 | 3.028 | 3.28 | | | | | | |
| 127 | | 138.5 | 185.6 | 2.744 | 2.856 | 2.316 | 2.344 | 0.428 | 0.512 | 0.844 | 0.821 |
| 128 | | 134.2 | 188.7 | 2.832 | 2.968 | 2.28 | 2.44 | 0.552 | 0.528 | 0.805 | 0.822 |
| 129 | | 132.3 | 171.6 | 3.024 | 3.38 | 2.528 | 2.764 | 0.496 | 0.616 | 0.836 | 0.818 |
| 130 | * | 139.3 | 183.4 | 2.872 | 3.054 | 2.416 | 2.514 | 0.456 | 0.54 | 0.841 | 0.823 |
| 131 | | | | | | | | | | | |
| 132 | | 134.2 | 179.4 | 3.166 | 3.414 | 2.648 | 2.684 | 0.518 | 0.73 | 0.836 | 0.786 |
| 133 | | 140.3 | 198.3 | 2.852 | 3.152 | 2.374 | 2.57 | 0.478 | 0.582 | 0.832 | 0.815 |
| 134 | | 133.9 | 180.4 | 3.174 | 3.256 | 2.616 | 2.638 | 0.558 | 0.618 | 0.824 | 0.810 |
| 135 | | 138 | 182.5 | 3.08 | 3.288 | 2.498 | 2.642 | 0.582 | 0.646 | 0.811 | 0.804 |
| 136 | | 129.4 | 180.8 | 3.22 | 3.41 | 2.652 | 2.762 | 0.568 | 0.648 | 0.824 | 0.810 |
| 137 | | 129.7 | 172.1 | 3.342 | 2.712 | 2.886 | 2.306 | 0.456 | 0.406 | 0.864 | 0.850 |
| 138 | | | | | | | | | | | |
| 139 | | | | | | | | | | | |
| 140 | * | | | | | | | | | | |
| 141 | | 136 | 188.6 | 3.126 | 3.02 | 2.642 | 2.54 | 0.484 | 0.48 | 0.845 | 0.841 |
| 142 | | 134.5 | 179.2 | 3.568 | 3.696 | 2.938 | 2.996 | 0.63 | 0.7 | 0.823 | 0.811 |
| 143 | | 136.8 | 167.8 | 3.29 | 3.674 | 2.822 | 3.096 | 0.468 | 0.578 | 0.858 | 0.843 |
| 144 | | 144.4 | 181.3 | 3.462 | 3.678 | 2.854 | 3.008 | 0.608 | 0.67 | 0.824 | 0.818 |
| 145 | | | | | | | | | | | |
| 146 | | 126.3 | 167.7 | 3.96 | 3.618 | 3.426 | 3.344 | 0.534 | 0.274 | 0.865 | 0.924 |
| 147 | | 154.9 | 181.1 | 3.184 | 3.35 | 2.678 | 2.804 | 0.506 | 0.546 | 0.841 | 0.837 |
| 148 | | 144.8 | 168.2 | 3.338 | 3.468 | 2.738 | 2.802 | 0.6 | 0.666 | 0.820 | 0.808 |
| 149 | | 141.8 | 179.8 | 3.29 | 3.384 | 2.802 | 2.796 | 0.488 | 0.588 | 0.852 | 0.826 |
| 150 | | 140.6 | 176.8 | 3.366 | 3.488 | 2.788 | 2.878 | 0.578 | 0.61 | 0.828 | 0.825 |
| 151 | | 154.1 | 185.2 | 3.244 | 3.24 | 2.682 | 2.664 | 0.562 | 0.576 | 0.827 | 0.822 |
| 153 | | | | | | | | | | | |
| 154 | | 151 | 182.3 | 3.576 | 3.292 | 2.96 | 2.726 | 0.616 | 0.566 | 0.828 | 0.828 |
| 155 | * | 153.9 | 198.3 | 3.248 | 3.194 | 2.684 | 2.634 | 0.564 | 0.56 | 0.826 | 0.825 |
| 156 | | 143.7 | 178.1 | 3.48 | 3.368 | 3.05 | 2.81 | 0.43 | 0.558 | 0.876 | 0.834 |
| 157 | | 156.4 | 188.1 | 3.304 | 3.278 | 2.75 | 2.724 | 0.554 | 0.554 | 0.832 | 0.831 |
| 158 | | | | | | | | | | | |
| 159 | | 148 | 193 | 3.424 | 3.138 | 2.832 | 2.6 | 0.592 | 0.538 | 0.827 | 0.829 |
| 160 | | | | | | | | | | | |
| 161 | | 142.9 | 182.8 | 3.382 | 3.1 | 2.702 | 2.442 | 0.68 | 0.658 | 0.799 | 0.788 |
| 162 | | | | | | | | | | | |
| | | 136.8 | 164.4 | 3.534 | 3.284 | 2.804 | 2.574 | 0.73 | 0.71 | 0.793 | 0.784 |
| 164 | | | | | | | | | | | |
| 165 | | 159.5 | 165.6 | 3.08 | 3.06 | 2.634 | 2.672 | 0.446 | 0.388 | 0.855 | 0.873 |
| 166 | | | | | | | | | | | |
| 167 | | | | | | | | | | | |
| 168 | | 150.7 | 172.4 | 2.876 | 2.804 | 2.456 | 2.4 | 0.42 | 0.404 | 0.854 | 0.856 |
| 169 | | 166.3 | 162.1 | 2.706 | 2.776 | 2.05 | 2.088 | 0.656 | 0.688 | 0.758 | 0.752 |
| 170 | | 157.2 | 149.7 | 3.074 | 3.118 | 2.442 | 2.492 | 0.632 | 0.626 | 0.794 | 0.799 |
| 171 | | 172 | 158.4 | 2.804 | 2.436 | 2.312 | 2.436 | 0.492 | | 0.825 | 1.000 |
| 172 | * | 166 | 151 | 3.106 | 3.200 | 2.762 | 2.844 | 0.344 | 0.356 | 0.889 | 0.889 |
| 173 | | | | | | | | | | | |

# A2.6

| | DSVI (mg/l) | | MLSS (g/l) | | MLVSS (g/l) | | ISS (g/l) | | VSS/TSS | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY # | C | E | C | E | C | E | C | E | C | E |
| 174 | | | | | | | | | | |
| 175 | 177.8 | 188.9 | 2.906 | 2.558 | 2.582 | 2.326 | 0.324 | 0.232 | 0.889 | 0.909 |
| 176 | 146.7 | 143.7 | 3.522 | 3.248 | 2.912 | 2.706 | 0.61 | 0.542 | 0.827 | 0.833 |
| 177 | | | | | | | | | | |
| 178 | 139.6 | 139.1 | 3.39 | 3.404 | 2.8 | 2.8 | 0.59 | 0.604 | 0.826 | 0.823 |
| 179 | 154.1 | 138.7 | 3.352 | 3.774 | 2.828 | 3.118 | 0.524 | 0.656 | 0.844 | 0.826 |
| 180 | | | | | | | | | | |
| 181 | | | | | | | | | | |
| 182 * | 138.6 | 141.5 | 3.414 | 3.346 | 2.784 | 2.734 | 0.63 | 0.612 | 0.815 | 0.817 |
| 183 | 175.7 | 179.4 | 3.51 | 3.438 | 2.92 | 2.86 | 0.59 | 0.578 | 0.832 | 0.832 |
| 184 | 155.5 | 148.3 | 3.43 | 3.484 | 2.804 | 2.86 | 0.626 | 0.624 | 0.817 | 0.821 |
| | ADD HSA CALCITE TO EXPERIMENTAL SYSTEM | | | | | | | | | |
| 185 * | 151.5 | 158.6 | 3.256 | 3.3 | 2.688 | 2.736 | 0.568 | 0.564 | 0.826 | 0.829 |
| 186 | 146.2 | 152.9 | 3.268 | 3.51 | 2.964 | 2.918 | 0.304 | 0.592 | 0.907 | 0.831 |
| 187 | | | | | | | 0 | 0 | ERR | ERR |
| 188 | 159.1 | 152.1 | 3.142 | 3.288 | 2.632 | 2.704 | 0.51 | 0.584 | 0.838 | 0.822 |
| 189 | 149.3 | 154.4 | 3.064 | 3.238 | 2.722 | 2.672 | 0.342 | 0.566 | 0.888 | 0.825 |
| 190 | 155.4 | 139.2 | 3.11 | 3.352 | 2.572 | 2.718 | 0.538 | 0.634 | 0.827 | 0.811 |
| 191 | 153.6 | 143.9 | 3.146 | 3.244 | 2.606 | 2.694 | 0.54 | 0.55 | 0.828 | 0.830 |
| 192 | 155.8 | 144.1 | 3.102 | 3.424 | 2.786 | 2.566 | 0.316 | 0.858 | 0.898 | 0.749 |
| 193 | 145 | 143.6 | 3.218 | 3.25 | 2.694 | 2.686 | 0.524 | 0.564 | 0.837 | 0.826 |
| 194 | | | | | | | | | | |
| 195 | 147.6 | 138.9 | 3.048 | 3.24 | 2.586 | 2.714 | 0.462 | 0.526 | 0.848 | 0.838 |
| 196 | 136.9 | 141 | 3.166 | 3.074 | 2.664 | 2.558 | 0.502 | 0.516 | 0.841 | 0.832 |
| 197 | 147.6 | 141.5 | 3.162 | 3.252 | 2.632 | 2.682 | 0.53 | 0.57 | 0.832 | 0.825 |
| 198 * | 144.6 | 127.2 | 3.228 | 3.406 | 2.584 | 2.61 | 0.644 | 0.796 | 0.800 | 0.766 |
| 199 | 141.3 | 127.4 | 3.302 | 3.402 | 2.744 | 2.816 | 0.558 | 0.586 | 0.831 | 0.828 |
| 200 | 143.0 | 140.7 | 3.146 | 3.032 | 2.720 | 2.748 | 0.426 | 0.284 | 0.865 | 0.906 |
| 201 | | | | | | | | | | |
| 202 | 138.3 | 135.4 | 3.158 | 3.2 | 2.626 | 2.644 | 0.532 | 0.556 | 0.832 | 0.826 |
| 203 | | | 2.83 | 3.612 | 2.582 | 3.132 | 0.248 | 0.48 | 0.912 | 0.867 |
| 204 | 141.8 | 123.6 | 3.056 | 3.264 | 2.536 | 2.68 | 0.52 | 0.584 | 0.830 | 0.821 |
| 205 | 135.6 | 130.8 | 3.196 | 3.314 | 2.734 | 2.774 | 0.462 | 0.54 | 0.855 | 0.837 |
| 206 | 141.4 | 127.300 | 3.064 | 3.142 | 2.534 | 2.574 | 0.53 | 0.568 | 0.827 | 0.819 |
| 207 | 130.7 | 127.300 | 3.188 | 3.274 | 2.676 | 2.692 | 0.512 | 0.582 | 0.839 | 0.822 |
| 210 * | 137.7 | 135.2 | 2.904 | 3.204 | 2.48 | 2.674 | 0.424 | 0.53 | 0.854 | 0.835 |
| 211 | 128.4 | 125.2 | 3.39 | 3.328 | 2.88 | 2.776 | 0.51 | 0.552 | 0.850 | 0.834 |
| 212 | 143.3 | 128.4 | 3.256 | 3.374 | 2.72 | 2.764 | 0.536 | 0.61 | 0.835 | 0.819 |
| 213 | 131.2 | 141.4 | 3.252 | 3.3 | 2.792 | 2.73 | 0.46 | 0.57 | 0.859 | 0.827 |
| 214 | 151.3 | 126.3 | 3.15 | 3.298 | 2.684 | 2.766 | 0.466 | 0.532 | 0.852 | 0.839 |
| 216 | 138.3 | 111.8 | 3.374 | 3.428 | 2.854 | | 0.52 | 3.428 | 0.846 | 0.000 |
| 217 | 134.5 | 110.1 | 3.222 | 3.632 | 2.530 | 3.038 | 0.692 | 0.594 | 0.785 | 0.836 |
| 218 | 123.0 | 107.8 | 3.390 | 3.740 | 2.862 | 3.096 | 0.528 | 0.644 | 0.844 | 0.828 |
| 219 | 137.3 | 109 | 3.4 | 3.516 | 2.874 | 2.926 | 0.526 | 0.59 | 0.845 | 0.832 |
| 220 | 139 | 105.800 | 3.3 | 3.466 | 2.788 | 2.878 | 0.512 | 0.588 | 0.845 | 0.830 |
| 221 | 131.7 | 110.4 | 3.544 | 3.472 | 2.912 | 2.834 | 0.632 | 0.638 | 0.822 | 0.816 |
| 223 | 138 | 101.400 | 3.262 | 3.944 | 2.748 | 3.244 | 0.514 | 0.7 | 0.842 | 0.823 |
| 224 * | 125.5 | 103.900 | 3.718 | 3.53 | 3.104 | 2.916 | 0.614 | 0.614 | 0.835 | 0.826 |
| 225 | 126.9 | 100 | 3.546 | 3.666 | 2.972 | 3.004 | 0.574 | 0.662 | 0.838 | 0.819 |
| 226 | 135.3 | 101.5 | 3.448 | 3.51 | 2.868 | 2.884 | 0.58 | 0.626 | 0.832 | 0.822 |
| 227 | 129.8 | 98.1 | 3.468 | 3.738 | 2.898 | 3.08 | 0.57 | 0.658 | 0.836 | 0.824 |
| 228 | 135.5 | 96.2 | 3.222 | 3.394 | 2.676 | 2.774 | 0.546 | 0.62 | 0.831 | 0.817 |

# A2.7

| | DSVI (mg/l) | | MLSS (g/l) | | MLVSS (g/l) | | ISS (g/l) | | VSS/TSS | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY # | C | E | C | E | C | E | C | E | C | E |
| 229 | | | | | | | | | | |
| 230 | 136.1 | 92.4 | 3.43 | 4.51 | 2.918 | 3.746 | 0.512 | 0.764 | 0.851 | 0.831 |
| 231 | 152.5 | 110.2 | 2.95 | 3.78 | 2.906 | 3.614 | 0.044 | 0.166 | 0.985 | 0.956 |
| 232 | 134.8 | 91.6 | 3.586 | 3.458 | 3.006 | 2.858 | 0.58 | 0.6 | 0.838 | 0.826 |
| 233 | 147.2 | 96.8 | 3.396 | 3.614 | 2.864 | 2.998 | 0.532 | 0.616 | 0.843 | 0.830 |
| 234 * | 151.3 | 102.2 | 3.524 | 3.588 | 2.954 | 3.02 | 0.57 | 0.568 | 0.838 | 0.842 |
| 235 | 154.1 | 108.2 | 3.244 | 3.08 | 2.73 | 2.568 | 0.514 | 0.512 | 0.842 | 0.834 |
| 236 | | | 2.982 | 3.16 | 2.476 | 2.644 | 0.506 | 0.516 | 0.830 | 0.837 |
| 237 | 153.6 | 97.2 | 3.038 | 3.154 | 2.576 | 2.588 | 0.462 | 0.566 | 0.848 | 0.821 |
| 238 | 144.5 | 95.9 | 3.23 | 3.128 | 2.686 | 2.542 | 0.544 | 0.586 | 0.832 | 0.813 |
| 239 | 149.3 | 95.7 | 3.014 | 3.134 | 2.496 | 2.558 | 0.518 | 0.576 | 0.828 | 0.816 |
| 240 | 143.9 | 93.3 | 3.128 | 3.216 | 2.646 | 2.682 | 0.482 | 0.534 | 0.846 | 0.834 |
| 241 | 153.1 | 95.3 | 3.048 | 3.148 | 2.58 | 2.608 | 0.468 | 0.54 | 0.846 | 0.828 |
| 242 | 145.6 | 96.5 | 3.206 | 3.108 | 2.708 | 2.562 | 0.498 | 0.546 | 0.845 | 0.824 |
| 243 | 159.1 | 103 | 3.038 | 2.906 | 2.586 | 2.358 | 0.452 | 0.548 | 0.851 | 0.811 |
| REMOVE HSA CALCITE FROM EXPERIMENTAL SYSTEM | | | | | | | | | | |
| 245 | 154 | 103.8 | 3.03 | 3.21 | 2.54 | 2.644 | 0.49 | 0.566 | 0.838 | 0.824 |
| 247 * | 153.4 | 104 | 3.086 | 3.206 | 2.496 | 2.54 | 0.59 | 0.666 | 0.809 | 0.792 |
| 249 | 148.2 | 103.2 | 3.262 | 3.39 | 2.796 | 2.872 | 0.466 | 0.518 | 0.857 | 0.847 |
| 250 | 157.7 | 111.6 | 3.064 | 3.136 | 2.658 | 2.694 | 0.406 | 0.442 | 0.867 | 0.859 |
| 251 | 140.3 | 103 | 3.444 | 3.3 | 2.87 | 2.72 | 0.574 | 0.58 | 0.833 | 0.824 |
| 252 | 148 | 110.8 | 3.378 | 3.37 | 2.806 | 2.774 | 0.572 | 0.596 | 0.831 | 0.823 |
| 254 | 143.2 | 108.7 | 3.724 | 3.528 | | 3.006 | | 0.522 | 0.000 | 0.852 |
| 256 * | 149.9 | 123.5 | 3.336 | 3.512 | 2.684 | 2.81 | 0.652 | 0.702 | 0.805 | 0.800 |
| 257 | 141.8 | 127.7 | 3.526 | 3.524 | 2.896 | 2.884 | 0.63 | 0.64 | 0.821 | 0.818 |
| 258 | 153.6 | 125.4 | 3.364 | 3.72 | 2.786 | 3.052 | 0.578 | 0.668 | 0.828 | 0.820 |
| 259 | 140.3 | 142.1 | 3.564 | 3.33 | 2.932 | 2.674 | 0.632 | 0.656 | 0.823 | 0.803 |
| 260 | 142 | 129 | 3.52 | 3.412 | 2.89 | 2.804 | 0.63 | 0.608 | 0.821 | 0.822 |
| 261 | 144.8 | 126.5 | 3.452 | 3.688 | 2.902 | 3.138 | 0.55 | 0.55 | 0.841 | 0.851 |
| 263 | 135.3 | 126.6 | 3.572 | 3.686 | 2.924 | 3.022 | 0.648 | 0.664 | 0.819 | 0.820 |
| 264 | 133.4 | 135.4 | 3.622 | 3.398 | 2.954 | 2.776 | 0.668 | 0.622 | 0.816 | 0.817 |
| 265 | 148.1 | 135.7 | 3.332 | 3.39 | 2.822 | 2.858 | 0.51 | 0.532 | 0.847 | 0.843 |
| 266 | 156.6 | 150.2 | 3.086 | 3.108 | 2.612 | 2.58 | 0.474 | 0.528 | 0.846 | 0.830 |
| 267 | 144.9 | 140.7 | 3.336 | 3.316 | 2.648 | 2.636 | 0.688 | 0.68 | 0.794 | 0.795 |
| 270 * | 145.1 | 123.1 | 3.216 | 3.656 | 2.62 | 3.046 | 0.596 | 0.61 | 0.815 | 0.833 |
| 271 | 142.2 | 143.9 | 3.282 | 3.244 | 2.788 | 2.756 | 0.494 | 0.488 | 0.849 | 0.850 |
| 272 | 138.4 | 140 | 3.252 | 3.218 | 2.75 | 2.672 | 0.502 | 0.546 | 0.846 | 0.830 |
| 275 | 125.7 | 133.5 | 3.714 | 3.246 | 2.866 | 2.722 | 0.848 | 0.524 | 0.772 | 0.839 |
| 276 | 143.6 | 133.5 | 3.134 | 3.246 | 2.514 | 2.654 | 0.62 | 0.592 | 0.802 | 0.818 |
| 277 | 139.6 | 127.7 | 3.342 | 3.394 | 2.644 | 2.738 | 0.698 | 0.656 | 0.791 | 0.807 |
| 279 | 177.3 | 126.6 | | 3.424 | 2.632 | 2.834 | | 0.59 | ERR | 0.828 |
| 280 | 144 | 138.1 | 3.288 | 3.138 | 2.706 | 2.612 | 0.582 | 0.526 | 0.823 | 0.832 |
| 281 | 150.9 | 141.7 | 3.204 | 3.176 | 2.6 | 2.656 | 0.604 | 0.52 | 0.811 | 0.836 |
| 288 | 170.2 | 129.7 | 2.84 | 2.878 | 2.4 | | | | 0.845 | 0.000 |
| 289 | 150.7 | 127.8 | 2.986 | 3.078 | | | | | 0.000 | 0.000 |

# A2.8

| | TKN IN | TKN EFF | | COD IN | COD EFF | | pH C | pH E | OUR (mg/l/hr) | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY # | (mg/l) | C | E | (mg/l) | C | E | | | C | E |
| 1 | 92.1 | 4.6 | 3.8 | 1020 | 131 | 29 | | | 30 | 30 |
| 2 | 90.7 | 5.2 | 4.6 | 991 | 43.2 | 45.2 | | | 30 | 30 |
| 3 | 93 | 4.1 | 5.1 | 981 | 33.5 | 47.8 | | | 30 | 30 |
| 5 | 95.2 | 5.2 | 3.8 | 981 | 39.6 | 47.8 | 7.96 | 8.79 | 30 | 30 |
| 6 | 87.4 | 2 | 2.1 | 975 | 36.6 | 61 | | | 30 | 30 |
| 7 * | 108 | 4.9 | 5.6 | 1007 | 65 | 83.3 | | | 30 | 30 |
| 8 | 106 | 5.1 | 6.5 | 1012 | 77.2 | 104 | | | 26.9 | 28.1 |
| 9 | 112 | 6.3 | 5.74 | 1003 | 91.4 | 38.6 | | | | |
| 10 | 112 | 6.2 | 6.2 | 1081 | 130 | 77.2 | | | | |
| 12 | 112 | 4.9 | 4.8 | 1080 | 52.8 | 65 | | | | |
| 13 | 114.8 | 5 | 5.3 | 963 | 58.9 | 61 | | | | |
| 14 | 110 | 4.9 | 4.6 | 1016 | 42.7 | 48.8 | 7.85 | 7.98 | | |
| 15 | 71.7 | 4.3 | 3.6 | 913 | 39.1 | 61.7 | 8.08 | 8.06 | | |
| 16 | 71.7 | 4.5 | 4.9 | 933 | 51.4 | 55.5 | 7.85 | 8.07 | | |
| 17 | 67.8 | 4.6 | 4.1 | 1118 | 53.5 | 49.3 | | | | |
| 19 | 66.1 | 4.3 | 4.6 | 1110 | 111 | 69.9 | 7.82 | 7.79 | | |
| 20 | 66.1 | 3.5 | 3.6 | 1102 | 45.2 | 45.2 | | | | |
| 21 | 64.4 | 2.8 | 2.8 | 1094 | 69.9 | 61.7 | 8.2 | 8.3 | | |
| 22 * | 75.6 | 3.2 | 3.4 | 904 | 53.5 | 53.5 | | | 31.2 | 31.2 |
| 23 | 67.8 | 4.5 | 3.8 | 879 | 45.2 | 53.5 | 7.94 | 8.04 | 34.9 | 32 |
| 25 | 83.4 | 4.5 | 4.8 | 1002 | 32.9 | 37 | | | | |
| 26 | 86.8 | 4.5 | 5.2 | 979 | 43.2 | 37 | 7.64 | 7.74 | | |
| 27 | 81.2 | 3.9 | 4.5 | 1005 | 55.5 | 76.1 | 7.85 | 7.65 | 27.15 | 29.5 |
| 28 | 83.4 | 5 | 3.9 | 916 | 80.2 | 59.6 | 7.88 | 7.96 | 34.6 | 30.4 |
| 29 | 61 | 3.1 | 6.3 | 1036 | 61.7 | 55.5 | 8 | 8.05 | 31.25 | 29.29 |
| 30 | 67.2 | 5.3 | 4.8 | 1000 | 57.6 | 78.1 | 8.01 | 8.01 | 31.84 | 29.25 |
| 31 | 69.4 | 4.1 | 3.6 | 913 | 69.9 | 55.5 | 7.82 | 7.8 | | |
| 33 | 78.4 | 3.8 | 4 | 946 | 76.1 | 78.1 | 7.83 | 7.81 | 28.09 | 29.30 |
| 34 | 75.6 | 3.6 | 2.9 | 970 | 77.5 | 61.2 | | | 30 | 30 |
| 37 * | 72.8 | 4.5 | 3.9 | 1016 | 61.2 | 57.1 | | | 30 | 30 |
| 38 | 95.2 | 12.9 | 8.3 | 954 | 89.8 | 71.4 | 7.76 | 7.76 | 30 | 30 |
| 40 | 94.1 | 10.5 | 4.2 | 987 | 66.3 | 54.1 | 7.78 | 7.64 | 30 | 30 |
| 41 | 112 | 5.9 | 5.6 | 1000 | 69.4 | 62.2 | 7.68 | 7.54 | 30 | 30 |
| 42 | 95.3 | 3.9 | 3 | 861 | 73.4 | 69.4 | 7.64 | 7.44 | 30 | 30 |
| 43 | 108.4 | 3.43 | 4.06 | 871 | 47.9 | 60.2 | 7.86 | 7.76 | 30 | 30 |
| 44 | 94.1 | 4.8 | 3.7 | 1122 | 61.2 | 57.1 | | | | |
| 45 * | 85 | 4.6 | 3.3 | 1140 | 46.9 | 46.9 | 8.41 | 8.2 | | |
| 47 | 87.4 | 4.6 | 3.3 | 1026 | 51 | 71.4 | 8.33 | 8.21 | 40.2 | 39 |
| 48 | 80.1 | 3.9 | 3.2 | 918 | 53 | 44.9 | 7.94 | 8.04 | | |
| 49 | 93 | 4.3 | 4 | 804 | 67.3 | 55 | 7.91 | 7.96 | | |
| 50 | 93 | 4.8 | 4.2 | 804 | 69.4 | 69.4 | 7.9 | 7.95 | | |
| 51 | 89 | 3.6 | 4.9 | 1048 | 65.3 | 49 | 7.92 | 8.01 | 35.4 | 34.2 |
| 52 | 91.3 | 6.1 | 2.9 | 1077 | 67.3 | | 7.92 | 8.04 | | |
| 55 * | 126.6 | 5.5 | 6.7 | 1212 | 54 | 66 | | | | |
| 56 | 112 | 5.7 | 7.4 | 1000 | 54 | 68 | 7.74 | 7.83 | 51.1 | 44.3 |
| 57 | 87.9 | 4.6 | 4.8 | 1028 | 42 | 46 | 7.6 | 7.64 | 43.7 | 40.2 |
| 58 | 104 | 6.6 | 3.2 | 960 | 42 | 42 | 7.68 | 7.71 | 34.5 | 41.9 |
| 59 | 103 | 4.6 | 3.2 | 992 | 48 | 50 | | | | |
| 61 | 105 | 3.6 | 3.6 | 1032 | 40 | 40 | 8.08 | 8.1 | | |
| 62 | 97 | 3.6 | 3.7 | 1020 | 52 | 52 | 7.94 | 8.04 | 41.9 | 40.6 |
| 63 | 101 | 3.8 | 3.5 | 916 | 46 | 36 | | | | |

| DAY # | TKN IN (mg/l) | TKN EFF C | E | COD IN (mg/l) | COD EFF C | E | pH C | pH E | OUR (mg/l/hr) C | E |
|---|---|---|---|---|---|---|---|---|---|---|
| 64 | 112 | 3.5 | 3.2 | 1108 | 52 | 46 | | | | |
| 65 | 93 | 4.6 | 5 | 944 | 56 | 50 | 7.92 | 8.02 | | |
| 68 | 106 | 5.9 | 4 | 908 | 48 | 52 | 7.94 | 8.06 | 44.7 | 36.2 |
| 69 | 101 | 4.8 | 3.1 | 1028 | 54 | 46 | 7.93 | 7.93 | 38.4 | 38.5 |
| 70 | * 131.6 | 5.3 | 2.9 | 952 | 36 | 46 | 7.6 | 7.57 | 44.2 | 44.2 |
| 71 | 130 | 3.8 | 4.1 | 984 | 54 | 46 | 7.34 | 7.38 | 49.7 | 46.7 |
| 72 | 150.6 | 4.3 | 6.3 | 1024 | 52 | 48 | 7.67 | 7.74 | 46.2 | 38.9 |
| 74 | 149 | 3.6 | 3.6 | 1008 | 88.7 | 64.5 | 7.89 | 7.94 | 38.7 | 60.8 |
| 75 | 139 | 4.3 | 5.9 | 964 | 70.6 | 70.6 | 7.98 | 8.07 | 77 | 60.4 |
| 76 | 139 | 2.9 | 3.5 | 1012 | 70.6 | 38.3 | 7.87 | 7.98 | 59.4 | 54.6 |
| 77 | 139 | 2.5 | 6.3 | 992 | 56 | 69 | 7.79 | 7.89 | 53 | 53.4 |
| 78 | 115 | 3.36 | 6.03 | 979.78 | 76.61 | 80.64 | 7.62 | 7.81 | 56.9 | 47.9 |
| 79 | 125 | 3.08 | 3.36 | 963.65 | 64.51 | 80.64 | 7.56 | 7.66 | 32.6 | 56 |
| 80 | 124 | 2.24 | 6.58 | 967.7 | 84.7 | 96.8 | 7.71 | 7.81 | 48.9 | 48.3 |
| 81 | * 99.68 | 4.34 | 5.04 | 1040 | 58.5 | 78.6 | 7.6 | 7.65 | 39.8 | 38.4 |
| 82 | 80.64 | 4.34 | 3.36 | 991.9 | 68.5 | 60.5 | | | 33.8 | 34.4 |
| 83 | 80.64 | 3.22 | 3.5 | 991.87 | 68.5 | 72.6 | 7.75 | 7.7 | 23.9 | 34.9 |
| 84 | 99.12 | 4.48 | 3.92 | 1112.83 | 64.51 | 52.42 | | | 31.8 | 34.1 |
| 85 | 89.04 | 4.34 | 3.78 | 963.7 | 86.7 | 86.7 | 7.8 | 7.95 | 34.3 | 37.4 |
| 86 | 97.44 | 3.78 | 3.36 | 963.65 | 64.51 | 68.54 | 7.76 | 8 | 35.7 | 35.4 |
| 87 | 89.6 | 3.64 | 3.78 | 1036.22 | 90.72 | 90.72 | 7.78 | 7.92 | 35.5 | 34.7 |
| 88 | 94.64 | 3.92 | 3.5 | 1000 | 76.61 | 80.34 | 7.92 | 8.01 | 38.3 | 38.1 |
| 89 | 80.08 | 3.64 | 3.22 | 1008 | 68.5 | 84.7 | 7.88 | 7.94 | 41.7 | 35.2 |
| 90 | 80.08 | 4.48 | 3.08 | 1008 | 72.6 | 52.4 | 7.9 | 7.85 | 39.3 | 34.4 |
| 91 | 85.7 | 2.8 | 3.4 | 968 | 75 | 71 | 7.85 | 7.93 | 39 | 40.2 |
| 92 | 94.1 | 3.08 | 3.64 | 1012 | 44 | 32 | | | | |
| 93 | 87.4 | 2.1 | 3.1 | 968 | 48.4 | 48.4 | 7.95 | 7.95 | | |
| 94 | * 85.12 | 2.94 | 2.38 | 915 | 88.7 | 76.6 | | | | |
| 95 | 89.6 | 3.08 | 3.78 | 1000 | 74.6 | 50.4 | | | | |
| 96 | 85.7 | 2.52 | 2.94 | 980 | 66.5 | 58.5 | | | | |
| 97 | 85.68 | 3.36 | 4.48 | 967 | 36.3 | 48.4 | 8.25 | 8.19 | 34.6 | 34.9 |
| 98 | 88.5 | 2.38 | 3.64 | 935 | 76.1 | 76.1 | | | 33.1 | 32 |
| 99 | 89 | 3.08 | 3.64 | 883 | 76.6 | 72.6 | 8.03 | 7.88 | 33.6 | 29.5 |
| 100 | 95 | 3.9 | 6.4 | 1023 | 72.3 | 68.3 | | | 28.8 | 27.1 |
| 101 | 93 | 3.36 | 3.78 | 952 | 70.3 | 66.3 | 7.94 | 7.86 | 24.66 | 27.56 |
| 102 | 97 | 3.78 | 4.06 | 967 | 96.8 | 76.6 | | | 31.17 | 32.8 |
| 105 | * 91.3 | 3.9 | 3.4 | 1032 | 52.4 | 52.4 | | | 30 | 30 |
| 106 | 102 | 13.4 | 7.7 | 927 | 58.5 | 46.4 | | | 30 | 30 |
| 107 | 94.6 | 2.5 | 3.5 | 1048 | 76.6 | 76.6 | 8.18 | 7.84 | 30 | 30 |
| 108 | 98.5 | 3.2 | 2.9 | 975 | 96.8 | 94.7 | | | 30 | 30 |
| 109 | 110 | 2.9 | 3.8 | 1024 | 80.6 | 68.5 | | | 30 | 30 |
| 110 | | | | | | | | | | |
| 111 | 111 | 2.9 | 2.7 | 1117 | 68.5 | 64.5 | | | 30 | 30 |
| 112 | 101 | 3.2 | 2.7 | 1036 | 48.4 | 48.4 | 7.69 | 7.57 | 30 | 30 |
| 113 | 110 | 4.3 | 4.8 | 903 | 40.3 | 36.3 | 7.61 | 7.5 | 30 | 30 |
| 114 | 109 | 4.2 | 2.9 | 984 | 137 | 197.6 | 7.68 | 7.82 | 30 | 30 |
| 115 | 103.04 | 4.50 | 3.82 | 1005.11 | 73.23 | 76.16 | 7.79 | 7.68 | 30 | 30 |
| 116 | | | | | | | | | | |
| 117 | * 107.5 | 3.64 | 3.64 | 1032 | 81.3 | 85.3 | | | 30 | 30 |
| 118 | 108 | 3.5 | 3.2 | 1032 | 89.4 | 65 | 8.16 | 8.12 | 30 | 30 |
| 119 | | | | | | | | | | |

# A2.10

| | TKN IN | TKN EFF | | COD IN | COD EFF | | pH C | pH E | OUR (mg/l/hr) | |
|---|---|---|---|---|---|---|---|---|---|---|
| DAY # | (mg/l) | C | E | (mg/l) | C | E | | | C | E |
| 120 | 80 | 3.8 | 6.3 | 983 | 85.3 | 93.5 | | | 30 | 30 |
| 121 | 100 | 3.6 | 3.8 | 976 | 40.3 | 60.5 | 7.74 | 7.68 | 30 | 30 |
| 122 | 96 | 3.2 | 3.6 | 975 | 54.4 | 66.5 | 7.78 | 7.84 | 30 | 30 |
| 123 | | | | | | | | | | |
| 124 | | | | | | | | | | |
| 125 | 85 | 3.36 | 5.32 | 930.7 | 77.2 | 97.5 | 7.1 | 7.18 | 30 | 30 |
| 126 | 94 | 6 | 4.1 | 983 | 81 | 77 | | | 30 | 30 |
| 127 | 111.4 | 5.5 | 6 | 1109 | 83.3 | 75.1 | 7.99 | 8.09 | 30 | 30 |
| 128 | 91.3 | 4.8 | 5.5 | 971 | 95.5 | 87.4 | | | 30 | 30 |
| 129 | 84.6 | 5.6 | 5.2 | 1000 | 97.5 | 81.3 | | | 30 | 30 |
| 130 * | 95.8 | 6.2 | 6.8 | 1048 | 58.9 | 54.9 | 7.74 | 7.94 | 30 | 30 |
| 131 | | | | | | | | | 30 | 30 |
| 132 | 95.8 | 4.3 | 4.6 | 1098 | 61 | 75.2 | 7.8 | 7.89 | 30 | 30 |
| 133 | 99.7 | 4.2 | 4.8 | 1032 | 85.3 | 48.8 | 7.85 | 8.01 | 30 | 30 |
| 134 | 96 | 4.1 | 8.3 | 1040 | 48.8 | 50.8 | 7.68 | 7.83 | 30 | 30 |
| 135 | 89.9 | 4.2 | 4.4 | 991 | 42.7 | 38.6 | 7.69 | 7.87 | 30 | 30 |
| 136 | 96.9 | 7 | 4.8 | 1069 | 61.7 | 49.3 | 7.87 | 8.01 | 30 | 30 |
| 137 | 98 | 5.6 | 5.18 | 1040 | 41.1 | 100.7 | | | 30 | 30 |
| 138 | | | | | | | | | | |
| 139 | | | | | | | | | | |
| 140 * | | | | | | | | | | |
| 141 | 90.2 | 6 | 4.3 | 1073 | 55.5 | 51.4 | | | 30 | 30 |
| 142 | 85.7 | 4.8 | 3.4 | 1077 | 41.1 | 43.2 | 7.76 | 7.89 | 30 | 30 |
| 143 | 79.5 | 3.8 | 4.2 | 892 | 49.3 | 59.6 | 7.92 | 8.03 | 30 | 30 |
| 144 | 92.4 | 3.4 | 2.9 | 1044 | 53.5 | 51.4 | 7.91 | 8.01 | 30 | 30 |
| 145 | | | | | | | | | | |
| 146 | 75 | 4.6 | 3.2 | 925 | 65.8 | 53.5 | 7.64 | 7.77 | 30 | 30 |
| 147 | 65 | 4.2 | 3.9 | 905 | 24.7 | 57.6 | 7.61 | 7.76 | 30 | 30 |
| 148 | 68.9 | 4.5 | 4.6 | 900 | 51.4 | 47.3 | 7.67 | 7.74 | 30 | 30 |
| 149 | 68.3 | 3.9 | 4.1 | 929 | 35 | 45.2 | 7.67 | 7.79 | 30 | 30 |
| 150 | 87.1 | 4.8 | 4.3 | 905 | 16.4 | 14.4 | 7.76 | 7.86 | 30 | 30 |
| 151 | 82 | 5.5 | 4.41 | 1024 | 61.2 | 81.6 | 7.75 | 7.82 | 30 | 30 |
| 153 | | | | | | | | | | |
| 154 | 102.5 | 4.5 | 3.5 | 1236 | 69.4 | 46.9 | 7.95 | 7.87 | 30 | 30 |
| 155 * | 79.5 | 4.1 | 2.5 | 1032 | 32.6 | 38.8 | 7.93 | 7.9 | 30 | 30 |
| 156 | 82 | 4.8 | 4.1 | 1011 | 73.4 | 81.6 | 7.96 | 7.98 | 30 | 30 |
| 157 | 81.800 | 5.2 | 4.8 | 995 | 79.6 | 65.3 | | | 30 | 30 |
| 158 | | | | | | | | | | |
| 159 | 81.8 | 3.6 | 3.8 | 1048 | 51 | 71.4 | 7.8 | 7.96 | 30 | 30 |
| 160 | | | | | | | | | | |
| 161 | 89.6 | 2.7 | 3.1 | 954 | 56.1 | 60.2 | | | 30 | 30 |
| 162 | | | | | | | | | | |
| | 79 | 5.3 | | 1004 | 83 | 102 | | | 30 | 30 |
| 164 | | | | | | | | | | |
| 165 | 88.5 | 4.2 | 3.2 | | | | 7.79 | 7.89 | 30 | 30 |
| 166 | | | | | | | | | | |
| 167 | | | | | | | | | | |
| 168 | 93 | 5.7 | 7.3 | 1030 | | 70.6 | | | 30 | 30 |
| 169 | | | | | | | | | 30 | 30 |
| 170 | | 3.9 | 5.7 | | 45.8 | 72.8 | 7.89 | 7.99 | 30 | 30 |
| 171 | 91 | 4.60 | 4.60 | 1075.00 | 79.20 | 77.10 | 7.76 | 7.82 | 30 | 30 |
| 172 * | 70 | 4.2 | 5.30 | 1063.00 | 64.60 | 64.60 | 7.63 | 7.69 | 30 | 30 |
| 173 | 71 | | | | | | | | | |

# A2.11

| DAY # | TKN IN (mg/l) | TKN EFF C | TKN EFF E | COD IN (mg/l) | COD EFF C | COD EFF E | pH C | pH E | OUR (mg/l/hr) C | OUR (mg/l/hr) E |
|---|---|---|---|---|---|---|---|---|---|---|
| 174 | 71 | | | | | | | | | |
| 175 | 72.8 | 5.7 | 4.9 | 1029 | 77.1 | 93.8 | | | 30 | 30 |
| 176 | 87.1 | 6.2 | 5.3 | 1042 | 83.4 | 89.6 | 7.92 | 8.05 | 30 | 30 |
| 177 | | | | | | | | | | |
| 178 | 84 | 8 | 5 | 1112 | 83.4 | 102.1 | 7.85 | 7.86 | 30 | 30 |
| 179 | 85.7 | 5.2 | 6.3 | 1100 | 56.3 | 83.4 | | | 30 | 30 |
| 180 | | | | | | | | | | |
| 181 | | | | | | | | | | |
| 182 * | 68.3 | 4.6 | 3.6 | 1067 | 85.4 | 85.4 | 7.92 | 7.94 | 30 | 30 |
| 183 | 84.6 | 4.3 | 5.4 | 921 | 91.7 | 98 | 7.9 | 7.9 | 30 | 30 |
| 184 | | | | | | | | | | |
| 185 * | 90.2 | 5.2 | 5.6 | 996 | 63 | 52.8 | 7.66 | 7.67 | 17.03704 | 29.375 |
| 186 | 82.3 | 6.7 | 5.3 | 1032 | | 44.37 | 7.98 | 7.95 | 32.1 | 30 |
| 187 | | | | | | | | | | |
| 188 | 82 | 2.8 | 4.4 | 914 | 12.2 | 14.2 | 8.04 | 7.91 | 30.7 | 22.7 |
| 189 | 88.5 | 4.7 | 4.7 | 959 | 48.8 | 52.8 | 8.11 | 8.09 | 27.7 | 36.7 |
| 190 | 84.6 | 6.3 | 4.9 | 1000 | 52.8 | 63 | 8.06 | 7.85 | 31.2 | 35.2 |
| 191 | 84.6 | 5.8 | 5.9 | 1000 | 52.8 | 63 | 8.15 | 8.04 | 29.4 | 32.4 |
| 192 | 87.8 | 6 | 5.9 | 1016 | 48.8 | 46.7 | 7.97 | 7.97 | 27.9 | 30 |
| 193 | 87.9 | 5.3 | 5.3 | 1012 | 48.8 | 52.8 | 7.8 | 7.79 | | |
| 194 | | | | | | | | | | |
| 195 | 88.5 | 4.1 | 3.6 | 1040 | 63 | 50.8 | 7.59 | 7.51 | 30.7 | 32.1 |
| 196 | 89.9 | 4.7 | 5.3 | 1032 | 42.7 | 69.1 | 7.66 | 7.71 | 26.4 | 25.2 |
| 197 | 88.8 | 4.1 | 4.4 | 947 | 30.5 | 36.6 | 7.92 | 7.82 | 27.8 | 29.7 |
| 198 * | 68.9 | 4.8 | 6.2 | 877 | 58.9 | 56.9 | 7.9 | 7.75 | 33.3 | 34.9 |
| 199 | | 5.5 | 4.6 | | 24.4 | 81.3 | 8.04 | 7.87 | | |
| 200 | 89 | 5.25 | 3.85 | 1024.00 | 154.40 | 59 | 7.87 | 7.93 | | |
| 201 | | | | | | | | | | |
| 202 | | 4.60 | 3.60 | 1024 | 57.1 | 59.2 | 7.87 | 7.93 | 33 | 32.7 |
| 203 | 88.5 | 3.78 | 6.020 | 1048 | 53 | 46.9 | 8 | 7.880 | 30.9 | 30.66 |
| 204 | 87.6 | 3.9 | 5.2 | 967 | 53 | 57.1 | 7.89 | 7.82 | 33.8 | 38.8 |
| 205 | 89 | 5 | 5.9 | 1000 | 49 | 49 | 7.85 | 7.76 | 32.2 | 32.9 |
| 206 | 106 | 3.9 | 3.800 | 1049 | 57.1 | 57.1 | 7.95 | 7.86 | 31.9 | 28.5 |
| 207 | 116 | 2.9 | 5 | 975 | 38.8 | 42.800 | 7.9 | 7.9 | 34.1 | 32.8 |
| 210 * | 104 | 13.4 | 11 | 1248 | 53 | 75.5 | 7.68 | 7.74 | 31.1 | 45.8 |
| 211 | 99 | 4.7 | 5.7 | 1138 | 53 | 55.1 | | | 36.8 | 35.1 |
| 212 | 87 | 5.4 | 5.5 | 1000 | 42.8 | 51 | 7.9 | 7.9 | 37.9 | 39.7 |
| 213 | 106 | | 4.1 | 914 | 44.9 | 53 | 7.76 | 7.63 | 36.7 | 37.8 |
| 214 | 82.3 | 3.9 | 4.8 | 918 | 36.5 | 42.8 | 7.63 | 7.61 | 33.3 | 33.8 |
| 216 | 85.1 | 3.4 | 3.7 | 1110 | 38.8 | 46.9 | | | 35.6 | 37.3 |
| 217 | 99.1 | 4.70 | 5.70 | 1114 | 50.80 | 54.90 | 7.68 | 7.74 | 44.2 | 41.8 |
| 218 | 86.8 | 5.60 | 3.85 | 1036 | 69.10 | 65.00 | 8.15 | 7.91 | 35.25 | 39.74 |
| 219 | 93.5 | 5.1 | 3.1 | 1077 | 56.9 | 54.9 | 7.96 | 7.9 | 36.58 | 27.71 |
| 220 | 85.1 | 5.6 | 3.600 | 1036 | 44.7 | 44.700 | 8.05 | 7.930 | 30.31 | 30 |
| 221 | | 4.48 | 4.2 | 989.6 | 53.8 | 47.8 | | | | |
| 223 | | 3.2 | 3.100 | 989.6 | 35.6 | 88.400 | 8 | 7.93 | 25.38 | 34.42 |
| 224 * | 72 | 4.9 | 4.8 | 930.7 | 44.7 | 50.800 | 7.86 | 7.86 | 30.41 | 33 |
| 225 | 93 | 4.6 | 4.9 | 1020 | 42.7 | 34.5 | 7.88 | 7.88 | 30.81 | 30.88 |
| 226 | 105 | 5.2 | 5 | 1064 | 44.7 | 40.6 | 7.92 | 7.92 | 33.3 | 36.2 |
| 227 | 102 | 4.8 | 5.2 | 1089 | 50.8 | 50.8 | 7.79 | 7.83 | 38.8 | 39.2 |
| 228 | 104 | 5 | 5 | 1099 | 52.8 | 50.8 | | | | |

| DAY # | TKN IN (mg/l) | TKN EFF C | TKN EFF E | COD IN (mg/l) | COD EFF C | COD EFF E | pH C | pH E | OUR (mg/l/hr) C | OUR (mg/l/hr) E |
|---|---|---|---|---|---|---|---|---|---|---|
| 243 | 95.8 | 5.1 | 6.7 | 1024 | 67.3 | 71.4 | | | 30.3 | 37.7 |
| 245 | 97.7 | 4.7 | 3.7 | 955 | 32.6 | 40.8 | 7.91 | 7.89 | 28.6 | 29.8 |
| 247 | * 112.6 | 4.8 | 5 | 1040 | 53 | 57.1 | | | | |
| 249 | | 4.7 | 5.3 | 1126 | 46.9 | 71.4 | 7.81 | 7.84 | 39.2 | 40.2 |
| 250 | 110 | 6.4 | 5.1 | 1100 | 65.3 | 75.5 | 7.8 | 7.69 | 33.2 | 33.5 |
| 251 | 115 | 5.5 | 5.1 | 1079 | 83.6 | 79.6 | 7.78 | 7.66 | 34.1 | 33.6 |
| 252 | 94 | 5.4 | 5.3 | 1032 | 816 | 69.4 | 7.76 | 7.76 | 39.1 | 39.5 |
| 254 | 116.8 | 5.5 | 5.5 | 1065 | 67.3 | 69.4 | | | | |
| 256 | * | 6.2 | 5.9 | 1211 | 79.6 | 63.2 | 7.57 | 7.74 | 34.7 | 42.1 |
| 257 | 106 | 5 | 5.5 | 1047 | 26.5 | 57.1 | 7.67 | 7.72 | 37.9 | 38.2 |
| 258 | 83.2 | 5.9 | 5.4 | 928 | 74.5 | 68.3 | | | 33.6 | 41.7 |
| 259 | 102 | 5.5 | 5.2 | 1065 | 65.3 | 73.4 | 7.89 | 7.97 | 31.1 | 34.5 |
| 260 | 106 | 5 | 5 | 1065 | 53 | 55.1 | | | | |
| 261 | 106 | 4.8 | 6.1 | 1028 | 59.2 | 55.1 | 7.67 | 7.63 | 34.1 | 34.2 |
| 263 | 126 | 4.5 | 5.2 | 1028 | 59.2 | 55.1 | 7.61 | 7.66 | 46 | 45.2 |
| 264 | 115 | 5 | 4.3 | 942 | 82.6 | 62.2 | 7.61 | 7.61 | 46.4 | 47.7 |
| 265 | 102 | 4.34 | 4.2 | 942 | 110 | 59.2 | 7.6 | 7.7 | 37.3 | 36.5 |
| 266 | 102 | 4.2 | 4 | 906 | 79.6 | 77.5 | 7.76 | 7.72 | 34.7 | 37.7 |
| 267 | 114 | 4.4 | 4.4 | 995 | 59.4 | 53.2 | 7.84 | 7.89 | 35.5 | 38.4 |
| 270 | * 112 | 4.6 | 4.1 | 1069 | 34.8 | 59.4 | | | | |
| 271 | 98 | 4.9 | 4.9 | 938 | 53.2 | 63.5 | 7.9 | 7.82 | 31.6 | 34.7 |
| 272 | 101 | 4.7 | 4.6 | 958 | 53.3 | 55.3 | 7.71 | 7.71 | 40.3 | 34.9 |
| 275 | 100 | 4.9 | 4.9 | 999 | 55.3 | 49.2 | 7.71 | 7.69 | 36.7 | 38.7 |
| 276 | 98 | 4.5 | 4.5 | 1152 | 43 | 43 | 7.67 | 7.76 | 36.8 | 37.5 |
| 277 | 104 | 5.3 | 3.9 | 1093 | 75.8 | 80 | 7.43 | 7.6 | 34.3 | 36.8 |
| 279 | 98 | 4.6 | 3.6 | 1094 | 77 | 80 | 7.76 | 7.72 | 36.1 | 33.8 |
| 280 | 99 | 5.1 | 5 | 1090 | 109 | 106 | 7.89 | 7.94 | 37.3 | 36.3 |
| 281 | 101 | 5.3 | 5.4 | 1057 | 53.2 | 51.2 | 7.92 | 7.91 | 35.2 | 35.5 |
| 288 | 83 | 5 | 5 | 950 | 63.5 | 73.7 | | | | |
| 289 | 72 | 3.9 | 4.6 | 909 | 73.7 | 90.1 | | | | |

# A2.13

PHOSPHATES (mg/l)

| DAY # | Influent | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22.2 | 37.8 | 41 | 36.5 | 28.6 | 21.9 | 19.4 | 39.4 | 42.9 | 41 | 29.8 | 22.2 | 17.8 |
| 2 | 21 | 26.3 | 33.7 | 30.8 | 25.7 | 20 | 20 | 36.8 | 39.4 | 42.2 | 29.8 | 22.2 | 21 |
| 3 | 21.3 | 33.8 | 27.2 | 25 | 18.8 | 16.3 | 15.4 | 35.3 | 34.7 | 37.8 | 29.1 | 20.7 | 20.7 |
| 5 | 21.3 | 31.6 | 32.8 | 32.8 | 12.2 | 16 | 14.1 | 32.5 | 34.4 | 39.1 | 27.9 | 17.3 | 15.7 |
| 6 | 21.7 | 34.6 | 34.6 | 34.9 | 24 | 15.7 | 15.1 | 33.2 | 34.6 | 38.8 | 27.6 | 16.1 | 14.4 |
| 7 * | 20.4 | 30.3 | 31.3 | 32.6 | 22 | 13.4 | 13.4 | 31.9 | 33.6 | 37.9 | 24 | 10.8 | 10.5 |
| 8 | 20.7 | 31.1 | 32.8 | 32.8 | 12.3 | 9.3 | 9.3 | 32.8 | 34.1 | 33.8 | 21 | 21.7 | 8 |
| 9 | 20.7 | 28.8 | 28.1 | 31.1 | 17.7 | 8.3 | 8.3 | 33.5 | 33.8 | 39.2 | 25.7 | 12.7 | 10 |
| 10 | 19.4 | 30.7 | 30.7 | 29.8 | 17.5 | 7.5 | 7.5 | 30.4 | 32 | 36.1 | 21 | 9.7 | 9 |
| 12 | 19.4 | 31.4 | 32.9 | 29.5 | 14.7 | 4.3 | 4.3 | 34.2 | 35.8 | 37.6 | 20 | 4.6 | 3.7 |
| 13 | 19 | 26.2 | 29 | 22.4 | 13.4 | 4.8 | 2.9 | 27.7 | 29.9 | 26.8 | 14.1 | 10.3 | 2 |
| 14 | 18.2 | 31.2 | 32.5 | 55.8 | 11.5 | 3.2 | 2.5 | 31.8 | 35.5 | 31.5 | 16.8 | 5.2 | 2.2 |
| 15 | 18.5 | 32.8 | 34.5 | 25.5 | 13.5 | 4.8 | 3.5 | 35.8 | 38.5 | 37.5 | 22.2 | 8.2 | 3.2 |
| 16 | 18.5 | 32.8 | 34.5 | 25.5 | 13.5 | 4.8 | 3.5 | 35.8 | 38.5 | 37.5 | 21.2 | 8.2 | 3.2 |
| 17 | 18.5 |  | 38.3 | 40.8 | 23.2 | 5.7 | 5 | 41.4 | 41.7 | 22.9 | 3.5 | 2.9 |  |
| 19 | 18.5 | 38.6 | 40.5 | 41.4 | 21.7 | 3.5 | 3.5 | 41.4 | 43.9 | 45.8 | 23.5 | 1.91 | 1.6 |
| 20 | 19 | 40 | 41.9 | 41.6 | 21.9 | 4.4 | 2.5 | 41.9 | 46 | 48.6 | 26.3 | 4.1 | 3.2 |
| 21 | 19.7 | 42.9 | 44.4 | 43.8 | 23.5 | 4.8 | 4.4 | 46 | 48.6 | 50.8 | 29.2 | 5.7 | 4.4 |
| 22 * | 19.5 | 40 | 41.5 | 42.2 | 21.1 | 57 | 4.1 | 41.2 | 41 | 40.8 | 20.1 | 7.1 | 4.1 |
| 23 | 17.9 | 44.5 | 45.1 | 40.5 | 21.1 | 4.1 | 4.1 | 46.5 | 47.1 | 42.2 | 22.7 | 8.3 | 4.1 |
| 25 | 22 | 42.5 | 47.1 | 43.8 | 21.3 | 5.1 | 3.7 | 45.1 | 50.4 | 44.6 | 23.6 | 4.1 | 3.7 |
| 26 | 23.1 | 48.3 | 50.6 | 42 | 20.1 | 4.8 | 3.5 | 45.6 | 51.6 | 44.7 | 21.7 | 3.8 | 2.1 |
| 27 | 20.7 | 44.7 | 47.3 | 41.3 | 20.1 | 3.8 | 2.1 | 45.3 | 49.3 | 42 | 19.7 | 7.1 | 2.8 |
| 28 | 21.1 | 38.5 | 42.1 | 40.5 | 20.5 | 10 | 5.4 | 44.4 | 45.4 | 42.5 | 23.1 | 10.3 | 4.4 |
| 29 | 20.5 | 45.4 | 48 | 38.9 | 22.5 | 10 | 8 | 40.2 | 44.1 | 33.6 | 17.5 | 6.4 | 6.4 |
| 30 | 19.6 | 43 | 47.6 | 37 | 21.9 | 7.8 | 7.1 | 42 | 47.2 | 39.3 | 23.6 | 8.1 | 6.4 |
| 31 | 20.9 | 41.6 | 44.6 | 37.4 | 20.6 | 7.1 | 7.1 | 42.3 | 45.6 | 40.3 | 21.9 | 20.6 | 6.4 |
| 33 | 21.6 | 41.6 | 40.3 | 33.1 | 19.4 | 9.7 | 8.8 | 42.8 | 43.4 | 37.2 | 21.3 | 11.3 | 8.8 |
| 34 | 20 |  |  |  |  |  | 12.2 |  |  |  |  |  | 6.3 |
| 37 * |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 38 | 18.4 | 37.3 | 40.4 | 40.1 | 52.5 |  | 14.5 | 40.9 | 42.2 | 41.2 | 24.9 | 13.7 | 13.7 |
| 40 | 17.9 | 32.3 | 34.9 | 26.5 | 14.7 | 5.1 | 11.1 | 39.6 | 40.9 | 35.4 | 17.1 | 5.1 | 5.8 |
| 41 | 18.6 | 32.6 | 35.8 | 26.7 | 12.6 | 5.1 | 5.1 | 37.4 | 40.4 | 31.5 | 15.1 | 7.3 | 5.4 |
| 42 | 17.8 | 30.4 | 33.1 | 23.7 | 10.2 | 2.4 | 2.9 | 35.6 | 39.3 | 29.1 | 12.6 | 5.6 | 2.9 |
| 43 | 14.7 | 34.3 | 37.5 | 28.3 | 15.5 | 4 | 4 | 35.6 | 37.5 | 34.3 | 16.8 | 5.1 | 2.1 |
| 44 | 19.6 | 36.5 | 35.6 | 29.4 | 15.7 | 5.4 | 4.3 | 37.5 | 43.8 | 35.9 | 17.9 | 9.8 | 5.9 |
| 45 * | 20.1 | 43 | 43.8 | 44.9 | 26.1 | 11.4 | 6.8 | 47.6 | 49.8 | 52.5 | 28.8 | 9.8 | 6.8 |
| 47 | 18.5 | 41.6 | 42.5 | 37 | 22.8 | 8.9 | 8.9 | 44.9 | 47.9 | 47.1 | 26.1 | 7.8 | 7.8 |
| 48 | 19.6 | 36.4 | 39.7 | 37.8 | 23.1 | 7.5 | 6.3 | 41.3 | 44.3 | 43.4 | 23.8 | 5.9 | 5.9 |
| 49 | 18 | 32.7 | 34.5 | 28.7 | 16.1 | 5.9 | 5.9 | 39 | 40.1 | 36.6 | 20.5 | 9.8 | 6.6 |
| 50 | 19.8 | 32 | 32.4 | 23.6 | 12.8 | 4.9 | 4.9 | 35 | 37.1 | 28 | 15.6 | 8.4 | 6.1 |
| 51 | 19.8 | 33.4 | 38.3 | 28 | 14 | 4.5 | 2.6 | 37.6 | 42.2 | 32.2 | 15.4 | 5.2 | 4.5 |
| 52 | 19.1 | 32.6 | 37 | 29.3 | 17 | 8.6 | 6.7 | 39.1 | 42.1 | 33.5 | 19.1 | 11.2 | 6.5 |
| 55 * | 21.6 | 40.5 | 41.6 | 31.6 | 20.7 | 14.4 | 12.3 | 37.9 | 40.5 | 33.7 | 18.8 | 10.2 | 10.2 |
| 56 | 18.2 | 40.8 | 46.1 | 41.9 | 26.4 | 13.1 | 13.1 | 40.3 | 41.1 | 30.4 | 15 | 4.4 | 4.4 |
| 57 | 18.7 | 35.2 | 37.9 | 29.4 | 13.7 | 2 | 2 | 37.3 | 41.1 | 31.5 | 15 | 0.9 | 0.9 |
| 58 | 18.3 | 34.5 | 35.7 | 25.6 | 11.6 | 4.3 | 4.3 | 33 | 36.9 | 24.6 | 12.4 | 5 | 2.5 |
| 59 | 18.7 | 35.2 | 40.6 | 30.5 | 15.1 | 5 | 3.8 | 31.5 | 38.9 | 29.1 | 14.8 | 4.3 | 3.8 |
| 61 | 18.3 | 36.4 | 40.1 | 31.5 | 18.3 | 8.5 | 6.3 | 37.4 | 41.8 | 29.3 | 15.9 | 6.3 | 4.1 |
| 62 | 18.3 | 33.8 | 37.9 | 29.3 | 16.8 | 7 | 6.5 | 36 | 41.3 | 28.6 | 15.9 | 5.8 | 5.3 |
| 63 | 16.9 | 32.4 | 36.1 | 26.6 | 16.6 | 8.4 | 7.4 | 34.4 | 37.9 |  | 15.1 | 6.4 | 5.9 |

# A2.14

PHOSPHATES (mg/l)

| DAY # | Influent | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | 22.1 | 29.1 | 33.1 | 25.4 | 12.1 | 6.9 | 6.1 | 36.6 | 38.9 | 27.1 | 14.4 | 8.6 | 5.1 |
| 65 | 18.6 | 33 | 33.8 | 26.6 | 15.7 | 10.4 | 8 | 35.6 | 37.5 | 22.1 | 11 | 6.4 | 4.6 |
| 68 | 18.1 | 32.7 | 35.1 | 27.7 | 15.7 | 9.1 | 9.1 | 32.7 | 36.4 | 25.3 | 13.3 | 9.4 | 6.2 |
| 69 | 21.3 | 35.3 | 38.3 | 29.8 | 15.2 | 7.5 | 7.5 | 37 | 40.3 | 29.8 | 15.5 | 7.2 | 6.7 |
| 70 * | 18.2 | 30.4 | 35.3 | 26 | 14.4 | 5.8 | 5.8 | 30.4 | 40 | 28.2 | 14.1 | 6.4 | 6.4 |
| 71 | 17.7 | 27.2 | 28 | 22.8 | 13 | 5.6 | 5.9 | 29 | 34.1 | 23.1 | 11.3 | 7.1 | 4.2 |
| 72 | 19.38 | 33.36 | 31.15 | 22.57 | 11.77 | 6.38 | 6.13 | 31.64 | 37.53 | 19.38 | 9.08 | 6.62 | 5.15 |
| 74 | 20.25 | 31.75 | 34.75 | 25 | 14.25 | 10.25 | 7.25 | 35.25 | 37 | 24 | 13.25 | 9 | 5 |
| 75 | 19.5 | 29.5 | 32 | 25.5 | 14.25 | 10.75 | 9.5 | 34.25 | 35.25 | 22 | 13.75 | 9.25 | 7.75 |
| 76 | 19.5 | 31.5 | 33.25 | 24 | 13.75 | 8.25 | 8 | 30 | 35 | 22.25 | 13.5 | 10 | 7.5 |
| 77 | 22.9 | 33.8 | 36.5 | 22.9 | 14.3 | 10.5 | 8.6 | 35.6 | 38.6 | 25.1 | 14.5 | 9.1 | 8 |
| 78 | 19.23 | 33.33 | 34.36 | 20.51 | 13.85 | 9.49 | 8.46 | 35.38 | 37.44 | 22.31 | 12.82 | 8.21 | 6.92 |
| 79 | 19.52 | 26.96 | 31.19 | 27.62 | 9.76 | 6.9 | 7.38 | 30.95 | 33.81 | 20.24 | 10.71 | 7.86 | 5.95 |
| 80 | 20 | 29.76 | 30.98 | 19.76 | 9.76 | 5.37 | 7.32 | 34.63 | 36.83 | 23.41 | 11.46 | 7.32 | 5.12 |
| 81 * | 18.81 | 28.1 | 31.43 | 16.9 | 9.76 | 7.62 | 5.95 | 28.1 | 32.38 | 21.463 | 11.19 | 7.14 | 5.24 |
| 82 | 22.82 | 29.49 | 32.31 | 23.33 | 13.59 | 7.18 | 6.67 | 35.12 | 36.92 | 25.96 | 14.87 | 10 | 6.41 |
| 83 | 21 | 29 | 33.5 | 23.75 | 12.75 | 7.5 | 7 | 29.5 | 33.25 | 25.5 | 13 | 8 | 6.5 |
| 84 | 21 | 32.25 | 34 | 25 | 13 | 7 | 8.75 | 32.25 | 36.75 | 26.5 | 13 | 7.75 | 5.5 |
| 85 | 20.08 | 32.47 | 34.21 | 25.53 | 13.39 | 9.42 | 7.19 | 34.21 | 37.19 | 25.78 | 12.64 | 7.44 | 4.71 |
| 86 | 19.29 | 30 | 32.38 | 24.05 | 12.38 | 8.57 | 6.43 | 31.67 | 34.52 | 25.48 | 13.1 | 8.81 | 5.48 |
| 87 | 21.14 | 31.59 | 33.86 | 26.59 | 14.09 | 10.23 | 7.05 | 35 | 36.59 | 27.95 | 14.55 | 9.09 | 6.14 |
| 88 | 20.72 | 32.77 | 34.46 | 26.75 | 15.66 | 10.36 | 6.75 | 33.49 | 37.59 | 27.71 | 14.22 | 9.4 | 6.51 |
| 89 | 20.95 | 33.81 | 35 | 28.1 | 15.95 | 10.24 | 8.33 | 36.19 | 37.62 | 29.52 | 15.48 | 10.71 | 6.9 |
| 90 | 20.95 | 29.3 | 31.6 | 24.1 | 15 | 8.5 | 6.8 | 29 | 33 | 25.3 | 13.6 | 8.2 | 6.8 |
| 91 | 20.25 | 33.4 | 36.6 | 26.8 | 13.4 | 7.1 | 5.6 | 35.9 | 38.8 | 28.8 | 13.7 | 8.3 | 4.4 |
| 92 | 20.4 | 33.3 | 36.4 | 26.4 | 13.9 | 8.4 | 4.4 | 32.3 | 36.2 | 26.1 | 12 | 7.7 | 3.5 |
| 93 | 21.3 | 30.5 | 34 | 24.4 | 12.1 | 7.4 | 5.5 | 29.1 | 32.4 | 24.1 | 12.4 | 8.1 | 4.4 |
| 94 * | 16.88 | 29.23 | 32.86 | 23.9 | 12.52 | 10.1 | 6.22 | 27.77 | 32.13 | 23.17 | 11.54 | 7.43 | 5.23 |
| 95 | 19.7 | 32.3 | 33.7 | 24.1 | 13.4 | 10.5 | 7.4 | 27.2 | 31.5 | 23.3 | 12.9 | 8.8 | 5.5 |
| 96 | 18.6 | 30.7 | 32.4 | 24.1 | 14.3 | 11.2 | 8.3 | 31 | 32.1 | 23.1 | 12.6 | 10 | 6.4 |
| 97 | 18.6 | 28.1 | 31 | 24.1 | 14.3 | 10.7 | 8.6 | 26.9 | 30.2 | 21.9 | 12.4 | 10.7 | 6.9 |
| 98 | 18.9 | 29.8 | 32.3 | 25.2 | 14.6 | 11.7 | 9.7 | 30.8 | 33.5 | 24.3 | 13.8 | 10.4 | 7.5 |
| 99 | 18.2 | 29.3 | 31.9 | 23.7 | 13.4 | 9.8 | 8.6 | 30.9 | 33.6 | 23.5 | 13.2 | 10.8 | 7.9 |
| 100 | 19.5 | 29.5 | 31.2 | 21.4 | 11.9 | 10.5 | 8.1 | 29.8 | 31.7 | 21.6 | 11 | 8.3 | 6.4 |
| 101 | 19.8 | 29.7 | 30.9 | 23.4 | 12.1 | 8.8 | 7.1 | 30.4 | 32.6 | 23.8 | 12.3 | 9.9 | 6.4 |
| 102 | 18.9 | 31.9 | 34.3 | 24 | 15.1 | 9 | 7.6 | 33.9 | 36.5 | 29.5 | 15.1 | 9.5 | 6.1 |
| 105 * | 18.6 | 30.4 | 32.9 | 24.6 | 12.8 | 10.1 | 7.3 | 31.2 | 34.5 | 25.4 | 13.3 | 8.8 | 5.8 |
| 106 | 18.8 | 28.7 | 32.4 | 23.5 | 12.6 | 10.6 | 6.7 | 32.2 | 34.4 | 22.8 | 12.1 | 8.4 | 6.2 |
| 107 | 18.8 | 29.2 | 31.7 | 22.7 | 12.1 | 10 | 6.7 | 29.4 | 33.8 | 23.2 | 11.8 | 7.6 | 5.3 |
| 108 | 20.2 | 29.8 | 32.4 | 22.9 | 11.7 | 10.5 | 6.6 | 31 | 33.9 | 22.7 | 11.2 | 8.3 | 4.6 |
| 109 | 19.7 | 27.8 | 31.4 | 19.7 | 10.6 | 7.5 | 6.5 | 30.4 | 30.6 | 19.2 | 10.4 | 8.6 | 4.2 |
| 110 | | | | | | | | | | | | | |
| 111 | 21 | 30.3 | 33 | 19.5 | 13 | 12 | 8.3 | 30.5 | 33 | 20.5 | 11.3 | 9 | 5.8 |
| 112 | 17.9 | 27.9 | 32.1 | 20.3 | 12.5 | 9.3 | 8.1 | 34 | 35.5 | 22.5 | 12.5 | 8.3 | 7.8 |
| 113 | 19.9 | 25.7 | 31.5 | 24.5 | 18.2 | 11.3 | 9.6 | 27.1 | 34.1 | 26.4 | 28.6 | 10.6 | 10.1 |
| 114 | | | | | | | | | | | | | |
| 115 | 19.36 | 28.73 | 32.18 | 22.21 | 12.94 | 10.16 | 7.48 | 30.73 | 33.73 | 22.84 | 13.90 | 8.70 | 6.23 |
| 116 | | | | | | | | | | | | | |
| 117 * | 21.7 | 30.6 | 32.6 | 21.2 | 14.2 | 13 | 13 | 32.9 | 34.6 | 23.9 | 14.2 | 11.2 | 8.2 |
| 118 | 21.7 | 30.9 | 32.6 | 23.9 | 15.4 | 10.5 | 10 | 34.9 | 35.9 | 21.9 | 12.5 | 10.7 | 8.5 |
| 119 | | | | | | | | | | | | | |

# A2.15

PHOSPHATES (mg/l)

| DAY # | Influent | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 120 | 21.7 | 31.4 | 34.3 | 26.2 | 15.4 | 13.7 | 10.6 | 33.1 | 35.4 | 26.7 | 12.8 | 8 | 9 |
| 121 | 20.7 | 32.3 | 33.9 | 27 | 13.2 | 9.8 | 7.8 | 34.5 | 36.1 | 29 | 12.9 | 7.6 | 4 |
| 122 | 21.3 | 32.4 | 34.1 | 25.1 | 12.1 | 10 | 7.1 | 35.3 | 37.9 | 27.9 | 13 | 7.6 | 5.5 |
| 123 | | | | | | | | | | | | | |
| 124 | | | | | | | | | | | | | |
| 125 | 23.7 | 27.8 | 29.8 | 19.5 | 10.1 | 8.9 | 6.9 | 33.2 | 34.2 | 24.7 | 13.2 | 10.3 | 7.4 |
| 126 | | | | | | | | | | | | | |
| 127 | 21.6 | 30.8 | 31.8 | 24.5 | 12.6 | 9 | 7.3 | 33.9 | 36.4 | 26.2 | 12.2 | 7.6 | 6.8 |
| 128 | 20.8 | 33.3 | 34 | 27.9 | 14.9 | 9.7 | 10.5 | | | | | | 10.7 |
| 129 | | | | | | | | | | | | | |
| 130 * | 23.9 | 29.7 | 35.8 | 31.4 | 15.8 | 7.2 | 5.8 | 31.7 | 38.6 | 30.8 | 15 | 5.8 | 5.3 |
| 131 | | | | | | | | | | | | | |
| 132 | 22.8 | 30.3 | 36.6 | 32.2 | 17.2 | 5.3 | 4.7 | 36.1 | 41.7 | 33.3 | 16.9 | 5.5 | 5 |
| 133 | 21.7 | 19 | 34.4 | 28.5 | 15.6 | 8 | 5.9 | 35.6 | 42.4 | 33.7 | 16.3 | 7.3 | 5.6 |
| 134 | 21.7 | 30.7 | 38.5 | 29.5 | 15.4 | 7.6 | 6.1 | 37.1 | 43.9 | 35.1 | 18 | 7.6 | 4.9 |
| 135 | 20.8 | 28.5 | 35.8 | 29.5 | 16.8 | 6.8 | 5.8 | 34.5 | 40 | 30.8 | 15.8 | 6.8 | 4.3 |
| 136 | 20.8 | 32.5 | 40.5 | 30.8 | 16.8 | 10 | 7.5 | 39 | 43.8 | 35.3 | 17.3 | 7.5 | 5.8 |
| 137 | 20.8 | 37.5 | 44.2 | 36.4 | 16.4 | 10.3 | 9.2 | | | | | | 8.1 |
| 138 | | | | | | | | | | | | | |
| 139 | | | | | | | | | | | | | |
| 140 * | | | | | | | | | | | | | |
| 141 | 23.3 | 35.8 | 44.4 | 31.4 | 18.1 | 8.3 | 6.1 | 38.3 | 47.2 | 33.9 | 19.2 | 7.2 | 6.9 |
| 142 | 23 | 31.4 | 38.3 | 32.5 | 17.9 | 7.9 | 7.9 | 34.5 | 42.9 | 35.8 | 20.4 | 8.2 | 6.6 |
| 143 | 19.4 | 31.4 | 37.1 | 29.6 | 16.3 | 6.1 | 5.3 | 31.7 | 38.6 | 32.7 | 19.4 | 7.6 | 6.6 |
| 144 | 23 | 32.1 | 38.9 | 31.6 | 16.2 | 6.4 | 5.9 | 36.3 | 41.9 | 34.6 | 19 | 8.6 | 6.4 |
| 145 | | | | | | | | | | | | | |
| 146 | 19.5 | 28 | 34.3 | 27 | 15.7 | 7.9 | 6.4 | 29.3 | 35.3 | 30.3 | 19 | 11.2 | 8.9 |
| 147 | 18.9 | 34.6 | 38.1 | 30.2 | 17 | 8.6 | 7 | 33.2 | 38.4 | 31.8 | 14.9 | 11.2 | 10.3 |
| 148 | 20.1 | 29.5 | 36.3 | 28.5 | 16.3 | 10.5 | 7.4 | 30.6 | 36.5 | 30.9 | 19.9 | 12.8 | 11 |
| 149 | 20.25 | 36.5 | 41.3 | 33.8 | 20.8 | 8.3 | 7.8 | 35.3 | 42.3 | 36.3 | 23.3 | 10.5 | 9.8 |
| 150 | 18 | 31.8 | 39.3 | 32 | 19 | 10.3 | 9 | 28.3 | 37.8 | 32.3 | 21.5 | 11.5 | 9.5 |
| 151 | 22.7 | 35.3 | 38.4 | 39.1 | 27 | 14.2 | 9.6 | 32.8 | 37.6 | 31.3 | 20 | 12.4 | 11.2 |
| 153 | | | | | | | | | | | | | |
| 154 | 21.7 | 31.6 | 39.4 | 32.3 | 19.7 | 9.9 | 9.6 | 31.3 | | | | | |
| 155 * | | | | | | | | | | | | | |
| 156 | | | | | | | | | | | | | |
| 157 | 22.9 | 32.6 | 37.4 | 29.8 | 16.2 | 8.5 | 8.5 | 30.5 | 35.4 | 29.8 | 19 | 11.1 | 10.8 |
| 158 | | | | | | | | | | | | | |
| 159 | 22.9 | 32.1 | 37.4 | 31.3 | 18.5 | 9.1 | 7.3 | 30 | 36.9 | 30.5 | 18.8 | 9.6 | 9.1 |
| 160 | | | | | | | | | | | | | |
| 161 | 21.9 | 30.6 | 34 | 30.6 | 19.5 | 9.1 | 9.1 | 33.5 | 38 | 33.7 | 22.8 | 9.8 | 9.5 |
| 162 | | | | | | | | | | | | | |
| | 21.2 | 31.4 | 35.6 | 31.4 | 18.6 | 10 | 8.6 | 32.3 | 37.5 | 32.1 | 19.5 | 10.5 | 10.5 |
| 164 | | | | | | | | | | | | | |
| 165 | | 31.6 | 34.4 | 30.4 | 17.9 | 9.5 | 8 | 31.4 | 36.1 | 29.4 | 19.2 | 10.7 | 10.2 |
| 166 | | | | | | | | | | | | | |
| 167 | | | | | | | | | | | | | |
| 168 | 19.7 | 27.7 | 33.1 | 27.7 | 17.7 | 10.4 | 10.2 | 27.2 | 32.4 | 26.2 | 18.7 | 11.2 | 10.9 |
| 169 | | | | | | | | | | | | | |
| 170 | 22.2 | 34.9 | 40 | 35.7 | 22.5 | 12.6 | 11.2 | 37.4 | 41.3 | 37.1 | 25.3 | 10.9 | 10.9 |
| 171 | | 33.00 | 41.00 | 35.50 | 21.40 | 12.90 | 11.80 | 36.00 | 42.6 | 35.5 | 20.6 | 12.9 | 12.9 |
| 172 * | 25.00 | 31.60 | 39.50 | 36.80 | 22.80 | 11.00 | 9.90 | 37.60 | 41.6 | 37.1 | 23.1 | 10.4 | 10.2 |
| 173 | | | | | | | | | | | | | |

# A2.16

PHOSPHATES (mg/l)

| DAY # | Influent | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 174 | | | | | | | | | | | | | |
| 175 | 23.9 | 31.8 | 41.8 | 33.4 | 22.1 | 10.4 | 9.9 | 38.9 | 42.6 | 36.8 | 19.9 | 9.9 | 8.9 |
| 176 | 24.4 | 33.5 | 38.5 | 36.2 | 22.4 | 10.9 | 9.9 | 35.7 | 40.2 | 32.7 | 22.4 | 11.4 | 7.7 |
| 177 | | | | | | | | | | | | | |
| 178 | | 34 | 41.7 | 35.2 | 20.4 | 7.4 | 7.4 | 40 | 45.5 | 40.2 | 24.4 | 8.4 | 7.9 |
| 179 | 22.9 | 33.4 | 38.6 | 36.2 | 22.2 | 7.6 | 6 | 38.3 | 47.9 | 42.2 | 28.7 | 8.6 | 8.4 |
| 180 | | | | | | | | | | | | | |
| 181 | | | | | | | | | | | | | |
| 182 * | 22.9 | 34.9 | 40.1 | 34.9 | 21.9 | 9.4 | 9.4 | 38.3 | 45.3 | 38.8 | 25.5 | 10.4 | 10.4 |
| 183 | 15 | 29.3 | 33.6 | 26.6 | 16.5 | 8.2 | 8.2 | 28.1 | 34.1 | 30.1 | 19.3 | 9.2 | 9.2 |
| 184 | | | | | | | | | | | | | |
| 185 * | 19.5 | 27.4 | 33 | 28.9 | 17.8 | 14.6 | 6.7 | 27.2 | 33.7 | 26.7 | 15.6 | 14.9 | 6.4 |
| 186 | 22.1 | 29.6 | 35.9 | 30.3 | 19.2 | 12.7 | 9.8 | 24.8 | 34 | 28.6 | 17.1 | 10.5 | 7.6 |
| 187 | | | | | | | | | | | | | |
| 188 | 20.7 | 30.9 | 36.2 | 30.9 | 21.6 | 14.1 | 13.1 | 28.9 | 34.5 | 29.4 | 19.7 | 11.7 | 10.9 |
| 189 | 20.2 | 31.8 | 36.7 | 31.1 | 20.4 | 13.4 | 13.4 | 28.4 | 34.8 | 29.4 | 18.7 | 11.9 | 11.2 |
| 190 | 20.4 | 32.6 | 36.3 | 31.1 | 20.9 | 13.8 | 13.8 | 26.9 | 36.5 | 31.3 | 20.4 | 13.5 | 12 |
| 191 | 20.9 | 30.6 | 35 | 31.6 | 22.4 | 14.8 | 14.5 | 30.1 | 34.8 | 31.1 | 21.4 | 12.8 | 11.5 |
| 192 | 22.1 | 26.7 | 37.4 | 31.3 | 21.8 | 14.8 | 14.8 | 32.5 | 36.5 | 31.3 | 21.1 | 13.3 | 12.2 |
| 193 | 21.6 | 32.7 | 36.5 | 30.8 | 19.5 | 14.1 | 13.3 | 31.3 | 34.8 | 28.7 | 19.7 | 12.9 | 12.2 |
| 194 | | | | | | | | | | | | | |
| 195 | 20.6 | 27.6 | 32 | 27.6 | 17.8 | 10.8 | 10.8 | 26.9 | 31.3 | 26.2 | 17.6 | 11.7 | 11.5 |
| 196 | 21.5 | 31.7 | 35.5 | 28 | 19.4 | 12.2 | 12 | 31.3 | 35.9 | 27.1 | 19.2 | 12.7 | 10.6 |
| 197 | 20.2 | 31.1 | 33.9 | 30.2 | 20 | 13.3 | 12.3 | 32.5 | 36.6 | 30.2 | 19.5 | 12.8 | 12.8 |
| 198 * | 21.4 | 28.1 | 35.3 | 29.5 | 18.8 | 13 | 13 | 31.1 | 35.9 | 28.1 | 19.3 | 12.1 | 12.1 |
| 199 | 21 | 23.4 | 28.9 | 24.2 | 16.7 | 13 | 12.7 | 27.5 | 31.6 | 26.4 | 17.7 | 10.3 | 11.4 |
| 200 | 20.2 | 28.3 | 32.8 | 27.8 | 17.8 | 12.5 | 12.5 | 32.2 | 34.8 | 28.8 | 18.4 | 11.9 | 11.9 |
| 201 | | | | | | | | | | | | | |
| 202 | 20.6 | 24.3 | 29.4 | 24.9 | 16.5 | 11.4 | 11.4 | 25.9 | 30.2 | 26.2 | 15.9 | 11.1 | 10.7 |
| 203 | 19.9 | 29.600 | 33.500 | 28.500 | 18.200 | 13.000 | 12.000 | 30.800 | 33.700 | 28.600 | 17.700 | 11.600 | 10.500 |
| 204 | 19.6 | 30.2 | 34.7 | 30.1 | 19.1 | 12.2 | 12.2 | 31.5 | 34.5 | 30.1 | 18.4 | 11.4 | 11.4 |
| 205 | 19.7 | 28.7 | 34.7 | 28.5 | 17.7 | 12.3 | 12.2 | 31 | 24.9 | 28.5 | 17.1 | 11 | 11 |
| 206 | | 27.300 | 32.600 | 26.900 | 16.600 | 12.100 | 10.400 | 29.500 | 33.900 | 27.800 | 16.000 | 9.900 | 9.400 |
| 207 | 20.6 | 28.100 | 33.100 | 27.200 | 20.300 | 10.100 | | 30.3 | 33.500 | 27.2 | 15.5 | 9.400 | 9.300 |
| 210 * | 21.5 | 28.4 | 31.2 | 29.4 | 19.7 | 14.2 | 14.2 | 28.1 | 30.5 | 27.9 | 17.2 | 12.1 | 12.1 |
| 211 | 20 | 29 | 31.4 | 28.3 | 17.8 | 10 | 10 | 29.2 | 31.7 | 27.6 | 15.4 | 7.9 | 7.9 |
| 212 | 17.2 | 26.8 | 30.7 | 28.5 | 17.6 | 9.2 | 9.4 | 27.5 | 30.3 | 26.5 | 15.9 | 7.8 | 7.3 |
| 213 | 15.2 | 23.9 | 29.7 | 26.6 | 15 | 7.1 | 6.5 | 22.8 | 23.7 | 23.8 | 14.3 | 5.8 | 5.7 |
| 214 | 15.9 | 26.9 | 30.5 | 26.1 | 13.5 | 6.7 | 4.8 | 24.5 | 29 | 24.1 | 14 | 6.7 | 4.7 |
| 216 | 19.3 | 25.3 | 32.9 | 27.9 | 15.6 | 7.5 | 5.9 | 27.1 | 31 | 23 | 15.4 | 6.9 | 6.3 |
| 217 | 18.4 | 30.5 | 35.5 | 28.9 | 16.2 | 7.6 | 6.2 | 29.4 | 31.8 | 30.2 | 16.9 | 9.4 | 7.2 |
| 218 | 20.20 | 30.30 | 37.30 | 33.40 | 17.80 | 9.10 | 7.50 | 31.50 | 32.70 | 34.30 | 20.10 | 9.20 | 8.80 |
| 219 | 21.5 | 28.9 | 27.5 | 34.5 | 18.6 | 10.2 | 9.7 | 32.7 | 35.1 | 34.3 | 19.9 | 10.1 | 9.26 |
| 220 | 21 | 31.900 | 38.200 | 33.800 | 18.700 | 10.900 | 9.900 | 30.200 | 36.100 | 34.500 | 19.700 | 8.900 | 7.800 |
| 221 | 18.1 | 30.6 | 34.2 | 32.4 | 17.2 | 9.5 | 8.7 | 30.4 | 33 | 32 | 17.5 | 9.5 | 8 |
| 223 | 18.1 | 22.300 | 27.100 | 23.400 | 14.200 | 8.500 | 8.800 | 25.100 | 29.600 | 25.400 | 15.300 | 7.700 | 7.700 |
| 224 * | 19.1 | 26.000 | 32.500 | 27.000 | 14.200 | 8.400 | 8.200 | 26.8 | 29.600 | | 14.2 | 7.800 | 7.500 |
| 225 | 17.9 | 22.5 | 31.1 | 26 | 14.5 | 8.8 | 8.2 | 25.6 | 31 | 25 | 14.5 | 8.1 | 7.1 |
| 226 | 21.9 | 29.2 | 33.5 | 28.2 | 15.4 | 9.2 | 9.2 | 30.7 | 33 | 28.2 | 15.7 | 9.2 | 8.1 |
| 227 | 21 | 29.5 | 35 | 29.5 | 15.8 | 8.9 | 8.9 | 27.3 | 32.8 | 29.6 | 17.2 | 9.5 | 8.8 |
| 228 | 19.7 | 29.5 | 34.8 | 30.4 | 14.9 | 8.7 | 8.3 | 27.8 | 32 | 29.7 | 17.5 | 8.8 | 8.4 |

# A2.17

PHOSPHATES (mg/l)

| DAY # | Influent | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 229 | | | | | | | | | | | | | |
| 230 | 19.7 | 30 | 35.7 | 31.5 | 16.1 | 9.6 | 9.6 | 26.1 | 31.9 | 28.7 | 17 | 10.3 | 8.6 |
| 231 | 20.2 | 28.3 | 35.5 | 29.6 | 16.4 | 8.9 | 8.5 | 26.4 | 31.9 | 26.7 | 16 | 8.2 | 8.2 |
| 232 | 21.1 | 28.8 | 35 | 28.7 | 14.5 | 8.2 | 8.2 | 28.2 | 32.9 | 28.1 | 15.7 | 9 | 8.5 |
| 233 | 18.9 | 30.8 | 34.5 | 27.3 | 14.3 | 8.5 | 8.3 | 26.3 | 33.9 | 28.6 | 16.6 | 8.8 | 8.3 |
| 234 * | 19.5 | 27.6 | 33 | 27.4 | | 8.3 | 8.1 | 27.3 | 31.8 | 26.2 | 15.2 | 8.1 | 7.9 |
| 235 | 20.5 | 30.4 | 35.2 | 28.2 | 15.5 | 9.9 | 8.6 | 28.8 | 33.2 | 26.4 | 15.8 | 9.2 | 9 |
| 236 | 20 | 25.7 | 30 | 24.1 | 16.2 | 12.2 | 9 | 25.7 | 32.3 | 23.4 | 15.1 | 11 | 9.2 |
| 237 | 19.4 | 31.8 | 36.5 | 26.6 | 15.5 | 12.6 | 12.1 | 29.4 | 35.3 | 27.5 | 16.4 | 11.7 | 11.1 |
| 238 | 21.6 | 28.2 | 31.7 | 30.3 | 18 | 12.8 | 12.8 | 31.8 | 35.3 | 28.2 | 17.2 | 12.5 | 10.2 |
| 239 | 24 | 47.7 | 58.8 | 48.7 | 26.5 | 17.1 | 17.1 | 45.6 | 56.1 | 46.7 | 27 | 15.7 | 15.7 |
| 240 | 28.6 | 47.3 | 57.7 | 41.9 | 25.9 | 17.3 | 16.7 | 37 | 56.1 | 41.9 | 24.1 | 14 | 14 |
| 241 | 23 | 28.4 | 35.1 | 26.7 | 15.7 | 10.8 | 10.6 | 29.8 | 32.3 | 27.2 | 16 | 11.8 | 10.4 |
| 242 | 20.8 | 27.8 | 33.4 | 27.9 | 16.2 | 11.9 | 11.6 | 28.7 | 34.2 | 27.3 | 15.1 | 9.8 | 9.8 |
| 243 | 24.7 | 31.4 | 35.5 | 30.7 | 17 | 10.8 | 10.8 | | 37.6 | 30.7 | 16.6 | 10.5 | 10.5 |
| 245 | 20.7 | 26.9 | 30.5 | 27.2 | 14.2 | 9.7 | 8.6 | 25.6 | 32.3 | 25 | 15.1 | 8.7 | 8.4 |
| 247 * | 25 | 35.3 | 41.7 | 31.2 | 17.7 | 9.3 | 9.3 | 35.7 | 40.7 | 32.4 | 17.3 | 11.9 | 10.1 |
| 249 | 26.7 | 33.5 | 37.6 | 33.1 | 18 | 11.6 | 10.7 | 37 | 42.7 | 32.1 | 18.3 | 11 | 10 |
| 250 | 23.7 | 36.9 | 44.2 | 36.5 | 18.1 | 9.7 | 9.7 | 36.3 | 43.4 | 34.6 | 18.8 | 9.5 | 9.5 |
| 251 | 26.6 | 37.4 | 45.1 | 37.2 | 18.6 | 11.9 | 11.8 | 37 | 41 | 36.1 | 19.4 | 12.8 | 11.1 |
| 252 | 26.2 | 42 | 48.5 | 41 | 19.8 | 11 | 10.3 | 37.4 | 46 | 38.6 | 20.7 | 11.9 | 11.1 |
| 254 | 25.1 | 35.1 | 45.9 | 36.6 | 17.6 | 10.1 | 10 | 36.3 | 44.5 | 35.9 | 17.7 | 8.3 | 8.3 |
| 256 * | 26.4 | 43.9 | 53.1 | 41.6 | 16.8 | 10.4 | 9.5 | 37 | 45.9 | 36.3 | 18.5 | 10 | 10 |
| 257 | 21 | 36.7 | 46.8 | 38.1 | 17.9 | 9.3 | 8.8 | 39.8 | 42.9 | 35.5 | 17.5 | 10.3 | 9 |
| 258 | 22.9 | 36.3 | 48.3 | 38.3 | 17.7 | 9.7 | 9.1 | 32.7 | 42.5 | 33.4 | 16.8 | 9.5 | 8.3 |
| 259 | 22.4 | 36.5 | 46.7 | 38.1 | 17.2 | 10 | 8.9 | 37.3 | 42.2 | 32.7 | 16.3 | 10.3 | 8.9 |
| 260 | 23.6 | 41.9 | 49.6 | 42.5 | 18.6 | 10.1 | 9.3 | 35.4 | 43.3 | 33.9 | 16.7 | 10 | 9 |
| 261 | 24.3 | 30.9 | 40.9 | 33.2 | 16.8 | 9.8 | 9.5 | 34.4 | 40.3 | 31.5 | 16.7 | 10 | 9.3 |
| 263 | 22.2 | 28.7 | 37.4 | 29.2 | 15 | 10 | 9.2 | 28.4 | 37.2 | 27.5 | 14.7 | 9.7 | 9.2 |
| 264 | | 27.4 | 33.1 | 26.7 | 14.7 | 10.9 | 9.9 | 31.1 | 37 | 25.8 | 15.5 | 10.7 | 9.1 |
| 265 | 19.6 | 30.7 | 38.4 | 28.9 | 14.7 | 11 | 10 | 27 | 34.8 | 26.7 | 15.7 | 9.8 | 9.7 |
| 266 | | 25.7 | 32.6 | 24.8 | 15 | 12.1 | 11.1 | 27.2 | 32.5 | 24.2 | 24.6 | 11.4 | 11 |
| 267 | 18.7 | 27.7 | 35.7 | 26.7 | 16.8 | 12.8 | 11.7 | 31.4 | 38 | 28.1 | 17.1 | 12.4 | 12.4 |
| 270 * | 20.6 | 27.2 | 29.6 | 20.4 | 15.4 | 13.6 | 13.6 | 23.4 | 29.4 | 25.2 | 16.4 | 12.1 | 12.1 |
| 271 | 21.6 | 30 | 36.6 | 31 | 16.1 | 12.2 | 12.2 | 31.3 | 35.1 | 31.4 | 17.4 | 12.5 | 11.9 |
| 272 | 18.9 | 32.2 | 39.3 | 32.5 | 16 | 11.5 | 11.5 | 29.2 | 36 | 31.6 | 17 | 11.5 | 11.5 |
| 275 | 21.4 | 31.6 | 38.5 | 32.3 | 16.5 | 11 | 10.9 | 30.1 | 38.2 | 31.7 | 18.2 | 11.3 | 11.3 |
| 276 | 20.2 | 30.4 | 34 | 27.2 | 14.7 | 10.7 | 10.2 | 29.4 | 33 | 25.6 | 15.8 | 11.1 | 10.5 |
| 277 | 20.2 | 31.2 | 35.9 | 30.7 | 15.9 | 10.4 | 10 | 30.9 | 35.6 | 28.7 | 16.2 | 11.1 | 10 |
| 279 | 20.2 | 30.4 | 34 | 27.2 | 14.7 | 10.7 | 10.2 | 29.4 | 33 | 25.6 | 15.8 | 11.1 | 10.5 |
| 280 | 20.2 | 31.2 | 35.9 | 30.7 | 15.9 | 10.4 | 10 | 30.9 | 35.6 | 28.7 | 16.2 | 11.1 | 10 |
| 281 | 20.6 | 22.2 | 29.8 | 25.4 | 15.4 | 11.3 | 10.7 | 26.5 | 30.2 | 26.5 | 16.2 | 13.6 | 11.5 |
| 288 | 20.6 | 28 | 33.3 | 28.6 | 14.8 | 9.5 | 10.1 | | 31.6 | 30.1 | 14.4 | 5.6 | 6.5 |
| 289 | 20.4 | | | | | | | 27.8 | 31.7 | 28.9 | 13.6 | 6.2 | 5 |

# A2.18

## PHOSPHATES (mg/l)

| DAY # | P-rem C | P-rem E | DAY # | P-rem C | P-rem E | DAY # | P-rem C | P-rem E | DAY # | P-rem C | P-rem E | DAY # | P-rem C | P-rem E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.8 | 4.4 | 64 | 16 | 17 | 120 | 11.1 | 12.7 | 174 | | | 229 | | |
| 2 | 1 | 0 | 65 | 10.6 | 14 | 121 | 12.9 | 16.7 | 175 | 14 | 15 | 230 | 10.1 | 11.1 |
| 3 | 5.9 | 0.6 | 68 | 9 | 11.9 | 122 | 14.2 | 15.8 | 176 | 14.5 | 16.7 | 231 | 11.7 | 12 |
| 5 | 7.2 | 5.6 | 69 | 13.8 | 14.6 | 123 | | | 177 | | | 232 | 12.9 | 12.6 |
| 6 | 6.6 | 7.3 | 70 * | 12.4 | 11.8 | 124 | | | 178 | 17 | 16.5 | 233 | 10.6 | 10.6 |
| 7 * | 7 | 9.9 | 71 | 11.8 | 13.5 | 125 | 16.8 | 16.3 | 179 | 16.9 | 14.5 | 234 * | 11.4 | 11.6 |
| 8 | 11.4 | 12.7 | 72 | 13.25 | 14.23 | 126 | | | 180 | | | 235 | 11.9 | 11.5 |
| 9 | 12.4 | 10.7 | 74 | 13 | 15.25 | 127 | 14.3 | 14.8 | 181 | | | 236 | 11 | 10.8 |
| 10 | 11.9 | 10.4 | 75 | 10 | 11.75 | 128 | 10.3 | 10.1 | 182 * | 13.5 | 12.5 | 237 | 7.3 | 8.3 |
| 12 | 15.1 | 15.7 | 76 | 11.5 | 12 | 129 | | | 183 | 6.8 | 5.8 | 238 | 8.8 | 11.4 |
| 13 | 16.1 | 17 | 77 | 14.3 | 14.9 | 130 * | 18.1 | 18.6 | 184 | | | 239 | 6.9 | 8.3 |
| 14 | 15.7 | 16 | 78 | 10.77 | 12.31 | 131 | | | | | | 240 | 11.9 | 14.6 |
| 15 | 15 | 15.3 | 79 | 12.14 | 13.57 | 132 | 18.1 | 17.8 | | | | 241 | 12.4 | 12.6 |
| 16 | 15 | 15.3 | 80 | 12.68 | 14.88 | 133 | 15.8 | 16.1 | 185 * | 12.8 | 13.1 | 242 | 9.2 | 11 |
| 17 | 13.5 | 18.5 | 81 * | 12.86 | 13.57 | 134 | 15.6 | 16.8 | 186 | 12.3 | 14.5 | 243 | 13.9 | 14.2 |
| 19 | 15 | 16.9 | 82 | 16.15 | 16.41 | 135 | 15 | 16.5 | 187 | | | | | |
| 20 | 16.5 | 15.8 | 83 | 14 | 14.5 | 136 | 13.3 | 15 | 188 | 7.6 | 9.8 | | | |
| 21 | 15.3 | 15.3 | 84 | 12.25 | 15.5 | 137 | 11.6 | 12.7 | 189 | 6.8 | 9 | 245 | 12.1 | 12.3 |
| 22 * | 15.4 | 15.4 | 85 | 12.89 | 15.37 | 138 | | | 190 | 6.6 | 8.4 | 247 * | 15.7 | 14.9 |
| 23 | 13.8 | 13.8 | 86 | 12.86 | 13.81 | 139 | | | 191 | 6.4 | 9.4 | 249 | 16 | 16.7 |
| 25 | 18.3 | 18.3 | 87 | 14.09 | 15 | 140 * | | | 192 | 7.3 | 9.9 | 250 | 14 | 14.2 |
| 26 | 19.6 | 21 | 88 | 13.97 | 14.21 | 141 | 17.2 | 16.4 | 193 | 8.3 | 9.4 | 251 | 14.8 | 15.5 |
| 27 | 18.6 | 17.9 | 89 | 12.62 | 14.05 | 142 | 15.1 | 16.4 | 194 | | | 252 | 15.9 | 15.1 |
| 28 | 15.7 | 16.7 | 90 | 14.15 | 14.15 | 143 | 14.1 | 12.8 | 195 | 9.8 | 9.1 | 254 | 15.1 | 16.8 |
| 29 | 12.5 | 14.1 | 91 | 14.65 | 15.85 | 144 | 17.1 | 16.6 | 196 | 9.5 | 10.9 | 256 * | 16.9 | 16.4 |
| 30 | 12.5 | 13.2 | 92 | 16 | 16.9 | 145 | | | 197 | 7.9 | 7.4 | 257 | 12.2 | 12 |
| 31 | 13.8 | 14.5 | 93 | 15.8 | 16.9 | 146 | 13.1 | 10.6 | 198 * | 8.4 | 9.3 | 258 | 13.8 | 14.6 |
| 33 | 12.8 | 12.8 | 94 * | 0.66 | 11.65 | 147 | 11.9 | 8.6 | 199 | 8.3 | 9.6 | 259 | 13.5 | 13.5 |
| 34 | 7.8 | 13.7 | 95 | 12.3 | 14.2 | 148 | 12.7 | 9.1 | 200 | 7.7 | 8.3 | 260 | 14.3 | 14.6 |
| 37 * | | | 96 | 10.3 | 12.2 | 149 | 12.45 | 10.45 | 201 | | | 261 | 14.8 | 15 |
| 38 | 3.9 | 4.7 | 97 | 10 | 11.7 | 150 | 9 | 8.5 | 202 | 9.2 | 9.9 | 263 | 13 | 13 |
| 40 | 6.8 | 12.1 | 98 | 9.2 | 11.4 | 151 | 13.1 | 11.5 | 203 | 7.9 | 9.4 | 264 | | |
| 41 | 13.5 | 13.2 | 99 | 9.6 | 10.3 | 153 | | | 204 | 7.4 | 8.2 | 265 | 9.6 | 9.9 |
| 42 | 14.9 | 14.9 | 100 | 11.4 | 13.1 | 154 | 12.1 | | 205 | 7.5 | 8.7 | 266 | | |
| 43 | 10.7 | 12.6 | 101 | 12.7 | 13.4 | 155 * | | | 206 | | | 267 | 7 | 6.3 |
| 44 | 15.3 | 13.7 | 102 | 11.3 | 12.8 | 156 | | | 207 | 20.6 | 11.3 | 270 * | 7 | 8.5 |
| | | | | | | 157 | 14.4 | 12.1 | 210 * | 7.3 | 9.4 | 271 | 9.4 | 9.7 |
| | | | | | | 158 | | | 211 | 10 | 12.1 | 272 | 7.4 | 7.4 |
| 45 * | 13.3 | 13.3 | 105 * | 11.3 | 12.8 | 159 | 15.6 | 13.8 | 212 | 7.8 | 9.9 | 275 | 10.5 | 10.1 |
| 47 | 9.6 | 10.7 | 106 | 12.1 | 12.6 | 160 | | | 213 | 8.7 | 9.5 | 276 | 10 | 9.7 |
| 48 | 13.3 | 13.7 | 107 | 12.1 | 13.5 | 161 | 12.8 | 12.4 | 214 | 11.1 | 11.2 | 277 | 10.2 | 10.2 |
| 49 | 12.1 | 11.4 | 108 | 13.6 | 15.6 | 162 | | | 216 | 13.4 | 13 | 279 | 10 | 9.7 |
| 50 | 14.9 | 13.7 | 109 | 13.2 | 15.5 | | 12.6 | 10.7 | 217 | 12.2 | 11.2 | 280 | 10.2 | 10.2 |
| 51 | 17.2 | 15.3 | 110 | | | 164 | | | 218 | 12.7 | 11.4 | 281 | 9.9 | 9.1 |
| 52 | 12.4 | 12.6 | 111 | 12.7 | 15.2 | 165 | 13.2 | 11 | 219 | 11.8 | 12.24 | 288 | 10.5 | 14.1 |
| 55 * | 9.3 | 11.4 | 112 | 9.8 | 10.1 | 166 | | | 220 | 11.1 | 13.2 | 289 | 20.4 | 15.4 |
| 56 | 5.1 | 13.8 | 113 | 10.3 | 9.8 | 167 | | | 221 | 9.4 | 10.1 | | | |
| 57 | 16.7 | 17.8 | 114 | | | 168 | 9.5 | 8.8 | 223 | 9.3 | 10.4 | | | |
| 58 | 14 | 15.8 | 115 | 11.8875 | 13.1375 | 169 | | | 224 * | 10.9 | 11.6 | | | |
| 59 | 14.9 | 14.9 | 116 | | | 170 | 11 | 11.3 | 225 | 9.7 | 10.8 | | | |
| 61 | 12 | 14.2 | 117 * | 8.7 | 13.5 | 171 | 10.4 | 9.3 | 226 | 12.7 | 13.8 | | | |
| 62 | 11.8 | 13 | 118 | 11.7 | 13.2 | 172 * | 15.1 | 14.8 | 227 | 12.1 | 12.2 | | | |
| 63 | 9.5 | 11 | 119 | | | 173 | | | 228 | 11.4 | 11.3 | | | |

NITRATE (mg/1)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.08 | 0.294 | 0.187 | 0.201 | 5.656 | 5.862 | 0.146 | 0.193 | 0.183 | 0.145 | 5.441 | 3.971 |
| 2 | 0.678 | 0.177 | 0.176 | 0.163 | 12.36 | 17.02 | 0.336 | 0.217 | 0.191 | 0.175 | 9.804 | 12.515 |
| 3 | 2.249 | 0.138 | 0.154 | 0.46 | 10.983 | 11.857 | 0.864 | 0.153 | 0.148 | 0.186 | 8.174 | 13.905 |
| 5 | 0.338 | 0.15 | 0.154 | 0.4 | 6.238 | 9.332 | 0.302 | 0.141 | 0.135 | 0.173 | 4.763 | 8.037 |
| 6 | 0.353 | 0.178 | 0.181 | 0.421 | 4.822 | 6.192 | 0.247 | 0.167 | 0.162 | 0.171 | 4.622 | 6.017 |
| 7 * | 0.179 | 0.167 | 0.193 | 0.483 | 5.654 | 5.503 | 0.197 | 0.172 | 0.159 | 0.221 | 5.188 | 5.467 |
| 8 | 1.268 | 0.101 | 0.137 | 0.589 | 13.008 | 14.918 | 0.613 | 0.124 | 0.15 | 0.504 | 12.892 | 15.871 |
| 9 | 0.329 | 0.132 | 0.175 | 0.685 | 8.398 | 11.14 | 0.313 | 0.082 | 0.122 | 0.088 | 7.075 | 7.583 |
| 10 | 0.238 | 0.104 | 0.188 | 0.738 | 6.933 | 7.14 | 0.238 | 0.197 | 0.187 | 0.204 | 8.269 | 8.678 |
| 12 | 0.255 | 0.15 | 0.577 | 0.922 | 8.007 | 7.516 | 0.24 | 0.175 | 0.391 | 0.303 | 8.077 | 8.355 |
| 13 | 0.663 | 0.121 | 0.175 | 0.144 | 6.573 | 7.209 | 0.388 | 0.111 | 0.175 | 0.137 | 8.573 | 8.647 |
| 14 | 0.107 | 0.049 | 0.385 | 0.947 | 7.85 | 7.798 | 0.14 | 0.087 | 0.244 | 0.225 | 9.433 | 8.881 |
| 15 | 0.705 | 0.091 | 0.156 | 0.525 | 4.255 | 9.04 | 0.537 | 0.033 | 0.079 | 0.119 | 3.978 | 13.04 |
| 16 | 0.218 | 0.039 | 0.103 | 0.844 | 4.255 | 9.04 | 0.154 | 0.02 | 0.102 | 0.616 | 3.904 | 10.1 |
| 17 |  | 0.038 | 0.043 | 0.105 | 3.987 | 8.79 |  | 0.024 | 0.024 | 0.043 | 4.135 | 9.24 |
| 19 | 0.073 | 0.017 | 0.024 | 0.033 | 4.117 | 7.77 | 0.051 | 0.032 | 0.033 | 0 | 5.23 | 8.983 |
| 20 | 0.104 | 0.059 | 0.018 | 0.014 | 4.08 | 8.173 | 0.061 | 0 | 0.036 | 0.342 | 4.16 | 9.132 |
| 21 | 0.068 | 0.053 | 0.008 | 0.003 | 4.083 | 8.466 | 0.038 | 0.003 | 0.014 | 0.806 | 5.582 | 9.113 |
| 22 * | 0.06 | 0.049 | 0.011 | 0.058 | 6.148 | 9.055 | 0.019 | 0.032 | 0.03 | 0.007 | 6.407 | 8.862 |
| 23 | 0.304 | 0.134 | 0.048 | 0.292 | 3.294 | 6.319 | 0.125 | 0.118 | 0.065 | 0.086 | 3.184 | 7.161 |
| 25 | 0.056 | 0.0807 | 0.036 | 0.38 | 3.569 | 7.641 | 0.049 | 0.063 | 0.036 | 0.094 | 3.227 | 8.328 |
| 26 | 0.168 | 0.047 | 0.459 | 0.058 | 1.577 | 7.694 | 0.116 | 0.083 | 0.199 | 0.043 | 3.422 | 7.964 |
| 27 | 0.097 | 0.057 | 0.075 | 0.365 | 3.735 | 7.889 | 0.088 | 0.041 | 0.065 | 0.428 | 3.422 | 5.429 |
| 28 | 0.053 | 0.026 | 0.035 | 0.396 | 3.643 | 8.441 | 0.036 | 0.001 | 0.044 | 0.392 | 4.183 | 7.66 |
| 29 | 0.054 | 0.034 | 0.061 | 0.395 | 4.374 | 8.694 | 0.015 | 0.032 | 0.06 | 0.338 | 4.3085 | 4.471 |
| 30 | 0.047 | 0.039 | 0.045 | 0.37 | 4.752 | 7.945 | 0.065 | 0.074 | 0.06 | 0.357 | 4.106 | 7.352 |
| 31 | 0.029 | 0.069 | 0.02 | 0.082 | 5.345 | 8.054 | 0.022 | 0.049 | 0.018 | 0.049 | 5.392 | 7.271 |
| 33 | 0.003 | 0.026 | 0.012 | 0.316 | 6.344 | 8.601 | 0.006 | 0.013 | 0.026 | 0.274 | 5.331 | 8.324 |
| 34 |  |  |  |  |  |  |  |  |  |  |  |  |
| 37 * |  |  |  |  |  |  |  |  |  |  |  |  |
| 38 | 2.7 | 0.174 | 0.077 | 0.076 | 3.508 | 9.993 | 0.837 | 0.144 | 0.1 | 0.016 | -0.647 | 1.482 |
| 40 | 0.327 | 0.136 | 0.146 | 0.456 | 0.866 | 2.484 | 0.222 | 0.149 | 0.144 | 0.165 | -0.261 | 0.797 |
| 41 | 0.187 | 0.124 | 0.1 | 0 | 0.486 | 0.947 | 0.188 | 0.157 | 0.151 | 0.083 | 1.284 | 1.41 |
| 42 | 0.083 | 0.077 | 0.057 | 0 | 0.92 | 1.088 | 0.106 | 0.115 | 0.09 | 0 | 1.804 | 2.226 |
| 43 | 0.11 | 0.086 | 0.154 | 0.041 | 2.495 | 4.178 | 0.137 | 0.055 | 0.071 | 0.028 | 1.99 | 1.107 |
| 44 | 0.075 | 0.1 | 0.116 | 0.459 | 3.258 | 3.129 | 0.083 | 0.093 | 0.091 | 0.353 | 2.845 | 2.425 |
| 45 * | 1.41 | 0.098 | 0.085 | 0.083 | 6.289 | 10.572 | 0.809 | 0.149 | 0.107 | 0.093 | 7.389 | 9.472 |
| 47 | 0.275 | 0.123 | 0.103 | 0.09 | 6.218 | 8.851 | 0.369 | 0.114 | 0.092 | 0.079 | 4.576 | 8.01 |
| 48 | 0.081 | 0.125 | 0.094 | 0.117 | 4.086 | 7.294 | 0.227 | 0.132 | 0.104 | 0.082 | 3.994 | 5.247 |
| 49 | 0.246 | 0.196 | 0.194 | 0.546 | 5.841 | 5.224 | 0.233 | 0.174 | 0.209 | 0.651 | 5.528 | 5.961 |
| 50 | 0.209 | 0.182 | 0.166 | 0.535 | 5.344 | 5.685 | 0.254 | 0.219 | 0.439 | 0.753 | 5.817 | 6.974 |
| 51 | 0.204 | 0.191 | 0.186 | 0.277 | 5.8 | 5.921 | 0.177 | 0.182 | 0.136 | 0.053 | 6.371 | 6.618 |
| 52 | 0.238 | 0.112 | 0.127 | 0.547 | 5.365 | 5.202 | 0.091 | 0.09 | 0.124 | 0.852 | 10.285 | 11.947 |
| 55 * | 0.186 | 0.148 | 0.143 | 0.668 | 7.652 | 9.852 | 0.066 | 0.104 | 0.12 | 0.672 | 9.046 | 6.861 |
| 56 | 0.088 | 0.057 | 0.092 | 0.626 | 9.796 | 7.153 | 0.1 | 0.103 | 0.076 | 0.647 | 7.154 | 1.388 |
| 57 | 0.433 | 0.089 | 0.03 | 0 | 4.1853 | 7.163 | 0.323 | 0.147 | 0.066 | 0.042 | 4.725 | 6.076 |
| 58 | 0.3415 | 0.165 | 0.167 | 0.567 | 5.971 | 6.229 | 0.389 | 0.195 | 0.309 | 0.687 | 5.506 | 6.076 |
| 59 | 0.176 | 0.19 | 0.179 | 0.42 | 13.304 | 15.148 | 0.358 | 0.243 | 0.119 | 0.121 | 7.92 | 11.733 |
| 61 | 0.196 | 0.122 | 0.075 | 0.062 | 6.258 | 10.078 | 0.198 | 0.152 | 0.081 | 0.079 | 7.127 | 10.032 |
| 62 | 0.149 | 0.13 | 0.08 | 0.079 | 6.383 | 7.667 | 0.233 | 0.154 | 0.154 | 0.128 | 7.336 | 8.855 |
| 63 | 0.188 | 0.138 | 0.134 | 0.107 | 6.109 | 6.909 | 0.183 | 0.154 | 0.154 | 0.145 | 7.283 | 7.944 |

NITRATE (mg/l)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | -0.045 | 0.102 | 0.163 | 0.724 | 7.204 | 8.998 | 0.147 | 0.065 | 0.213 | 0.998 | 7.469 | 7.566 |
| 65 | 0.193 | 0.066 | 0.06 | 0.497 | 6.864 | 7.481 | 0.293 | 0.08 | 0.169 | 1.013 | 6.789 | 8.934 |
| 68 | 0.562 | 0.153 | 0.167 | 0.808 | 8.097 | 8.632 | 0.113 | 0.032 | 0.077 | 0.573 | 4.824 | 6.826 |
| 69 | 0.028 | 0.012 | -0.015 | 0.107 | 5.544 | 6.036 | 0.034 | 0.107 | -0.01 | 0 | 5.917 | 6.985 |
| 70 * | 0.075 | 0.075 | 0.03 | 0 | 19.75 | 20.2 | -0.08 | 0.045 | 0.091 | 0.425 | 12.2 | 18.15 |
| 71 | 0.18 | 0.5 | 0.12 | 0.85 | 24.8 | 24.8 | 0.7 | 0.18 | 0.07 | 2.45 | 18.8 | 24.2 |
| 72 | 0.15 | 0.18 | 0.38 | 3.8 | 26.8 | 23.4 | 2.1 | 0.26 | 0.16 | 5.075 | 19.4 | 26.8 |
| 74 | 0.1 | 0.16 | 0.43 | 5.35 | 28.6 | 28.4 | 0.44 | 0.22 | 0.78 | 5.05 | 23 | 28.4 |
| 75 | 0.12 | 0.12 | 0.35 | 5.4 | 28 | 25.4 | 0.32 | 0.21 | 0.62 | 5.4 | 27.2 | 31 |
| 76 | 0.18 | 0.21 | 0.41 | 7.6 | 33.4 | 32 | 0.25 | 0.25 | 0.82 | 6.15 | 29 | 32.4 |
| 77 | 0.26 | 0.25 | 2.8 | 0.5 | 38 | 32.2 | 0.26 | 0.35 | 0.96 | 6.8 | 16.4 | 28 |
| 78 | 0.14 | 0.2 | 0.65 | 4.5 | 25 | 34.2 | 0.38 | 0.41 | 0.95 | 5.7 | 18.8 | 32.2 |
| 79 | 0.16 | 0.18 | 0.74 | 6.15 | 22 | 35 | 0.4 | 0.43 | 0.96 | 5.1 | 17 | 31.6 |
| 80 | | | | | | | | | | | | |
| 81 * | 0.14 | 0.1 | 0.3 | 3.5 | 28.2 | 36.6 | 0.21 | 0.21 | 0.87 | 3.75 | 15.8 | 33.2 |
| 82 | 0.07 | 0.09 | 0.16 | 1.8 | 18 | 19.2 | 0.28 | 0.1 | 0.21 | 1.3 | 10.8 | 22.2 |
| 83 | 0.09 | 0.1 | 0.16 | 1.5 | 16.8 | 14.8 | 0.21 | 0.15 | 0.18 | 1 | 10.6 | 17.6 |
| 84 | 0.561 | 0.28 | 0.223 | 0.696 | 12.175 | 15.832 | 0.459 | 0.365 | 0.361 | 0.808 | 9.78 | 14.542 |
| 85 | 0.564 | 0.401 | 0.326 | 0.891 | 8.957 | 13.471 | 0.677 | 0.23 | 0.243 | 0.839 | 7.704 | 9.034 |
| 86 | 0.912 | 0.541 | 0.439 | 1.013 | 7.818 | 9.689 | 0.251 | 0.235 | 0.311 | 1.037 | 8.445 | 10.105 |
| 87 | 0.223 | 0.564 | 0.338 | 1.044 | 8.483 | 9.196 | 0.505 | 0.413 | 0.277 | 1.15 | 9.014 | 9.427 |
| 88 | 0.192 | 0.312 | 0.448 | 1.254 | 9.932 | 9.504 | 0.57 | 0.234 | 0.359 | 1.426 | 10.867 | 10.692 |
| 89 | 0.186 | 0.609 | 0.565 | 1.326 | 10.095 | 10.236 | 0.382 | 0.39 | 0.518 | 1.345 | 10.263 | 9.714 |
| 90 | 0.233 | 1.223 | 0.319 | 0.386 | 8.64 | 9.584 | 0.278 | 0.254 | 0.369 | 0.428 | 10.814 | 10.367 |
| 91 | 0.08 | 0.006 | 0.649 | 0.498 | 10.923 | 14.772 | 0.142 | 0.072 | 0.28 | 0.543 | 10.724 | 14.132 |
| 92 | 0.404 | 0.204 | 0.072 | 0.592 | 9.938 | 13.134 | 0.146 | 0.124 | 0.087 | 0.501 | 7.025 | 11.122 |
| 93 | 0.057 | 0.122 | 0.107 | 0.599 | 6.729 | 9.884 | 0.33 | 0.173 | 0.137 | 0.763 | 7.126 | 12.467 |
| 94 * | | | | | | | 0.417 | 0.069 | 0.104 | 0.746 | 5.96 | 7.597 |
| 95 | 0.339 | 0.082 | 0.11 | 0.786 | 6.279 | 7.306 | 0.221 | 0.171 | 0.201 | 0.756 | 5.992 | 6.653 |
| 96 | 0.059 | 0.077 | 0.184 | 0.907 | 7.515 | 7.875 | 0.115 | 0.332 | 0.161 | 1.013 | 6.711 | 8.038 |
| 97 | 0.072 | 0.069 | 0.159 | 0.976 | 7.04 | 8.71 | 0.08 | 0.08 | 0.156 | 1.122 | 7.348 | 8.206 |
| 98 | 0.226 | 0.152 | 0.12 | 0.537 | 9.828 | 14.596 | 0.409 | 0.246 | 0.25 | 0.533 | 8.007 | 12.184 |
| 99 | 0.077 | 0.074 | 0.172 | 0.936 | 8.504 | 11.843 | 0.082 | 0.118 | 0.224 | 1.043 | 8.657 | 10.84 |
| 100 | 0.384 | 0.208 | 0.343 | 1.015 | 7.955 | 9.612 | 0.411 | 0.217 | 0.206 | 0.661 | 7.16 | 8.409 |
| 101 | 0.286 | 0.133 | 0.209 | 0.73 | 6.842 | 8.236 | 0.212 | 0.22 | 0.277 | 0.909 | 7.337 | 7.665 |
| 102 | 0.311 | 0.2 | 0.262 | 0.902 | 7.726 | 8.062 | 0.29 | 0.186 | 0.274 | 0.981 | 8.539 | 9.174 |
| | | | | | | | | | | | | |
| 105 * | 0.231 | 0.152 | 0.138 | 0.418 | 13.19 | 16.087 | 1.035 | 0.619 | 0.302 | 0.557 | 10.87 | 16.47 |
| 106 | 0.604 | 0.243 | 0.212 | 0.533 | 9.491 | 14.992 | 0.426 | 0.24 | 0.215 | 0.642 | 8.021 | 13.15 |
| 107 | 0.386 | 0.218 | 0.182 | 0.711 | 8.905 | 12.634 | 0.165 | 0.185 | 0.202 | 0.643 | 8.474 | 11.18 |
| 108 | 1.238 | 0.452 | 0.412 | 1.271 | 12.267 | 11.906 | 0.192 | 0.267 | 0.413 | 1.295 | 11.741 | 10.458 |
| 109 | 0.494 | 0.302 | 0.501 | | 13.207 | 14.084 | 1.296 | 0.62 | 0.69 | 0 | 15.283 | 14.2258 |
| 110 | | | | | | | | | | | | |
| 111 | 0.678 | 0.322 | 0.848 | 2.896 | 16.599 | 17.192 | 0.252 | 0.413 | 0.847 | 0 | 17.131 | 16.844 |
| 112 | 0.743 | 0.381 | 0.779 | 2.61 | 17.118 | 18.624 | 0.814 | 0.469 | 0.864 | 0 | 19.116 | 19.054 |
| 113 | 0.331 | 0.185 | 0.156 | 1.728 | 15.215 | 15.512 | 0.179 | 0.247 | 0.524 | 2.381 | 16.126 | 15.794 |
| 114 | 0.513 | 0.296 | 0.121 | 0.916 | 12.391 | 22.505 | 0.499 | 0.297 | 0.14 | 0.903 | 13.271 | 20.751 |
| 115 | 0.198 | 0.182 | 0.351 | 0 | 18.021 | 25.693 | 0.325 | 0.226 | 0.486 | 0 | 14.144 | 26.392 |
| 116 | | | | | | | | | | | | |
| 117 * | 0.302 | 0.158 | 0.276 | 1.424 | 9.6559 | 21.2 | 0.327 | 0.294 | 0.605 | 1.928 | 11.764 | 15.124 |
| 118 | 0.266 | 0.14 | 0.105 | 0 | 16.431 | 12.093 | 0.226 | 0.413 | 2.681 | 0 | 21.552 | 22.864 |
| 119 | | | | | | | | | | | | |

NITRATE (mg/l)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | -0.045 | 0.102 | 0.163 | 0.724 | 7.204 | 8.998 | 0.147 | 0.065 | 0.213 | 0.998 | 7.469 | 7.566 |
| 65 | 0.193 | 0.066 | 0.06 | 0.497 | 6.864 | 7.481 | 0.293 | 0.08 | 0.169 | 1.013 | 6.789 | 8.934 |
| 68 | 0.562 | 0.153 | 0.167 | 0.808 | 8.097 | 8.632 | 0.113 | 0.032 | 0.077 | 0.573 | 4.824 | 6.826 |
| 69 | 0.028 | 0.012 | -0.015 | 0.107 | 5.544 | 6.036 | 0.034 | 0.107 | -0.01 | 0 | 5.917 | 6.985 |
| 70 * | 0.075 | 0.075 | 0.03 | 0 | 19.75 | 20.2 | -0.08 | 0.045 | 0.091 | 0.425 | 12.2 | 18.15 |
| 71 | 0.18 | 0.5 | 0.12 | 0.85 | 24.8 | 24.8 | 0.7 | 0.18 | 0.07 | 2.45 | 18.8 | 24.2 |
| 72 | 0.15 | 0.18 | 0.38 | 3.8 | 26.8 | 23.4 | 2.1 | 0.26 | 0.16 | 5.075 | 19.4 | 26.8 |
| 74 | 0.1 | 0.16 | 0.43 | 5.35 | 28.6 | 28.4 | 0.44 | 0.22 | 0.78 | 5.05 | 23 | 28.4 |
| 75 | 0.12 | 0.12 | 0.35 | 5.4 | 28 | 25.4 | 0.32 | 0.21 | 0.62 | 5.4 | 27.2 | 31 |
| 76 | 0.18 | 0.21 | 0.41 | 7.6 | 33.4 | 32 | 0.25 | 0.25 | 0.82 | 6.15 | 29 | 32.4 |
| 77 | 0.26 | 0.25 | 2.8 | 0.5 | 38 | 32.2 | 0.26 | 0.35 | 0.96 | 6.8 | 16.4 | 28 |
| 78 | 0.14 | 0.2 | 0.65 | 4.5 | 25 | 34.2 | 0.38 | 0.41 | 0.95 | 5.7 | 18.8 | 32.2 |
| 79 | 0.16 | 0.18 | 0.74 | 6.15 | 22 | 35 | 0.4 | 0.43 | 0.96 | 5.1 | 17 | 31.6 |
| 80 | | | | | | | | | | | | |
| 81 * | 0.14 | 0.1 | 0.3 | 3.5 | 28.2 | 36.6 | 0.21 | 0.21 | 0.87 | 3.75 | 15.8 | 33.2 |
| 82 | 0.07 | 0.09 | 0.16 | 1.8 | 18 | 19.2 | 0.28 | 0.1 | 0.21 | 1.3 | 10.8 | 22.2 |
| 83 | 0.09 | 0.1 | 0.16 | 1.5 | 16.8 | 14.8 | 0.21 | 0.15 | 0.18 | 1 | 10.6 | 17.6 |
| 84 | 0.561 | 0.28 | 0.223 | 0.696 | 12.175 | 15.832 | 0.459 | 0.365 | 0.361 | 0.808 | 9.78 | 14.542 |
| 85 | 0.564 | 0.401 | 0.326 | 0.891 | 8.957 | 13.471 | 0.677 | 0.23 | 0.243 | 0.839 | 7.704 | 9.034 |
| 86 | 0.912 | 0.541 | 0.439 | 1.013 | 7.818 | 9.689 | 0.251 | 0.235 | 0.311 | 1.037 | 8.445 | 10.105 |
| 87 | 0.223 | 0.564 | 0.338 | 1.044 | 8.483 | 9.196 | 0.505 | 0.413 | 0.277 | 1.15 | 9.014 | 9.427 |
| 88 | 0.192 | 0.312 | 0.448 | 1.254 | 9.932 | 9.504 | 0.57 | 0.234 | 0.359 | 1.426 | 10.867 | 10.692 |
| 89 | 0.186 | 0.609 | 0.565 | 1.326 | 10.095 | 10.236 | 0.382 | 0.39 | 0.518 | 1.345 | 10.263 | 9.714 |
| 90 | 0.233 | 1.223 | 0.319 | 0.386 | 8.64 | 9.584 | 0.278 | 0.254 | 0.369 | 0.428 | 10.814 | 10.367 |
| 91 | 0.08 | 0.006 | 0.649 | 0.498 | 10.923 | 14.772 | 0.142 | 0.072 | 0.28 | 0.543 | 10.724 | 14.132 |
| 92 | 0.404 | 0.204 | 0.072 | 0.592 | 9.938 | 13.134 | 0.146 | 0.124 | 0.087 | 0.501 | 7.025 | 11.122 |
| 93 | 0.057 | 0.122 | 0.107 | 0.599 | 6.729 | 9.884 | 0.33 | 0.173 | 0.137 | 0.763 | 7.126 | 12.467 |
| 94 * | | | | | | | 0.417 | 0.069 | 0.104 | 0.746 | 5.96 | 7.597 |
| 95 | 0.339 | 0.082 | 0.11 | 0.786 | 6.279 | 7.306 | 0.221 | 0.171 | 0.201 | 0.756 | 5.992 | 6.653 |
| 96 | 0.059 | 0.077 | 0.184 | 0.907 | 7.515 | 7.875 | 0.115 | 0.332 | 0.161 | 1.013 | 6.711 | 8.038 |
| 97 | 0.072 | 0.069 | 0.159 | 0.976 | 7.04 | 8.71 | 0.08 | 0.08 | 0.156 | 1.122 | 7.348 | 8.206 |
| 98 | 0.226 | 0.152 | 0.12 | 0.537 | 9.828 | 14.596 | 0.409 | 0.246 | 0.25 | 0.533 | 8.007 | 12.184 |
| 99 | 0.077 | 0.074 | 0.172 | 0.936 | 8.504 | 11.843 | 0.082 | 0.118 | 0.224 | 1.043 | 8.657 | 10.84 |
| 100 | 0.384 | 0.208 | 0.343 | 1.015 | 7.955 | 9.612 | 0.411 | 0.217 | 0.206 | 0.661 | 7.16 | 8.409 |
| 101 | 0.286 | 0.133 | 0.209 | 0.73 | 6.842 | 8.236 | 0.212 | 0.22 | 0.277 | 0.909 | 7.337 | 7.665 |
| 102 | 0.311 | 0.2 | 0.262 | 0.902 | 7.726 | 8.062 | 0.29 | 0.186 | 0.274 | 0.981 | 8.539 | 9.174 |
| 105 * | 0.231 | 0.152 | 0.138 | 0.418 | 13.19 | 16.087 | 1.035 | 0.619 | 0.302 | 0.557 | 10.87 | 16.47 |
| 106 | 0.604 | 0.243 | 0.212 | 0.533 | 9.491 | 14.992 | 0.426 | 0.24 | 0.215 | 0.642 | 8.021 | 13.15 |
| 107 | 0.386 | 0.218 | 0.182 | 0.711 | 8.905 | 12.634 | 0.165 | 0.185 | 0.202 | 0.643 | 8.474 | 11.18 |
| 108 | 1.238 | 0.452 | 0.412 | 1.271 | 12.267 | 11.906 | 0.192 | 0.267 | 0.413 | 1.295 | 11.741 | 10.458 |
| 109 | 0.494 | 0.302 | 0.501 | | 13.207 | 14.084 | 1.296 | 0.62 | 0.69 | 0 | 15.283 | 14.2258 |
| 110 | | | | | | | | | | | | |
| 111 | 0.678 | 0.322 | 0.848 | 2.896 | 16.599 | 17.192 | 0.252 | 0.413 | 0.847 | 0 | 17.131 | 16.844 |
| 112 | 0.743 | 0.381 | 0.779 | 2.61 | 17.118 | 18.624 | 0.814 | 0.469 | 0.864 | 0 | 19.116 | 19.054 |
| 113 | 0.331 | 0.185 | 0.156 | 1.728 | 15.215 | 15.512 | 0.179 | 0.247 | 0.524 | 2.381 | 16.126 | 15.794 |
| 114 | 0.513 | 0.296 | 0.121 | 0.916 | 12.391 | 22.505 | 0.499 | 0.297 | 0.14 | 0.903 | 13.271 | 20.751 |
| 115 | 0.198 | 0.182 | 0.351 | 0 | 18.021 | 25.693 | 0.325 | 0.226 | 0.486 | 0 | 14.144 | 26.392 |
| 116 | | | | | | | | | | | | |
| 117 * | 0.302 | 0.158 | 0.276 | 1.424 | 9.6559 | 21.2 | 0.327 | 0.294 | 0.605 | 1.928 | 11.764 | 15.124 |
| 118 | 0.266 | 0.14 | 0.105 | 0 | 16.431 | 12.093 | 0.226 | 0.413 | 2.681 | 0 | 21.552 | 22.864 |
| 119 | | | | | | | | | | | | |

NITRATE (mg/l)

| DAY # |  | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 120 |  | 0.252 | 0.278 | 0.296 | 1.072 | 16.56 | 16.806 | 0.268 | 0.264 | 0.256 | 0.89 | 14.399 | 16.609 |
| 121 |  | 0.223 | 0.233 | 0.242 | 1.048 | 14.914 | 18.223 | 0.211 | 0.232 | 0.324 | 0.879 | 12.929 | 14.13 |
| 122 |  | 0.154 | 0.242 | 0.313 | 1.165 | 12.582 | 12.411 | 0.216 | 0.167 | 0.409 | 1.157 | 11.552 | 11.533 |
| 123 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 124 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 125 |  | 0.199 | 0.2 | 0.282 | 1.114 | 11.111 | 13.187 | 0.281 | 0.262 | 0.466 | 1.793 | 11.497 | 12.707 |
| 126 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 127 |  | 0.209 | 0.224 | 0.303 | 0.99 | 14.699 | 16.445 | 0.158 | 0.223 | 0.278 | 1.124 | 15.537 | 17.029 |
| 128 |  | 0.197 | 0.226 | 0.26 | 1.111 | 14.233 | 15.53 |  |  |  |  |  |  |
| 129 |  | 0.111 | 0.174 | 0.281 | 1.585 | 14.9 | 13.266 | 0.122 | 0.176 | 0.319 | 1.284 | 12.062 | 14.53 |
| 130 | * | 0.132 | 0.177 | 0.135 | 0.105 | 9.548 | 10.57 | 0.153 | 0.157 | 0.122 | 0.079 | 9.212 | 9.798 |
| 131 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 132 |  | 0.185 | 0.12 | 0.098 | 0.055 | 8.184 | 9.958 | 0.129 | 0.135 | 0.114 | 0.098 | 9.38 | 9.455 |
| 133 |  | 0.078 | 0.156 | 0.14 | 0.114 | 15.626 | 13.388 | 0.108 | 0.129 | 0.12 | 0.116 | 13.25 | 12.06 |
| 134 |  | 0.167 | 0.211 | 0.114 | 0.137 | 12.359 | 12.332 | 0.167 | 0.178 | 0.14 | 0.121 | 11.013 | 11.381 |
| 135 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 136 |  | 0.175 | 0.155 | 0.11 | 0.074 | 11.484 | 26.585 | 0.185 | 0.135 | 0.105 | 0.109 | 9.064 | 13.99 |
| 137 |  | 0.183 | 0.165 | 0.12 | 0.411 | 11.407 | 15.002 |  |  |  |  | 15.72 | 14.683 |
| 138 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 139 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 140 | * |  |  |  |  |  |  |  |  |  |  |  |  |
| 141 |  | 0.201 | 0.212 | 0.17 | 0.13 | 8.906 | 11.555 | 0.838 | 0.225 | 0.168 | 0.126 | 6.135 | 8.101 |
| 142 |  | 0.212 | 0.231 | 0.149 | 0.098 | 4.97 | 6.317 | 0.17 | 0.173 | 0.144 | 0.12 | 4.868 | 3.922 |
| 143 |  | 0.149 | 0.173 | 0.149 | 0.122 | 5.143 | 5.686 | 0.183 | 0.168 | 0.136 | 0.109 | 6.553 | 6.284 |
| 144 |  | 0.166 | 0.203 | 0.144 | 0.126 | 7.435 | 6.833 | 0.192 | 0.166 | 0.15 | 0.14 | 8.06 | 6.776 |
| 145 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 146 |  | 0.153 | 0.16 | 0.135 | 0.117 | 6.551 | 6.906 | 0.151 | 0.164 | 0.146 | 0.153 | 7.805 | 7.551 |
| 147 |  | 3.108 | 0.368 | 0.2 | 0.136 | 7.007 | 6.833 | 0.173 | 0.163 | 0.157 | 0.126 | 7.577 | 6.689 |
| 148 |  | 0.205 | 0.104 | 0.095 | 0.087 | 11.425 | 12.105 | 0.181 | 0.162 | 0.15 | 0.132 | 10.964 | 11.113 |
| 149 |  | 0.214 | 0.339 | 0.17 | 0.122 | 10.371 | 12.398 | 0.161 | 0.149 | 0.139 | 0.134 | 8.78 | 10.531 |
| 150 |  | 0.136 | 0.284 | 0.15 | 0.136 | 8.451 | 10.965 | 0.321 | 0.155 | 0.143 | 0.108 | 7.077 | 7.029 |
| 151 |  | 0.333 | 0.393 | 0.111 | 0.108 | 2.891 | 3.786 | 0.114 | 0.117 | 0.103 | 0.108 | 6.864 | 5.894 |
| 153 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 154 |  | 0.139 | 0.324 | 0.111 | 0.102 | 6.328 | 5.772 | 0.149 | 0.12 | 0.13 | 0.122 | 5.592 | 5.514 |
| 155 | * | 0.124 | 0.117 | 0.1 | 0.1 | 5.653 | 7.237 | 0.155 | 0.157 | 0.129 | 0.12 | 8.869 | 7.34 |
| 156 |  | 2.172 | 0.629 | 0.342 | 0.16 | 8.301 | 7.951 | 2.159 | 0.29 | 0.158 | 0.33 | 8.466 | 7.323 |
| 157 |  | 0.095 | 0.012 | 0.051 | 0.044 | 7.196 | 6.52 | 0.077 | 0.119 | 0.069 | 0.039 | 6.622 | 6.307 |
| 158 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 159 |  | 0.162 | 0.001 | 0.06 | 0.026 | 6.634 | 5.684 | 0.058 | 0.064 | 0.035 | 0.027 | 5.927 | 5.065 |
| 160 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 161 |  | 0.13 | 0.001 | 0.049 | 0.024 | 6.21 | 5.405 | 0.068 | 0.077 | 0.079 | 0.037 | 5.529 | 5.176 |
| 162 |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | 0.001 | 0.001 | 0.072 | 0.015 | 4.903 | 3.694 | 0.038 | 0 | 0.031 | 0.022 | 5.004 | 1.49 |
| 164 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 165 |  | 0.616 | 0.167 | 0.116 | 0.107 | 12.283 | 13.679 | 0.185 | 0.179 | 0.115 | 0.112 | 9.935 | 10.936 |
| 166 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 167 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 168 |  | 0.176 | 0.139 | 0.081 | 0.08 | 10.303 | 12.953 | 0.159 | 0.15 | 0.094 | 0.104 | 9.083 | 10.094 |
| 169 |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 170 |  | 1.081 | 0.19 | 0.198 | 0.199 | 7.124 | 7.848 | 0.157 | 0.126 | 0.116 | 0.103 | 6.721 | 6.978 |
| 171 |  | 0.171 | 0.148 | 0.111 | 0.091 | 6.95 | 6.672 | 0.118 | 0.118 | 0.11 | 0.088 | 6.611 | 6.455 |
| 172 | * | 0.149 | 0.071 | 0.201 | 0.173 | 12.867 | 11.655 | 0.154 | 0.167 | 0.128 | 0.12 | 9.369 | 9.044 |
| 173 |  |  |  |  |  |  |  |  |  |  |  |  |  |

# A2.22

NITRATE (mg/l)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 174 | | | | | | | | | | | | |
| 175 | 0.148 | 0.128 | 0.107 | 0.074 | 7.377 | 7.648 | 0.113 | 0.105 | 0.09 | 0.081 | 6.696 | 6.843 |
| 176 | 0.243 | 0.218 | 0.198 | 0.166 | 5.765 | 6.15 | 0.205 | 0.205 | 0.186 | 0.173 | 4.87 | 5.637 |
| 177 | | | | | | | | | | | | |
| 178 | 0.16 | 0.07 | 0.021 | 0 | 6.978 | 11.04 | 0.054 | 0.084 | 0 | 0 | 5.067 | 5.317 |
| 179 | 0.14 | 0.087 | 0.047 | 0.015 | 6.232 | 6.553 | 0.115 | 0.043 | 0.004 | 0 | 4.734 | 4.106 |
| 180 | | | | | | | | | | | | |
| 181 | | | | | | | | | | | | |
| 182 | 0.03 | 0.033 | 0.048 | 0.003 | 5.145 | 5.11 | 0 | 0.027 | 0.028 | 0 | 5.436 | 5.49 |
| 183 * | 0.12 | 0.095 | 0.091 | 0.075 | 13.619 | 10.35 | 0.068 | 0.066 | 0.057 | 0.044 | 10.248 | 8.148 |
| 184 | | | | | | | | | | | | |
| 185 * | 0.032 | 0.039 | 0.025 | 0.057 | 9.527 | 8.98 | 0.082 | 0.056 | 0.051 | 0.032 | 8.688 | 8.643 |
| 186 | 0.055 | 0.057 | 0.039 | 0.032 | 7.234 | 6.955 | 0.118 | 0.045 | 0.04 | 0.029 | 8.238 | 8.562 |
| 187 | | | | | | | | | | | | |
| 188 | 0.084 | 0.007 | 0.004 | 0.059 | 9.35 | 11.423 | 0.102 | 0.054 | 0.075 | 0 | 9.695 | 12.417 |
| 189 | 0.025 | 0.044 | 0.012 | 0 | 6.082 | 8.037 | 0.088 | 0.042 | 0 | 0 | -0.248 | 11.16 |
| 190 | 0.075 | 0.022 | 0 | 0 | 7.022 | 6.743 | 0.226 | 0.038 | 0 | 0 | 6.814 | 8.086 |
| 191 | 0.016 | 0.017 | 0 | 0 | 8.22 | 7.42 | 0 | 0 | 0.008 | 0.023 | 11.726 | 11.516 |
| 192 | 0.035 | 0.002 | 0 | 0.014 | 6.645 | 6.957 | 0.113 | 0.044 | 0 | 0 | 7.617 | 8.258 |
| 193 | 0.017 | 0.028 | 0.011 | 0.002 | 7.94 | 6.491 | 0.048 | 0.017 | 0.006 | 0 | 7.046 | 7.768 |
| 194 | | | | | | | | | | | | |
| 195 | 0.026 | 0.03 | 0.019 | 0.012 | 6.761 | 6.48 | 0.07 | 0.048 | 0.021 | 0 | 7.665 | 7.061 |
| 196 | 0 | 0 | 0 | 0.01 | 6.352 | 5.661 | 0 | 0.023 | 0 | 0 | 7.727 | 6.609 |
| 197 | -0.114 | -0.074 | -0.014 | 0 | 5.155 | 4.646 | 0.28 | 0.06 | -0.036 | 0 | 6.946 | |
| 198 * | 0.016 | -0.062 | -0.027 | 0 | 6.718 | 5.57 | -0.08 | 0.014 | -0.014 | -0.611 | 7.087 | |
| 199 | -0.022 | -0.146 | -0.053 | 0 | 6.761 | 6.025 | -0.117 | -0.089 | -0.053 | 0 | 5.809 | 6.069 |
| 200 | 0.004 | -0.012 | -0.06 | 0 | 10.311 | 14.4 | -0.044 | -0.032 | -0.049 | 0 | 8.541 | 14.155 |
| 201 | | | | | | | | | | | | |
| 202 | 0.013 | 0.008 | -0.04 | 0 | 6.879 | 9.68 | -0.118 | 0.04 | -0.024 | 0 | 9.072 | 13.134 |
| 203 | 0.059 | 0.051 | -0.014 | 0 | 7.056 | 7.769 | 0.011 | 0.058 | 0.013 | 0 | 9.341 | 10.712 |
| 204 | 0.051 | 0.049 | -0.004 | 0.006 | 7.845 | 6.799 | 0.097 | 0.045 | 0.001 | 0.008 | 7.8 | 7.816 |
| 205 | -0.089 | -0.109 | -0.032 | 0 | 7.642 | 7.514 | 0.001 | -0.048 | -0.032 | 0 | 7.666 | 7.263 |
| 206 | -0.086 | -0.083 | -0.044 | 0 | 6.19 | 6.167 | 0.005 | -0.031 | -0.034 | 0 | 7.141 | 6.99 |
| 207 | -0.005 | 0.02 | -0.031 | 0 | 10.22 | 10.067 | 0.09 | 0.031 | 0.018 | 0 | 12.523 | 12.049 |
| 210 * | 0.061 | -0.042 | -0.057 | 0 | 14.391 | 12.083 | 0.081 | -0.04 | -0.059 | 0 | 16.699 | 13.526 |
| 211 | -0.006 | -0.003 | -0.025 | 0 | 10.999 | 15.689 | 0.688 | 0.11 | 0.009 | 0 | 11.627 | 14.679 |
| 212 | -0.012 | 0.033 | -0.002 | 0 | 10.801 | 12.19 | 0.037 | 0.041 | -0.026 | 0 | 9.061 | 11.022 |
| 213 | 0.012 | 0.023 | -0.021 | 0 | 9.081 | 9.822 | 0.823 | 0.101 | 0.006 | 0 | 7.904 | 9.252 |
| 214 | 0.092 | 0.028 | -0.003 | 0.025 | 9.365 | 8.451 | 0.063 | 0.004 | -0.029 | 0 | 9.285 | 9.05 |
| 216 | -0.024 | -0.006 | -0.027 | 0 | 11.041 | 11.337 | 0.048 | 0.04 | 0.017 | 0 | 13.447 | 12.184 |
| 217 | 0.014 | -0.042 | 0.013 | 0.006 | 10.844 | 9.982 | 0.072 | -0.149 | 0.026 | 0.007 | 9.215 | 9.431 |
| 218 | -0.121 | -0.051 | 0.026 | 0 | 9.459 | 9.309 | -0.362 | -0.1 | 0.022 | 0 | 9.24 | 8.384 |
| 219 | 0.829 | 0.957 | 0.118 | 0.104 | 15.431 | 16.84 | 1.14 | 0.551 | 0.047 | 0.027 | 16.983 | 15.275 |
| 220 | 0.154 | 0.405 | 0.058 | 0.041 | 11.235 | 12.538 | 0.663 | 0.273 | 0.076 | 0.037 | 13.198 | 12.533 |
| 221 | 0.015 | -0.023 | 0.069 | 0.071 | 9.285 | 11.118 | 0.026 | 0.041 | 0.092 | 0.048 | 12.753 | 13.147 |
| 223 | 0.064 | -0.037 | 0.037 | 0.015 | 6.802 | 7.248 | 0.623 | 0.057 | 0.011 | 0.108 | 6.797 | 7.681 |
| 224 * | 0.115 | 0.062 | 0.021 | 0 | 8.122 | 7.29 | 0.044 | 0.011 | 0.025 | 0.006 | 9.574 | 7.808 |
| 225 | 0.132 | 0.074 | 0.04 | 0.013 | 13.408 | 15.017 | 0.076 | 0.066 | 0.036 | 0.048 | 14.738 | 14.466 |
| 226 | 0.036 | 0.019 | 0.054 | 0.031 | 10.631 | 12.684 | 0.047 | 0.022 | 0.029 | 0.069 | 14.659 | 16.363 |
| 227 | 0.077 | 0.08 | 0.062 | 0.046 | 10.371 | 11.05 | 0.167 | 0.093 | 0.087 | 0.028 | 11.66 | 11.994 |
| 228 | 0.112 | 0.089 | 0.077 | 0.353 | 9.662 | 10.477 | 0.176 | 0.149 | 0.098 | 0.047 | 8.418 | 9.94 |

NITRATE (mg/l)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 229 | 0.216 | 0.216 | 0.16 | 0.118 | 8.357 | 9.054 | 0.369 | 0.229 | 0.18 | 0.111 | 8.775 | 9.054 |
| 230 | -0.14 | -0.14 | -0.1 | 0 | -0.131 | -0.262 | -0.129 | -0.127 | -0.084 | 0 | -0.193 | -0.21 |
| 231 | 0.098 | 0.092 | 0.063 | 0.044 | 8.288 | 8.86 | 0.085 | 0.058 | 0.072 | 0.033 | 6.707 | 8.793 |
| 232 | 0.065 | 0.085 | 0.068 | 0.008 | 8.425 | 8.682 | 0.116 | 0.07 | 0.037 | 0.001 | 8.11 | 8.171 |
| 233 | 0.047 | 0.01 | 0.053 | 0.03 | 8.677 | 8.318 | 0.063 | 0.028 | 0.049 | 0.031 | 9.317 | 7.219 |
| 234 * | 0.055 | 0.05 | 0.057 | 0.048 | 7.813 | 8.397 | 0.1 | 0.064 | 0.047 | 0.038 | 8.073 | 7.112 |
| 235 | 0.369 | 0.365 | 0.156 | 0.086 | 9.497 | 11.925 | 0.327 | 0.19 | 0.097 | 0.012 | 8.766 | 14.773 |
| 236 | 0.339 | 0.187 | 0.115 | 2.871 | 12.062 | 11.359 | 0.339 | 0.217 | 0.069 | 0.023 | 8.708 | 10.124 |
| 237 | 0.14 | 0.115 | 0.201 | 0 | 12.824 | 14.374 | 0.196 | 0.128 | 0.177 | 0.125 | 10.914 | 11.318 |
| 238 | 0.111 | 0.003 | 0.14 | 0.121 | 8.335 | 9.551 | 0.313 | 0.231 | 0.19 | 0.108 | 8.384 | 9.473 |
| 239 | 0.158 | 0.124 | 0.125 | 0.116 | 6.799 | 6.695 | 0.312 | 0.173 | 0.129 | 0.087 | 8.213 | 7.304 |
| 240 | 0.252 | 0.214 | 0.093 | 0.012 | 12.994 | 15.646 | 0.369 | 0.206 | 0.058 | 0 | 14.03 | 16.902 |
| 241 | 0.206 | 0.208 | 0.071 | 0.002 | 19.698 | 17.187 | 0.245 | 0.02 | -0.106 | 0 | 19.098 | 17.954 |
| 242 | 0.174 | 0.118 | -0.018 | 0 | 9.101 | 13.4 | 0.245 | 0.188 | 0.024 | 0 | 11.253 | 14.552 |
| 243 | 0.17 | 0.115 | -0.325 | 0.017 | 9.533 | 8.48 | 0.248 | 0.264 | 0.196 | 0.06 | 12.459 | 11.409 |
| | | | | | | | | | | | | |
| 245 | 0.056 | 0.053 | -0.009 | 0 | 7.258 | 9.962 | 0.467 | 0.141 | 0.092 | 0.068 | 13.747 | 13.495 |
| 247 * | 0.071 | 0.028 | -0.016 | 0 | 8.846 | 13.432 | 0.474 | 0.07 | -0.022 | 0.127 | 14.592 | 16.151 |
| 249 | 0.117 | 0.079 | -0.018 | 0 | 8.404 | 12.052 | 0.727 | 0.295 | 0.017 | 0 | 6.945 | 12.442 |
| 250 | -0.031 | -0.087 | -0.131 | 0 | 6.521 | 9.536 | 0.102 | -0.057 | -0.128 | 0 | 5.878 | 9.427 |
| 251 | 0.103 | 0.015 | -0.033 | 0 | 14.646 | 19.893 | 0.148 | 0.031 | -0.033 | 0 | 16.873 | 21.017 |
| 252 | 0.119 | 0.047 | -0.014 | 0 | 8.284 | 18.742 | 0.195 | 0.092 | -0.007 | 0 | 8.926 | 18.132 |
| 254 | 0.054 | -0.016 | -0.029 | 0 | 14.739 | 18.982 | 0.221 | 0.061 | -0.02 | 0 | 14.504 | 18.544 |
| 256 * | 0.023 | -0.035 | -0.007 | 0.036 | 17.503 | 19.972 | 0.142 | -0.016 | -0.031 | 0 | 14.893 | 18.54 |
| 257 | 0.019 | -0.073 | -0.045 | 0 | 8.463 | 12.474 | -0.035 | -0.035 | -0.033 | 0 | 8.784 | 14.659 |
| 258 | -0.035 | -0.073 | -0.055 | 0 | 6.384 | 9.364 | 0.111 | -0.034 | -0.024 | 0 | 7.078 | 9.556 |
| 259 | 0.017 | -0.055 | -0.04 | 0 | 9.645 | 13.645 | 0.01 | -0.09 | -0.059 | 0 | 10.696 | 14.744 |
| 260 | 0.009 | -0.02 | -0.036 | 0 | 6.553 | 7.591 | 0.048 | -0.008 | -0.026 | 0 | 7.607 | 10.75 |
| 261 | 0.019 | -0.003 | -0.036 | 0 | 6.306 | 7.353 | 0.892 | 0.071 | 0.007 | 0 | 6.515 | 7.336 |
| 263 | 0.141 | 0.052 | 0.009 | 0 | 24.115 | 11.218 | 0.453 | 0.391 | 0.166 | 0.07 | 31.012 | 25.363 |
| 264 | 0.04 | 0.003 | -0.012 | 0 | 12.737 | 10.163 | 0.036 | -0.031 | 0.013 | 0 | 11.854 | 10.116 |
| 265 | 0.032 | -0.005 | -0.012 | 0 | 14.469 | 13.209 | 0.021 | -0.02 | -0.018 | 0 | 10.029 | 11.058 |
| 266 | -0.021 | -0.006 | -0.038 | 0 | 12.582 | 11.667 | 0.019 | -0.097 | -0.014 | 0 | 11.302 | 9.798 |
| 267 | 0.026 | -0.15 | -0.197 | 0 | 13.744 | 13.946 | -0.093 | -0.159 | -0.218 | 0 | 16.238 | 16.456 |
| 270 * | 0.067 | -0.139 | -0.139 | 3.1065 | 14.032 | 18.408 | -0.078 | -0.091 | -0.197 | 0 | 11.393 | 15.092 |
| 271 | -0.133 | -0.05 | -0.186 | 0 | 8.46 | 13.918 | -0.05 | -0.011 | -0.134 | 0 | 10.391 | 11.563 |
| 272 | -0.158 | -0.057 | -0.166 | 0 | 9.175 | 10.731 | -0.098 | -0.069 | -0.191 | 0 | 9.025 | 9.285 |
| 275 | -0.103 | -0.073 | -0.147 | 0 | 8.112 | 7.596 | -0.057 | 0.065 | -0.115 | 0 | 10.875 | 10.636 |
| 276 | -0.011 | -0.035 | -0.091 | 0 | 10.783 | 13.994 | 0.116 | -0.066 | -0.111 | 0 | 14.45 | 17.072 |
| 277 | -0.175 | -0.225 | -0.163 | 0 | -0.224 | -0.4 | -0.214 | -0.21 | -0.163 | 0 | -0.224 | -0.514 |
| 279 | -0.015 | -0.057 | -0.064 | 0.122 | 8.853 | 9.192 | -0.073 | -0.014 | -0.021 | 0 | 13.441 | 14.413 |
| 280 | -0.055 | -0.03 | -0.09 | 0 | 8.809 | 8.979 | -0.095 | -0.042 | -0.105 | 0 | 8.085 | 9.913 |
| 281 | -0.066 | -0.093 | -0.101 | 0 | 6.651 | 6.847 | -0.089 | -0.079 | -0.093 | 0 | 9.3 | 8.05 |
| 288 | -0.048 | -0.044 | -0.098 | 0 | 4.865 | 4.833 | -0.094 | -0.118 | -0.129 | 0 | 4.365 | 4.376 |
| 289 | -0.071 | -0.01 | 0.03 | 0.386 | 6.772 | 3.856 | 0.188 | -0.079 | -0.005 | 0 | 11.89 | 11.658 |

NITRITES (mg/l)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.041 | 0.024 | 0.02 | 0.034 | 0.03 | 0.098 | 0.02 | 0.028 | 0.024 | 0.02 | 0.106 | 0.185 |
| 2 | 0.057 | 0.016 | 0.045 | 0.016 | 0.006 | 0.123 | 0.024 | 0.032 | 0.016 | 0.032 | 0.057 | 0.407 |
| 3 | 0.059 | 0.089 | 0.034 | 0.097 | 0.114 | 0.294 | 0.061 | 0.061 | 0.04 | 0.068 | 0.026 | 0.089 |
| 5 | 0.047 | 0.051 | 0.047 | 0.097 | 0.118 | 0.185 | 0.07 | 0.047 | 0.059 | 0.028 | 0.013 | 0.097 |
| 6 | 0.059 | 0.063 | 0.047 | 0.03 | 0.086 | 0.164 | 0.059 | 0.047 | 0.013 | 0.017 | 0.022 | 0.076 |
| 7 * | 0.022 | 0.034 | 0.074 | 0.139 | 0.176 | 0.327 | 0.03 | 0.055 | 0.082 | 0.059 | 0.247 | 0.231 |
| 8 | 0.026 | 0.034 | 0.038 | 0.126 | 0.197 | 0.394 | 0.036 | 0.051 | 0.051 | 0.105 | 0.181 | 0.231 |
| 9 | 0.03 | 0.043 | 0.026 | 0.122 | 0.197 | 0.616 | 0.072 | 0.093 | 0.026 | 0.047 | 0.072 | 0.222 |
| 10 | 0.003 | 0.084 | 0.013 | 0.122 | 0.214 | 0.402 | 0.003 | 0.004 | 0.08 | 0.089 | 0.063 | 0.181 |
| 12 | 0.051 | 0.038 | 0.059 | 0.135 | 0.193 | 0.289 | 0.04 | 0.026 | 0.126 | 0.109 | 0.189 | 0.109 |
| 13 | 0.486 | 0.093 | 0.013 | 0.004 | 0.047 | 0.201 | 0.063 | 0.051 | 0.013 | 0.011 | 0.022 | 0.08 |
| 14 | 0.055 | 0.105 | 0.093 | 0.176 | 0.218 | 0.402 | 0.061 | 0.061 | 0.089 | 0.055 | 0.084 | 0.109 |
| 15 | 0.206 | 0.079 | 0.181 | 0.119 | 0.204 | 0.366 | 0.161 | 0.131 | 0.111 | 0.111 | 0.061 | 0.208 |
| 16 | 0.133 | 0.138 | 0.127 | 0.241 | 0.185 | 0.073 | 0.123 | 0.144 | 0.115 | 0.162 | 0.135 | 0.077 |
| 17 |  | 0.079 | 0.054 | 0.065 | 0.052 | 0.056 |  | 0.073 | 0.04 | 0.054 | 0.171 | 0.073 |
| 19 | 0.104 | 0.067 | 0.04 | 0.057 | 0.056 | 0.142 | 0.073 | 0.065 | 0.05 | 0.092 | 0.142 | 0.127 |
| 20 | 0.073 | 0.065 | 0.052 | 0.063 | 0.069 | 0.137 | 0.063 | 0.146 | 0.048 | 0.075 | 0.146 | 0.212 |
| 21 | 0.069 | 0.071 | 0.056 | 0.054 | 0.09 | 0.111 | 0.059 | 0.081 | 0.056 | 0.065 | 0.059 | 0.131 |
| 22 * | 0.05 | 0.088 | 0.046 | 0.059 | 0.293 | 0.189 | 0.065 | 0.065 | 0.054 | 0.063 | 0.301 | 0.248 |
| 23 | 0.096 | 0.072 | 0.089 | 0.122 | 0.292 | 0.181 | 0.088 | 0.074 | 0.085 | 0.078 | 0.402 | 0.31 |
| 25 | 0.081 | 0.0833 | 0.059 | 0.166 | 0.295 | 0.247 | 0.081 | 0.074 | 0.059 | 0.07 | 1.331 | 0.532 |
| 26 | 0.163 | 0.083 | 0.469 | 0.065 | 0.067 | 0.329 | 0.104 | 0.081 | 0.104 | 0.065 | 1.552 | 1.589 |
| 27 | 0.074 | 0.08 | 0.089 | 0.181 | 0.753 | 0.554 | 0.083 | 0.096 | 0.113 | 0.312 | 1.552 | 4.54 |
| 28 | 0.118 | 0.152 | 0.185 | 0.351 | 1.331 | 0.557 | 0.135 | 0.177 | 0.259 | 0.591 | 2.733 | 2.309 |
| 29 | 0.096 | 0.089 | 0.131 | 0.262 | 1.294 | 0.72 | 0.115 | 0.118 | 0.104 | 0.229 | 0.1105 | 3.139 |
| 30 | 0.083 | 0.111 | 0.092 | 0.225 | 1.054 | 0.498 | 0.155 | 0.118 | 0.104 | 0.314 | 1.7 | 1.368 |
| 31 | 0.059 | 0.081 | 0.061 | 0.096 | 0.808 | 0.805 | 0.052 | 0.074 | 0.063 | 0.074 | 1.663 | 2.143 |
| 33 | 0.085 | 0.083 | 0.118 | 0.417 | 1.405 | 1.368 | 0.089 | 0.089 | 0.111 | 0.487 | 2.696 | 1.368 |
| 34 |  |  |  |  |  | 1.294 |  |  |  |  |  | 2.364 |
| 37 * |  |  |  |  |  | 7.02 |  |  |  |  |  | 11.87 |
| 38 | 0.034 | 0.042 | 0.038 | 0.032 | 20.53 | 16.97 | 0.053 | 0.047 | 0.091 | 0.251 | 14.13 | 12.51 |
| 40 | 0.036 | 0.055 | 0.045 | 0.053 | 12.108 | 13.161 | 0.045 | 0.042 | 0.047 | 0.14 | 11.582 | 12.432 |
| 41 | 0.055 | 0.079 | 0.237 | 2.267 | 11.217 | 12.027 | 0.054 | 0.059 | 0.18 | 1.66 | 10.164 | 11.946 |
| 42 | 0.121 | 0.114 | 0.236 | 1.648 | 9.892 | 9.979 | 0.091 | 0.108 | 0.33 | 2.582 | 10.153 | 10.24 |
| 43 | 0.24 | 0.099 | 0.062 | 0.125 | 8.763 | 8.415 | 0.156 | 0.123 | 0.069 | 0.208 | 9.458 | 9.197 |
| 44 | 0.078 | 0.078 | 0.164 | 0.87 | 6.156 | 7.111 | 0.069 | 0.073 | 0.151 | 0.868 | 5.678 | 9.023 |
| 45 * | 0.025 | 0.03 | 0.023 | 0.078 | 4.034 | 3.512 | 0.032 | 0.032 | 0.021 | 0.028 | 4.121 | 3.556 |
| 47 | 0.025 | 0.045 | 0.038 | 0.025 | 1.861 | 3.121 | 0.036 | 0.047 | 0.023 | 0.056 | 2.513 | 2.643 |
| 48 | 0.067 | 0.069 | 0.047 | 0.051 | 2.079 | 1.775 | 0.06 | 0.062 | 0.051 | 0.073 | 1.775 | 1.644 |
| 49 | 0.047 | 0.051 | 0.086 | 0.334 | 1.644 | 1.601 | 0.073 | 0.06 | 0.078 | 0.243 | 1.297 | 0.732 |
| 50 | 0.078 | 0.164 | 0.121 | 0.438 | 1.745 | 1.8 | 0.158 | 0.134 | 0.151 | 0.721 | 1.8 | 1.039 |
| 51 | 0.03 | 0.043 | 0.021 | 0.26 | 0.431 | 1.3 | 0.03 | 0.025 | 0.071 | 0.986 | 1.246 | 2.451 |
| 52 | 0.134 | 0.095 | 0.113 | 0.36 | 1.196 | 1.095 | 0.156 | 0.084 | 0.116 | 0.327 | 1.184 | 1.184 |
| 55 * | 0.098 | 0.093 | 0.228 | 1.198 | 4.967 | 1.33 | 0.075 | 0.08 | 0.093 | 0.461 | 2.711 | 6.908 |
| 56 | 0.125 | 0.134 | 0.156 | 0.852 | 2.823 | 5.898 | 0.055 | 0.066 | 0.093 | 0.385 | 1.297 | 11.375 |
| 57 | 0.053 | 0.08 | 0.053 | 0.048 | 1.678 | 1.431 | 0.062 | 0.066 | 0.053 | 0.062 | 1.354 | 1.656 |
| 58 | 0.0865 | 0.134 | 0.089 | 0.264 | 1.689 | 1.431 | 0.111 | 0.161 | 0.098 | 0.259 | 1.364 | 1.656 |
| 59 | 0.08 | 0.066 | 0.048 | 0.066 | 1.409 | 1.476 | 0.084 | 0.089 | 0.044 | 0.057 | 1.207 | 0.848 |
| 61 | 0.055 | 0.107 | 0.044 | 0.116 | 2.06 | 1.768 | 0.053 | 0.055 | 0.053 | 0.062 | 0.971 | 0.859 |
| 62 | 0.051 | 0.062 | 0.046 | 0.062 | 1.274 | 0.578 | 0.062 | 0.053 | 0.053 | 0.057 | 0.982 | 0.713 |
| 63 | 0.048 | 0.062 | 0.044 | 0.071 | 0.96 | 0.601 | 0.053 | 0.053 | 0.053 | 0.062 | 0.668 | 0.668 |

NITRITES (mg/1)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 64 | 0.252 | 0.098 | 0.191 | 0.924 | 1.335 | 1.378 | 0.089 | 0.171 | 0.112 | 0.29 | 1.364 | 0.385 |
| 65 | 0.147 | 0.124 | 0.138 | 0.428 | 1.963 | 1.203 | 0.147 | 0.118 | 0.2 | 0.755 | 0.896 | 1.32 |
| 68 | 0.206 | 0.13 | 0.13 | 0.317 | 1.729 | 0.765 | 0.127 | 0.109 | 0.135 | 0.352 | 1.291 | 0.502 |
| 69 | 0.098 | 0.1 | 0.098 | 0.162 | 0.999 | 2.006 | 0.092 | 0.162 | 0.086 | 0.118 | 0.911 | 0.414 |
| 70 * | 0.075 | 0.085 | 0.09 | 0.375 | 1.45 | 1 | 0.08 | 0.075 | 0.009 | 0.575 | 1.8 | 1.25 |
| 71 | 0.125 | 0.325 | 0.1 | 0.525 | 2.125 | 3.15 | 0.125 | 0.1 | 0.09 | 0.55 | 2.45 | 1.24 |
| 72 | 0.1 | 0.105 | 0.155 | 0.075 | 3.3 | 3.3 | 0.2 | 0.09 | 0.08 | 0.575 | 1.05 | 1.475 |
| 74 | 0.115 | 0.105 | 0.195 | 1.075 | 4.25 | 2.475 | 0.155 | 0.13 | 0.41 | 1 | 2.45 | 1 |
| 75 | 0.105 | 0.1 | 0.185 | 0.875 | 3.3 | 4.1 | 0.12 | 0.12 | 0.235 | 1.1 | 3.125 | 4.05 |
| 76 | 0.11 | 0.115 | 0.165 | 0.75 | 2.6 | 2.43 | 0.12 | 0.145 | 0.285 | 1.275 | 2.7 | 1.4 |
| 77 | 0.16 | 0.11 | 0.67 | 0.4 | 2.65 | 1.5 | 0.14 | 0.125 | 0.24 | 1.175 | 2.7 | 1.35 |
| 78 | 0.125 | 0.11 | 0.205 | 0.725 | 2.85 | 1.8 | 0.17 | 0.135 | 0.28 | 1.1 | 2.4 | 1.4 |
| 79 | 0.16 | 0.115 | 0.145 | 0.475 | 1.45 | 1.25 | 0.22 | 0.22 | 0.37 | 1 | 2.05 | 1.25 |
| 80 | 0.135 | 0.145 | 0.235 | 0.95 | 2.85 | 3.9 | 0.145 | 0.145 | 0.23 | 0.95 | 1.9 | 1.9 |
| 81 * | 0.17 | 0.145 | 0.21 | 0.725 | 1.45 | 4.25 | 0.145 | 0.145 | 0.31 | 0.8 | 1.35 | 1.7 |
| 82 | 0.125 | 0.135 | 0.125 | 0.4 | 0.8 | 1.15 | 0.145 | 0.125 | 0.145 | 0.475 | 1.25 | 1 |
| 83 | 0.145 | 0.14 | 0.115 | 0.375 | 0.65 | 1.55 | 0.145 | 0.13 | 0.13 | 0.4 | 1.1 | 0.95 |
| 84 | 0.131 | 0.083 | 0.062 | 0.121 | 0.465 | 0.798 | 0.108 | 0.108 | 0.065 | 0.088 | 0.427 | 0.21 |
| 85 | 0.065 | 0.075 | 0.068 | 0.114 | 0.312 | 0.184 | 0.062 | 0.055 | 0.057 | 0.088 | 0.312 | 0.235 |
| 86 | 0.062 | 0.073 | 0.096 | 0.165 | 0.824 | 0.363 | 0.096 | 0.065 | 0.075 | 0.139 | 0.824 | 0.261 |
| 87 | 0.062 | 0.065 | 0.088 | 0.165 | 0.708 | 0.7 | 0.062 | 0.06 | 0.062 | 0.137 | 0.568 | 0.312 |
| 88 | 0.124 | 0.114 | 0.103 | 0.19 | 0.747 | 0.235 | 0.114 | 0.129 | 0.108 | 0.206 | 0.517 | 0.3 |
| 89 | 0.106 | 0.083 | 0.103 | 0.231 | 1.054 | 0.286 | 0.114 | 0.098 | 0.096 | 0.185 | 0.772 | 0.338 |
| 90 | 0.083 | 0.221 | 0.083 | 0.134 | 1.412 | 0.312 | 0.093 | 0.078 | 0.088 | 0.139 | 0.491 | 0.312 |
| 91 | 0.079 | 0.064 | 0.074 | 0.181 | 0.696 | 0.191 | 0.106 | 0.079 | 0.087 | 0.151 | 0.523 | 0.236 |
| 92 | 0.059 | 0.081 | 0.116 | 0.146 | 0.566 | 0.194 | 0.094 | 0.079 | 0.072 | 0.141 | 0.284 | 0.274 |
| 93 | 0.094 | 0.104 | 0.111 | 0.176 | 0.506 | 0.174 | 0.096 | 0.082 | 0.096 | 0.169 | 0.406 | 0.266 |
| 94 * | 0.077 | 0.072 | 0.077 | 0.136 | 0.441 | 0.209 | 0.084 | 0.082 | 0.084 | 0.156 | 0.309 | 0.306 |
| 95 | 0.072 | 0.062 | 0.064 | 0.131 | 0.361 | 0.226 | 0.057 | 0.062 | 0.077 | 0.146 | 0.351 | 0.284 |
| 96 | 0.077 | 0.082 | 0.079 | 0.166 | 0.611 | 1.068 | 0.096 | 0.079 | 0.094 | 0.156 | 0.449 | 0.386 |
| 97 | 0.094 | 0.082 | 0.096 | 0.186 | 0.863 | 0.234 | 0.094 | 0.079 | 0.084 | 0.181 | 0.406 | 0.366 |
| 98 | 0.127 | 0.138 | 0.147 | 0.243 | 0.544 | 0.366 | 0.154 | 0.13 | 0.141 | 0.232 | 0.497 | 0.366 |
| 99 | 0.174 | 0.193 | 0.212 | 0.311 | 0.623 | 0.396 | 0.177 | 0.18 | 0.199 | 0.539 | 0.47 | 0.388 |
| 100 | 0.155 | 0.152 | 0.212 | 0.637 | 0.783 | 0.371 | 0.19 | 0.136 | 0.185 | 0.61 | 0.566 | 0.796 |
| 101 | 0.152 | 0.095 | 0.089 | 0.152 | 0.573 | 0.346 | 0.086 | 0.086 | 0.114 | 0.167 | 0.623 | 0.139 |
| 102 | 0.197 | 0.121 | 0.129 | 0.197 | 0.623 | 0.131 | 0.179 | 0.174 | 0.149 | 0.204 | 0.51 | 0.109 |
| 105 ★ | 0.143 | 0.063 | 0.125 | 0.191 | 0.657 | 0.114 | 0.266 | 0.191 | 0.141 | 0.218 | 0.485 | 0.146 |
| 106 | 0.151 | 0.117 | 0.134 | 0.173 | 0.48 | 0.101 | 0.149 | 0.127 | 0.117 | 0.189 | 0.427 | 0.143 |
| 107 | 0.133 | 0.101 | 0.095 | 0.154 | 0.512 | 0.106 | 0.084 | 0.134 | 0.151 | 0.202 | 0.389 | 0.175 |
| 108 | 0.389 | 0.213 | 0.197 | 0.314 | 1.026 | 0.141 | 0.175 | 0.183 | 0.245 | 0.699 | 0.999 | 0.205 |
| 109 | 0.24 | 0.162 | 0.178 | 0.75 | 1.471 | 0.178 | 0.352 | 0.218 | 0.328 | 1.326 | 1.471 | 0.314 |
| 110 | | | | | | | | | | | | |
| 111 | 0.236 | 0.08 | 0.142 | 0.551 | 1.263 | 0.531 | 0.073 | 0.182 | 0.254 | 1.062 | 1.008 | 0.464 |
| 112 | 0.192 | 0.145 | 0.169 | 0.464 | 1.298 | 1.73 | 0.197 | 0.154 | 0.202 | 0.799 | 0.546 | 1.715 |
| 113 | 0.008 | 0.12 | 0.1 | 0.224 | 0.432 | 0.273 | 0.105 | 0.12 | 0.127 | 0.651 | 0.628 | 0.407 |
| 114 | 0.063 | 0.055 | 0.055 | 0.221 | 0.531 | 1.362 | 0.105 | 0.068 | 0.05 | 0.606 | 0.492 | 0.73 |
| 115 | 0.125 | 0.099 | 0.127 | 0.371 | 0.934 | 0.418 | 0.125 | 0.097 | 0.167 | 0.550 | 0.883 | |
| 116 | | | | | | | | | | | | |
| 117 ★ | 0.134 | 0.109 | 0.174 | 0.611 | 1.0211 | | 0.137 | 0.156 | 0.238 | 1.033 | 0.456 | 0.744 |
| 118 | 0.12 | 0.106 | 0.134 | 0.332 | 0.139 | 0.127 | 0.125 | 0.282 | | 0.369 | 0.536 | 0.381 |
| 119 | | | | | | | | | | | | |

NITRITES (mg/1)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 120 | 0.036 | 0.038 | 0.042 | 0.097 | 0.324 | 0.078 | 0.048 | 0.038 | 0.046 | 0.135 | 0.46 | 3.455 |
| 121 | 0.151 | 0.17 | 0.168 | 0.208 | 0.379 | 0.395 | 0.192 | 0.164 | 0.18 | 0.334 | 0.34 | 1.163 |
| 122 | 0.322 | 0.103 | 0.119 | 0.135 | 0.253 | 0.569 | 0.115 | 0.439 | 0.103 | 0.157 | 0.271 | 1.447 |
| 123 | | | | | | | | | | | | |
| 124 | | | | | | | | | | | | |
| 125 | 0.074 | 0.044 | 0.078 | 0.33 | 0.419 | 0.082 | 0.064 | 0.054 | 0.176 | 1.097 | 0.326 | 0.273 |
| 126 | | | | | | | | | | | | |
| 127 | 0.046 | 0.046 | 0.056 | 0.099 | 0.237 | 0.277 | 0.052 | 0.062 | 0.052 | 0.099 | 0.293 | 1.183 |
| 128 | 0.058 | 0.044 | 0.062 | 0.105 | 0.255 | | | | | | | |
| 129 | 0.07 | 0.066 | 0.093 | 0.115 | 0.334 | 0.776 | 0.074 | 0.064 | 0.07 | 0.111 | 0.192 | 3.09 |
| 130 * | 0.034 | 0.093 | 0.046 | 0.046 | 0.174 | 0.492 | 0.058 | 0.054 | 0.074 | 0.064 | 0.064 | 1.264 |
| 131 | | | | | | | | | | | | |
| 132 | 0.048 | 0.046 | 0.038 | 0.044 | 0.048 | 0.21 | 0.052 | 0.046 | 0.044 | 0.06 | 0.044 | 0.713 |
| 133 | 0.133 | 0.099 | 0.048 | 0.044 | 0.054 | 0.206 | 0.058 | 0.044 | 0.046 | 0.042 | 0.046 | 0.194 |
| 134 | 0.125 | 0.089 | 0.044 | 0.044 | 0.044 | 0.22 | 0.058 | 0.062 | 0.07 | 0.06 | 0.05 | 0.575 |
| 135 | | | | | | | | | | | | |
| 136 | 0.104 | 0.15 | 0.084 | 0.074 | 0.121 | 0.21 | 0.074 | 0.065 | 0.082 | 0.091 | 0.184 | 0.758 |
| 137 | 0.148 | 0.121 | 0.061 | 0.222 | 0.067 | 0.138 | | | | | 0.337 | 0.588 |
| 138 | | | | | | | | | | | | |
| 139 | | | | | | | | | | | | |
| 140 * | | | | | | | | | | | | |
| 141 | 0.065 | 0.067 | 0.057 | 0.07 | 0.342 | 0.312 | 0.148 | 0.061 | 0.052 | 0.048 | 0.095 | 0.099 |
| 142 | 0.061 | 0.225 | 0.065 | 0.063 | 0.087 | 0.312 | 0.07 | 0.067 | 0.07 | 0.067 | 0.059 | 1.005 |
| 143 | 0.104 | 0.08 | 0.065 | 0.065 | 0.176 | 0.288 | 0.082 | 0.078 | 0.084 | 0.078 | 0.076 | 0.607 |
| 144 | 0.067 | 0.142 | 0.07 | 0.074 | 0.11 | 0.189 | 0.074 | 0.074 | 0.07 | 0.074 | 0.14 | 0.639 |
| 145 | | | | | | | | | | | | |
| 146 | 0.074 | 0.08 | 0.065 | 0.07 | 0.078 | 0.116 | 0.095 | 0.082 | 0.074 | 0.074 | 0.133 | 0.911 |
| 147 | | 0.278 | 0.138 | 0.078 | 0.146 | 0.32 | 0.08 | 0.07 | 0.07 | 0.061 | 0.099 | 0.726 |
| 148 | 0.069 | 0.129 | 0.082 | 0.077 | 0.155 | 0.305 | 0.073 | 0.071 | 0.062 | 0.066 | 0.066 | 1.027 |
| 149 | 0.06 | 0.06 | 0.056 | 0.069 | 0.099 | 0.292 | 0.058 | 0.056 | 0.066 | 0.064 | 0.17 | 0.913 |
| 150 | 0.062 | 0.129 | 0.069 | 0.069 | 0.222 | 0.34 | 0.064 | 0.064 | 0.069 | 0.069 | 0.073 | 0.952 |
| 151 | 0.433 | 0.519 | 0.129 | 0.125 | 0.658 | 0.732 | 0.112 | 0.116 | 0.116 | 0.125 | 0.424 | 0.84 |
| 153 | | | | | | | | | | | | |
| 154 | 0.108 | 0.311 | 0.108 | 0.103 | 0.268 | 0.27 | 0.112 | 0.099 | 0.103 | 0.097 | 0.173 | 0.251 |
| 155 * | 0.081 | 0.088 | 0.077 | 0.077 | 0.112 | 0.19 | 0.064 | 0.062 | 0.069 | 0.064 | 0.22 | 0.641 |
| 156 | | 0.22 | 0.112 | 0.073 | 0.095 | 0.307 | 0.207 | 0.116 | 0.116 | 0.118 | 0.207 | 0.519 |
| 157 | 0.082 | 0.207 | 0.092 | 0.092 | 0.231 | 1.045 | 0.08 | 0.086 | 0.088 | 0.09 | 0.251 | 0.843 |
| 158 | | | | | | | | | | | | |
| 159 | 0.251 | 0.346 | 0.104 | 0.11 | 0.239 | 0.358 | 0.092 | 0.1 | 0.108 | 0.123 | 0.115 | 0.7 |
| 160 | | | | | | | | | | | | |
| 161 | 0.096 | 0.414 | 0.115 | 0.112 | 0.247 | 0.775 | 0.096 | 0.1 | 0.119 | 0.127 | 0.235 | 0.588 |
| 162 | | | | | | | | | | | | |
| | 0.529 | 0.447 | 0.119 | 0.121 | 1.139 | 1.101 | 0.119 | 0.33 | 0.119 | 0.135 | 0.207 | 0.859 |
| 164 | | | | | | | | | | | | |
| 165 | 0.398 | 0.41 | 0.147 | 0.149 | 0.414 | 0.302 | 0.302 | 0.334 | 0.141 | 0.163 | 0.195 | 0.605 |
| 166 | | | | | | | | | | | | |
| 167 | | | | | | | | | | | | |
| 168 | 0.485 | 0.477 | 0.207 | 0.183 | 0.469 | 0.386 | 0.187 | 0.247 | 0.207 | 0.242 | 0.277 | 0.678 |
| 169 | | | | | | | | | | | | |
| 170 | 0.183 | 0.259 | 0.129 | 0.147 | 0.31 | 0.485 | 0.112 | 0.104 | 0.102 | 0.102 | 0.199 | 0.97 |
| 171 | 0.104 | 0.121 | 0.113 | 0.127 | 0.227 | 0.505 | 0.112 | 0.119 | 0.108 | 0.11 | 0.31 | 0.851 |
| 172 * | 0.094 | 0.121 | 0.094 | 0.09 | 0.215 | 0.4 | 0.096 | 0.115 | 0.102 | 0.098 | 0.119 | 0.444 |
| 173 | | | | | | | | | | | | |

NITRITES (mg/l)

| DAY # | | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 174 | | | | | | | | | | | | | |
| 175 | | 0.108 | 0.115 | 0.098 | 0.092 | 0.314 | 0.3 | 0.117 | 0.113 | 0.102 | 0.137 | 0.225 | 0.334 |
| 176 | | 0.196 | 0.247 | 0.16 | 0.155 | 0.208 | 0.734 | 0.16 | 0.164 | 0.16 | 0.16 | 0.235 | 0.698 |
| 177 | | | | | | | | | | | | | |
| 178 | | 0.251 | 0.241 | 0.132 | 0.132 | 0.237 | 1.197 | 0.185 | 0.169 | 0.146 | 0.144 | 0.283 | 0.894 |
| 179 | | 0.228 | 0.224 | 0.142 | 0.137 | 0.265 | 0.949 | 0.224 | 0.196 | 0.192 | 0.196 | 0.329 | 1.1 |
| 180 | | | | | | | | | | | | | |
| 181 | | | | | | | | | | | | | |
| 182 | * | 0.137 | 0.148 | 0.133 | 0.121 | 0.205 | 0.383 | | 0.169 | 0.139 | 0.146 | 0.201 | 0.721 |
| 183 | | 0.169 | 0.187 | 0.133 | 0.121 | 0.196 | 0.452 | 0.142 | 0.137 | 0.139 | 0.13 | 0.123 | 0.789 |
| 184 | | | | | | | | | | | | | |
| | ADD | | | | | | | | | | | | |
| 185 | * | 0.128 | 0.128 | 0.142 | 0.139 | 0.333 | 0.88 | 0.142 | 0.14 | 0.123 | 0.121 | 0.392 | 0.294 |
| 186 | | 0.105 | 0.096 | 0.107 | 0.121 | 0.125 | 0.117 | 0.178 | 0.158 | 0.113 | 0.109 | 0.125 | 0.231 |
| 187 | | | | | | | | | | | | | |
| 188 | | 0.105 | 0.1 | 0.096 | 0.109 | 0.117 | 0.756 | 0.1 | 0.121 | 0.127 | 0.1 | 1.263 | 0.305 |
| 189 | | 0.123 | 0.117 | 0.109 | 0.129 | 0.129 | 0.887 | 0.141 | 0.133 | 0.113 | 0.137 | 0.248 | 0.477 |
| 190 | | 0.1 | 0.092 | 0.094 | 0.107 | 0.121 | 0.825 | 0.166 | 0.137 | 0.096 | 0.094 | 0.211 | 0.567 |
| 191 | | 0.105 | 0.117 | 0.121 | 0.125 | 0.162 | 0.69 | 0.131 | 0.125 | 0.106 | 0.125 | 0.182 | 0.256 |
| 192 | | 0.113 | 0.105 | 0.1 | 0.107 | 0.139 | 0.34 | 0.137 | 0.117 | 0.1 | 0.096 | 0.223 | 0.522 |
| 193 | | 0.117 | 0.113 | 0.096 | 0.105 | 0.17 | 0.534 | 0.113 | 0.117 | 0.094 | 0.096 | 0.115 | 0.342 |
| 194 | | | | | | | | | | | | | |
| 195 | | 0.129 | 0.125 | 0.129 | 0.129 | 0.129 | 0.274 | 0.227 | 0.141 | 0.127 | 0.121 | 0.174 | 0.236 |
| 196 | | 0.219 | 0.182 | 0.121 | 0.117 | 0.131 | 0.551 | 0.121 | 0.125 | 0.105 | 0.105 | 0.383 | 0.145 |
| 197 | | 0.095 | 0.174 | 0.119 | 0.121 | 0.141 | 0.273 | | 0.302 | 0.129 | 0.116 | 0.261 | 0.351 |
| 198 | * | 0.177 | 0.196 | 0.1 | 0.119 | 0.172 | 0.37 | 0.194 | 0.174 | 0.08 | 0.08 | 0.65 | 0.481 |
| 199 | | 0.129 | 0.24 | 0.119 | 0.129 | 0.129 | 0.322 | 0.211 | 0.189 | 0.119 | 0.114 | 0.131 | 0.414 |
| 200 | | 0.104 | 0.104 | 0.104 | 0.112 | 0.189 | | 0.177 | 0.124 | 0.085 | 0.080 | 0.235 | 0.245 |
| 201 | | | | | | | | | | | | | |
| 202 | | 0.095 | 0.1 | 0.09 | 0.102 | 0.124 | 0.223 | 0.177 | 0.133 | 0.1 | 0.097 | 0.187 | 0.153 |
| 203 | | 0.114 | 0.114 | 0.09 | 0.097 | 0.269 | 0.201 | 0.194 | 0.179 | 0.112 | 0.109 | 0.240 | 0.158 |
| 204 | | 0.138 | 0.124 | 0.104 | 0.119 | 0.447 | 0.365 | 0.269 | 0.16 | 0.148 | 0.133 | 0.17 | 0.476 |
| 205 | | 0.262 | 0.266 | 0.124 | 0.134 | 0.328 | 0.456 | 0.293 | 0.213 | 0.132 | 0.136 | 0.304 | 0.707 |
| 206 | | 0.227 | 0.208 | 0.12 | 0.132 | 0.169 | 0.192 | 0.281 | 0.188 | 0.126 | 0.130 | 0.184 | 0.335 |
| 207 | | 0.184 | 0.173 | 0.116 | 0.14 | 0.132 | 0.43 | 0.312 | 0.256 | 0.103 | 0.141 | 0.281 | 0.467 |
| 210 | * | 0.262 | 0.192 | 0.142 | 0.134 | | | 0.177 | 0.175 | 0.13 | 0.134 | | |
| 211 | | 0.134 | 0.146 | 0.124 | 0.126 | 0.219 | | 0.262 | 0.206 | 0.134 | 0.128 | 0.312 | |
| 212 | | 0.126 | 0.138 | 0.116 | 0.118 | 0.128 | 0.182 | 0.178 | 0.217 | 0.14 | 0.138 | 0.138 | 0.196 |
| 213 | | 0.116 | 0.134 | 0.12 | 0.126 | 0.118 | 0.242 | 0.142 | 0.157 | 0.122 | 0.118 | 0.141 | 0.235 |
| 214 | | 0.368 | 0.244 | 0.146 | 0.147 | 0.122 | 0.171 | 0.13 | 0.138 | 0.128 | 0.12 | 0.202 | 0.149 |
| 216 | | 0.138 | 0.134 | 0.126 | 0.126 | 0.177 | 0.169 | 0.498 | 0.261 | 0.169 | 0.143 | 0.223 | 0.188 |
| 217 | | 0.114 | 0.185 | 0.079 | 0.079 | 0.085 | 0.371 | 0.114 | 0.263 | 0.088 | 0.092 | 0.128 | 0.633 |
| 218 | | 0.249 | 0.179 | 0.088 | 0.079 | 0.172 | 0.322 | 0.894 | 0.517 | 0.099 | 0.079 | 0.103 | 0.238 |
| 219 | | 0.134 | 0.201 | 0.083 | 0.097 | 0.101 | 0.486 | 0.69 | 0.278 | 0.094 | 0.092 | 0.194 | 0.407 |
| 220 | | 0.092 | 0.11 | 0.068 | 0.07 | 0.112 | 0.154 | 0.256 | 0.167 | 0.088 | 0.074 | 0.092 | 0.159 |
| 221 | | 0.216 | 0.291 | 0.11 | 0.07 | 0.119 | 0.079 | 0.369 | 0.205 | 0.124 | 0.108 | 0.238 | 0.293 |
| 223 | | 0.085 | 0.163 | 0.074 | 0.074 | 0.061 | 0.063 | 0.101 | 0.234 | 0.145 | 0.123 | 0.066 | 0.079 |
| 224 | * | 0.31 | 0.184 | 0.12 | 0.116 | 0.086 | 0.31 | 0.127 | 0.19 | 0.101 | 0.12 | 0.129 | 0.4 |
| 225 | | 0.111 | 0.1 | 0.092 | 0.098 | 0.111 | 0.177 | 0.167 | 0.136 | 0.082 | 0.084 | 0.177 | 0.309 |
| 226 | | 0.347 | 0.378 | 0.113 | 0.115 | 0.237 | 0.556 | 0.353 | 0.284 | 0.117 | 0.119 | 0.256 | 0.645 |
| 227 | | 0.208 | 0.233 | 0.098 | 0.1 | 0.218 | 0.376 | 0.355 | 0.22 | 0.115 | 0.09 | 0.185 | 0.688 |
| 228 | | 0.131 | 0.14 | 0.09 | 0.686 | 0.09 | 0.251 | 0.165 | 0.136 | 0.076 | 0.078 | 0.078 | 0.231 |

NITRITES (mg/l)

| DAY # | 1 C | 2 C | 3 C | 4 C | 5 C | E C | 1 E | 2 E | 3 E | 4 E | 5 E | E E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 229 | | | | | | | | | | | | |
| 230 | 0.14 | 0.14 | 0.1 | 0.09 | 0.131 | 0.262 | 0.129 | 0.127 | 0.084 | 0.082 | 0.193 | 0.21 |
| 231 | 0.111 | 0.096 | 0.09 | 0.102 | 0.069 | 0.752 | 0.144 | 0.158 | 0.088 | 0.078 | 0.115 | 0.819 |
| 232 | 0.123 | 0.144 | 0.127 | 0.173 | 0.071 | 0.93 | 0.127 | 0.104 | 0.123 | 0.131 | 0.107 | 0.465 |
| 233 | 0.196 | 0.268 | 0.107 | 0.102 | 0.098 | 0.736 | 0.278 | 0.229 | 0.111 | 0.094 | 0.156 | 0.719 |
| 234 * | 0.14 | 0.138 | 0.082 | 0.084 | 0.125 | 0.657 | 0.241 | 0.152 | 0.092 | 0.08 | 0.144 | 0.547 |
| 235 | 0.1 | 0.104 | 0.073 | 0.08 | 0.136 | 0.237 | 0.104 | 0.102 | 0.069 | 0.078 | 0.109 | 0.297 |
| 236 | 0.098 | 0.08 | 0.082 | | 0.1 | 0.297 | 0.117 | 0.1 | 0.078 | 0.086 | 0.167 | 0.268 |
| 237 | 0.253 | 0.247 | 0.053 | 3.323 | 0.096 | 1.58 | 0.241 | 0.177 | 0.064 | 0.079 | 0.236 | 0.591 |
| 238 | 0.219 | 0.27 | 0.051 | 0.07 | 0.034 | 0.967 | 0.207 | 0.175 | 0.058 | 0.058 | 0.066 | 0.919 |
| 239 | 0.134 | 0.092 | 0.06 | 0.075 | 0.053 | 0.536 | 0.119 | 0.132 | 0.062 | 0.079 | 0.156 | 0.812 |
| 240 | 0.153 | 0.139 | 0.045 | 0.041 | 0.066 | 0.283 | 0.049 | 0.115 | 0.041 | 0.045 | 0.07 | 0.598 |
| 241 | 0.134 | 0.126 | 0.047 | 0.064 | 0.107 | 0.676 | 0.226 | 0.268 | 0.224 | 0.153 | 0.153 | 0.742 |
| 242 | 0.088 | 0.079 | 0.045 | 0.047 | 0.049 | 0.183 | 0.147 | 0.126 | 0.081 | 0.079 | 0.117 | 0.334 |
| 243 | 0.092 | 0.134 | 0.47 | 0.036 | 0.147 | 5.36 | 0.073 | 0.07 | 0.04 | 0.039 | 0.211 | 4.52 |
| REMC | | | | | | | | | | | | |
| 245 | 0.036 | 0.039 | 0.036 | 0.039 | 0.066 | 0.1 | 0.066 | 0.045 | 0.039 | 0.049 | 0.096 | 0.088 |
| 247 * | 0.047 | 0.051 | 0.043 | 0.047 | 0.043 | 0.151 | 0.062 | 0.081 | 0.043 | 0.128 | 0.034 | 0.039 |
| 249 | 0.041 | 0.039 | 0.032 | 0.062 | 0.224 | 0.096 | 0.083 | 0.045 | 0.036 | 0.039 | 0.119 | 0.228 |
| 250 | 0.149 | 0.14 | 0.132 | 0.132 | 0.151 | 0.917 | 0.316 | 0.241 | 0.149 | 0.138 | 0.272 | 0.766 |
| 251 | 0.138 | 0.171 | 0.136 | 0.136 | 0.167 | 0.606 | 0.191 | 0.169 | 0.136 | 0.14 | 0.298 | 0.452 |
| 252 | 0.178 | 0.167 | 0.138 | 0.136 | 0.151 | 0.189 | 0.296 | 0.274 | 0.158 | 0.149 | 0.202 | 0.287 |
| 254 | 0.162 | 0.153 | 0.153 | 0.162 | 0.201 | 0.289 | 0.349 | 0.266 | 0.157 | 0.157 | 0.174 | 0.464 |
| 256 * | 0.245 | 0.251 | 0.157 | 0.291 | 0.193 | 0.349 | 0.349 | 0.291 | 0.187 | 0.162 | 0.178 | 0.337 |
| 257 | 0.262 | 0.341 | 0.195 | 0.207 | 0.178 | 0.629 | 0.316 | 0.251 | 0.17 | 0.195 | 0.251 | 1.069 |
| 258 | 0.237 | 0.249 | 0.178 | 0.164 | 0.157 | 0.458 | 0.524 | 0.328 | 0.187 | 0.22 | 0.251 | 0.791 |
| 259 | 0.27 | 0.311 | 0.166 | 0.164 | 0.175 | 0.508 | 0.636 | 0.302 | 0.166 | 0.171 | 0.238 | 1.143 |
| 260 | 0.241 | 0.232 | 0.162 | 0.171 | 0.171 | 0.372 | 0.251 | 0.245 | 0.183 | 0.188 | 0.232 | 0.432 |
| 261 | 0.162 | 0.166 | 0.162 | 0.162 | 0.171 | 0.362 | 0.224 | 0.228 | 0.162 | 0.162 | 0.209 | 0.379 |
| 263 | 0.177 | 0.16 | 0.16 | 3.95 | 0.315 | 0.459 | 0.168 | 0.255 | 0.158 | 0.266 | 0.228 | 0.676 |
| 264 | 0.16 | 0.16 | 0.156 | 5.122 | 0.302 | 3.247 | 0.3 | 0.281 | 0.162 | 0.523 | 0.442 | 3.294 |
| 265 | 0.168 | 0.168 | 0.2 | 4.513 | 0.179 | 0.697 | 0.173 | 0.183 | 0.23 | 0.185 | 0.162 | 0.867 |
| 266 | 0.221 | 0.181 | 0.164 | 4.513 | 0.209 | 0.629 | 0.379 | 0.334 | 0.171 | 0.774 | 0.251 | 0.888 |
| 267 | 0.421 | 0.312 | 0.304 | 4.469 | 0.323 | 0.398 | 0.346 | 0.321 | 0.304 | 4.206 | 0.326 | 0.546 |
| 270 * | 0.303 | 0.301 | 0.301 | 3.789 | 0.312 | 0.375 | 0.303 | 0.309 | 0.297 | 0.304 | 0.316 | 0.362 |
| 271 | 0.309 | 0.309 | 0.3 | 0.718 | 0.336 | 0.426 | 0.337 | 0.326 | 0.303 | 0.309 | 0.347 | 0.84 |
| 272 | 0.307 | 0.316 | 0.301 | 0.301 | 0.315 | 0.423 | 0.316 | 0.315 | 0.298 | 0.298 | 0.326 | 0.482 |
| 275 | 0.328 | 0.319 | 0.309 | 0.314 | 0.407 | 0.507 | 0.316 | 0.333 | 0.312 | 0.307 | 0.418 | 0.657 |
| 276 | 0.21 | 0.367 | 0.2 | 0.194 | 0.331 | 0.309 | 0.344 | 0.316 | 0.188 | 0.197 | 0.235 | 0.419 |
| 277 | 0.175 | 0.225 | 0.163 | 0.17 | 0.224 | 0.4 | 0.214 | 0.21 | 0.163 | 0.16 | 0.224 | 0.514 |
| 279 | 0.175 | 0.173 | 0.167 | 0.855 | 0.22 | 0.264 | 0.17 | 0.2 | 0.162 | 0.175 | 0.224 | 0.4 |
| 280 | 0.19 | 0.19 | 0.167 | 0.451 | 0.264 | 0.859 | 0.217 | 0.177 | 0.195 | 0.219 | 1.243 | 0.181 |
| 281 | 0.277 | 0.234 | 0.204 | 0.765 | 0.254 | 0.568 | 0.237 | 0.22 | 0.177 | 0.225 | 0.538 | 0.768 |
| 288 | 0.183 | 0.204 | 0.182 | 0.173 | 0.254 | 0.414 | 0.21 | 0.234 | 0.2 | 0.173 | 0.371 | 0.615 |
| 289 | 0.21 | 0.22 | 0.222 | 1.202 | 0.264 | 6.042 | 0.306 | 0.289 | 0.193 | 0.207 | 0.546 | 1.063 |

# A2.29

# AVERAGES FOR EACH STEADY STATE PERIOD

**LABORATORY RESULTS**

| PERIOD NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| DSVI C | 176.1 | 124.3 | 108.8 | 122.3 | 133.7 | 150.2 | 145.5 | 139.7 | 147.4 |
| DSVI E | 171.4 | 128.8 | 114 | 130.7 | 157.8 | 169.4 | 139.5 | 106.5 | 125.9 |
| MLSS C | 3.271 | 3.26 | 3.257 | 3.365 | 3.038 | 3.306 | 3.143 | 3.287 | 3.310 |
| MLSS E | 3.479 | 3.173 | 3.454 | 3.571 | 3.213 | 3.269 | 3.291 | 3.454 | 3.328 |
| VSS C | 2.827 | 2.723 | 2.725 | 2.741 | 2.574 | 2.753 | 2.664 | 2.773 | 2.726 |
| VSS E | 2.978 | 2.623 | 2.8 | 2.782 | 2.591 | 2.728 | 2.716 | 2.875 | 2.769 |
|  | 0.864 | 0.835 | 0.837 | 0.815 | 0.847 | 0.833 | 0.848 | 0.844 | 0.826 |
|  | 0.856 | 0.827 | 0.811 | 0.779 | 0.806 | 0.835 | 0.826 | 0.832 | 0.826 |
| TKN IN | 103 | 79 | 110 | 89 | 99 | 81 | 89 | 94 | 103 |
| TKN EFF C | 4.9 | 4.8 | 4.3 | 3.5 | 4.6 | 4.8 | 4.8 | 5.0 | 5.0 |
| TKN EFF E | 4.8 | 4.3 | 4.3 | 3.7 | 4.6 | 4.4 | 5.0 | 5.0 | 4.9 |
| COD IN | 1009 | 979 | 998 | 986 | 1013 | 1005 | 995 | 1011 | 1030 |
| COD EFF C | 66.8 | 62.2 | 57.4 | 70.2 | 71 | 58.8 | 53.1 | 51.0 | 89.1 |
| COD EFF E | 59.1 | 59.3 | 56.1 | 66.9 | 72.9 | 66.2 | 52.8 | 55.9 | 65.5 |
| pH C | 7.9 | 7.9 | 7.8 | 7.9 | 7.8 | 7.8 | 7.91 | 7.84 | 7.74 |
| pH E | 8.4 | 7.8 | 7.9 | 7.9 | 7.8 | 7.9 | 7.85 | 7.79 | 7.75 |
| OUR C | 29.6 | 30.6 | 46.5 | 34.1 | 30 | 30 | 30.0 | 32.8 | 36.0 |
| OUR E | 29.8 | 30.1 | 45.9 | 34.2 | 30 | 30 | 31.4 | 35.9 | 37.4 |
| PHOSPHATE |  |  |  |  |  |  |  |  |  |
| I | 20.4 | 19.4 | 19.3 | 19.9 | 20.8 | 21.2 | 20.7 | 20.1 | 22.3 |
| 1 C | 31.2 | 39.2 | 33.8 | 30.8 | 29.8 | 31.9 | 29.0 | 29.5 | 32.4 |
| 2 C | 32.2 | 41.4 | 36.3 | 33.2 | 34.1 | 37.7 | 34.2 | 34.8 | 39.3 |
| 3 C | 32.8 | 36.2 | 28 | 24.3 | 25.6 | 31.9 | 29.0 | 29.8 | 32.0 |
| 4 C | 18.2 | 20.5 | 15.8 | 13.5 | 14.1 | 19.1 | 19.1 | 16.8 | 16.5 |
| 5 C | 11.7 | 8.2 | 7.8 | 9.2 | 9.6 | 9.2 | 12.9 | 10.1 | 10.7 |
| E C | 11 | 5.7 | 6.9 | 7.2 | 7.7 | 8.2 | 12.2 | 9.5 | 10.3 |
| 1 E | 33.3 | 41.3 | 33 | 31.4 | 33.1 | 33.3 | 29.5 | 28.9 | 32.0 |
| 2 E | 35.1 | 43.9 | 39.5 | 34.4 | 36.6 | 39.4 | 33.8 | 33.7 | 37.8 |
| 3 E | 36.8 | 39.1 | 29.3 | 25.2 | 26.6 | 33.3 | 28.6 | 29.1 | 30.5 |
| 4 E | 23.9 | 20.4 | 15.6 | 13.1 | 14.3 | 20.7 | 18.3 | 16.9 | 17.0 |
| 5 E | 14.5 | 7.4 | 14.5 | 8.9 | 8.3 | 10.1 | 11.9 | 9.5 | 10.5 |
|  | 11.3 | 4.8 | 5.7 | 5.9 | 6.5 | 9.2 | 10.8 | 8.8 | 9.9 |
|  | 9.4 | 13.7 | 12.4 | 12.7 | 13.1 | 13.2 | 8.1 | 10.6 | 10.6 |
|  | 9.2 | 14.8 | 13.6 | 14 | 14.4 | 12.1 | 8.8 | 11.3 | 10.8 |

NITRITE

| PERIOD NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.078 | 0.099 | 0.078 | 0.099 | 0.1 | 0.11 | 0.138 | 0.168 | 0.202 |
| 2 C | 0.056 | 0.086 | 0.056 | 0.086 | 0.103 | 0.108 | 0.144 | 0.169 | 0.209 |
| 3 C | 0.042 | 0.117 | 0.042 | 0.117 | 0.134 | 0.112 | 0.110 | 0.092 | 0.189 |
| 4 C | 0.092 | 0.318 | 0.092 | 0.318 | 0.438 | 0.24 | 0.120 | 0.228 | 1.114 |
| 5 C | 0.133 | 3.369 | 0.133 | 3.369 | 2.295 | 0.71 | 0.183 | 0.113 | 0.223 |
| E C | 0.291 | 3.27 | 2.203 | 0.624 | 0.38 | 0.477 | 0.457 | 0.429 | 0.880 |
| 1 E | 0.045 | 0.092 | 0.045 | 0.092 | 0.103 | 0.114 | 0.188 | 0.237 | 0.269 |
| 2 E | 0.046 | 0.095 | 0.046 | 0.095 | 0.1 | 0.102 | 0.162 | 0.192 | 0.238 |
| 3 E | 0.052 | 0.104 | 0.052 | 0.104 | 0.132 | 0.114 | 0.112 | 0.104 | 0.178 |
| 4 E | 0.053 | 0.366 | 0.053 | 0.366 | 0.517 | 0.25 | 0.112 | 0.099 | 0.349 |
| 5 E | 0.09 | 3.345 | 0.09 | 3.345 | 1.909 | 0.591 | 0.298 | 0.153 | 0.299 |
| E E | 0.168 | 3.867 | 2.196 | 0.433 | 0.875 | 0.73 | 0.358 | 0.435 | 0.786 |

TOTAL $(NO_3+NO_2 = NO_x)$

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.723 | 0.353 | 0.723 | 0.353 | 0.323 | 0.372 | 0.151 | 0.289 | 0.214 |
| 2 C | 0.203 | 0.156 | 0.203 | 0.156 | 0.253 | 0.374 | 0.138 | 0.276 | 0.185 |
| 3 C | 0.266 | 0.198 | 0.266 | 0.198 | 0.428 | 0.383 | 0.096 | 0.146 | 0.116 |
| 4 C | 0.604 | 0.502 | 0.604 | 0.502 | 1.986 | 1.287 | 0.107 | 0.340 | 0.874 |
| 5 C | 8.173 | 7.123 | 8.173 | 7.123 | 16.484 | 11.121 | 7.703 | 10.565 | 10.350 |
| E C | 9.582 | 10.342 | 16.86 | 13.127 | 16.198 | 8.576 | 8.134 | 11.611 | 12.478 |
| 1 E | 0.38 | 0.225 | 0.38 | 0.225 | 0.431 | 0.417 | 0.240 | 0.482 | 0.4 |
| 2 E | 0.198 | 0.153 | 0.198 | 0.153 | 0.276 | 0.31 | 0.168 | 0.290 | 0.251 |
| 3 E | 0.239 | 0.173 | 0.239 | 0.173 | 0.43 | 0.39 | 0.109 | 0.151 | 0.133 |
| 4 E | 0.264 | 0.562 | 0.264 | 0.562 | 2.361 | 1.28 | 0.090 | 0.112 | 0.212 |
| 5 E | 7.783 | 6.875 | 7.783 | 6.875 | 12.667 | 9.44 | 8.567 | 10.995 | 11.643 |
| E E | 9.162 | 10.198 | 16.378 | 12.405 | 15.847 | 7.612 | 9.405 | 11.715 | 13.845 |

NITRATES

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.645 | 0.259 | 0.645 | 0.259 | 0.228 | 0.26 | 0.008 | 0.104 | 0.009 |
| 2 C | 0.147 | 0.066 | 0.147 | 0.066 | 0.151 | 0.264 | 0.000 | 0.092 | 0.000 |
| 3 C | 0.224 | 0.077 | 0.224 | 0.077 | 0.285 | 0.27 | 0.000 | 0.046 | 0.000 |
| 4 C | 0.513 | 0.176 | 0.513 | 0.176 | 1.42 | 1.042 | 0.000 | 0.103 | 0.000 |
| 5 C | 8.04 | 3.447 | 8.04 | 3.447 | 12.963 | 10.399 | 7.139 | 8.962 | 8.211 |
| E C | 9.291 | 6.773 | 14.097 | 12.483 | 15.849 | 8.124 | 7.323 | 9.609 | 9.404 |
| 1 E | 0.335 | 0.137 | 0.335 | 0.137 | 0.326 | 0.304 | 0.042 | 0.210 | 0.106 |
| 2 E | 0.152 | 0.056 | 0.152 | 0.056 | 0.174 | 0.209 | 0.018 | 0.084 | 0.011 |
| 3 E | 0.187 | 0.066 | 0.187 | 0.066 | 0.284 | 0.275 | 0.000 | 0.040 | 0 |
| 4 E | 0.211 | 0.187 | 0.211 | 0.187 | 1.729 | 1.03 | 0.045 | 0.011 | 0 |
| 5 E | 7.693 | 3.37 | 7.693 | 3.37 | 10.679 | 8.849 | 6.821 | 9.298 | 9.198 |
| E E | 8.994 | 6.231 | 13.748 | 11.971 | 15.009 | 6.906 | 7.903 | 9.694 | 10.589 |
| SBSI | 163 | 121 | 142 | 143 | 205 | 231 | 207 | 221 | 318 |

# APPENDIX 3

## NITROGEN AND COD MASS BALANCES

### 4.1 NITROGEN BALANCE

Nitrogen Balance =

$(MN_{te} + MN_{nc} + MN_s + MN_d) / (MN_{ti}) \times 100\%$

where

$MN_{ti}$ = mass of TKN in influent (mgN/d)

$MN_{te}$ = mass of TKN in the effluent (mgN/d)

$MN_{nc}$ = mass of nitrate + nitrite in effluent (mgN/d)

$MN_s$ = mass of N required for sludge production (mgN/d)

= mass of sludge wasted per day

= $f_n$ x mass of VSS wasted per day

$f_n$ = TKN/VSS ratio of the sludge taken as 0.1 mgN/mgVSS

The mass of nitrate ($NO_3$) and nitrite ($NO_2$) denitrified daily can be calculated from a $NO_x$ ($NO_x = NO_3 + NO_2$) mass balance on the anoxic reactors by subtracting the mass of $NO_x$ leaving the reactor from that entering the reactor. This is expressed mathematically as follows:

First anoxic reactor: $MN_d = MN_{ns} - MN_{n3}$

$MN_{ns}$= nitrate and nitrite mass recycled to anoxic reactor via the s recycle from the settler (mgN/d)

$MN_{n3}$= nitrate and nitrite leaving the first anoxic reactor (reactor 3)

$MO_d = 2.86 \times MN_d$ (mgO/d)

$MO_n = 4.57 \times MN_c$ (mgO/d)

$MN_c = MN_d + MN_{ne}$ (mgN/d)

or $= MN_{ti} - MN_{te} - MN_{sw}$ (mgN/d)

The two ways of calculating $MN_c$ will give identical results if the N balance is 100% because the latter way assumes 100% N balance; a difference will result if the balance is not 100%, the magnitude of the difference being related to the accuracy of the N balance. The calculated $MO_d$ and $MO_n$ values are required in the COD balance.

## 4.2 COD BALANCE

Mathematically, the COD balance may be expressed as follows:

COD balance = $(MS_{te} + MS_{ws} + MO_c) \times 100 \times (1/MS_{ti})$ %

The carbonaceous oxygen demand, $MO_c$ was calculated as follows:

$MO_c = MO_{tm} + MO_d - MO_n$ (mgO/d)

where

$MO_c$ = mass of oxygen required for COD utilisation (mgO/d)

$MO_d$ = mass of oxygen recovered through denitrification obtained from the N balance. (mgO/d)

$MO_n$ = mass of oxygen required for nitrification (mgO/d)

$MO_{tm}$ = measured mass of oxygen consumed daily in the aerobic reactor

$= (OUR \times 24 \times V_{aer})$ (mgO/d) where

OUR = measured oxygen utilisation rate (mgO/l/hr)

$V_{aer}$ = volume of the aerobic reactor (l)

The OUR was measured by discontinuing the air supply to the aerobic reactor and then monitoring the dissolved oxygen (DO) concentration-time profile. The DO was increased to around 6mgO/l and allowed to decrease to below 1 mg/l. The DO concentration was plotted with time on a strip-chart recorder and the slope of the DO vs time plot was accepted as the biological OUR in mgO/l/h. The air supply was restored immediately after the OUR test. The measured OUR comprises both oxygen utilisation for COD degradation and nitrification ($MO_n$). Knowing the mass of oxygen consumed daily ($MO_{tm}$) from the measured OUR, the carbonaceous oxygen demand $MO_c$ was calculated by adding $MO_d$ and subtracting $MO_n$ obtained from the N balance. The other parameters required for the COD balance were as follows:

Mass COD in the effluent ($MS_{te}$) (mgCOD/d)
= Effluent COD concentration ($S_{te}$) * flowrate (Q)

Mass COD in the wasted sludge ($MS_{ws}$)
= COD/VSS ratio ($f_{cv}$) * mass VSS wasted daily
= 1.48 mgCOD/mgVSS * 1 l/day * aerobic reactor VSS concentration

The results of the COD and N mass balances for each steady state period are listed overleaf.

| | C | E | C | E | C | E | C | E | C | E | C | E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STEADY STATE PERIOD NO. | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| **4. NITROGEN MASS BALANCE** | | | | | | | | | | | | |
| Influent TKN | 1028 | | 789 | | 1101 | | 894 | | 985 | | 814 | |
| Effluent TKN | 49 | 44.8 | 48 | 45.1 | 43 | 45.7 | 35 | 46.0 | 46 | 47.8 | 48 | 44.0 |
| N VSS | 282.7 | 273.0 | 272.3 | 271.9 | 272.5 | 273.0 | 274.1 | 274.3 | 257.4 | 273.6 | 275.3 | 272.8 |
| Effluent nit | 95.82 | 91.6 | 103.42 | 102.0 | 168.6 | 163.8 | 131.27 | 124.1 | 161.98 | 158.5 | 85.76 | 76.1 |
| Denitrificat | 340.3 | 356.4 | 326.4 | 328.3 | 444.4 | 464.6 | 366.2 | 361.4 | 600.9 | 487.9 | 374.6 | 327.0 |
| Balance | 74.7 | 74.5 | 95.1 | 94.7 | 84.3 | 86.0 | 90.2 | 90.1 | 108.3 | 98.2 | 96.3 | 88.4 |
| **5. COD BALANCE** | | | | | | | | | | | | |
| MSTI | 10092 | | 9787 | | 9978 | | 9857 | | 10134 | | 10054 | |
| MSus | 668 | 591 | 622 | 593 | 574 | 561 | 702 | 669 | 710 | 729 | 588 | 662 |
| Waste | 4184 | 4407 | 4030 | 3882 | 4033 | 4144 | 4057 | 4117 | 3810 | 3835 | 4074 | 4037 |
| OUR | 3598 | 3621 | 3743 | 3668 | 5724 | 5617 | 4093 | 4150 | 2912 | 3122 | 3648 | 3773 |
| Balance | 83.7 | 85.4 | 85.8 | 83.2 | 103.5 | 103.5 | 89.8 | 90.7 | 73.3 | 75.8 | 82.7 | 84.3 |

DATA CALCULATIONS C:CONTROL E:EXPERIMENT

| | C | E | C | E | C | E | WEIGHTED AVERAGE C | WEIGHTED AVERAGE E |
|---|---|---|---|---|---|---|---|---|
| STEADY STATE PERIOD NO. | 7 | | 8 | | 9 | | | |
| **4. NITROGEN MASS BALANCE** | | | | | | | | |
| Influent TKN | 889 | | 942 | | 1025 | | | |
| Effluent TKN | 47.7 | 49.735 | 50.4 | 50.3 | 49.9 | 49.1 | | |
| N VSS | 266.4 | 271.59 | 277.3 | 287.5 | 272.6 | 276.9 | | |
| Effluent nit | 81.339 | 94.1 | 116.1053 | 117.2 | 124.782 | 138.5 | | |
| Denitrificat | 347.2 | 376.4 | 472.4 | 478.2 | 449.6 | 522.0 | | |
| Balance | 83.5 | 89.1 | 97.3 | 99.1 | 87.5 | 96.2 | 89.70 | 89.29 |
| **5. COD BALANCE** | | | | | | | | |
| MSTI | 9954 | | 10108 | | 10296 | | | |
| MSus | 528 | 531 | 559 | 510 | 655 | 646 | | |
| Waste | 4020 | 3943 | 4255 | 4104 | 4098 | 4034 | | |
| OUR | 3833 | 3716 | 4252 | 3785 | 4309 | 4277 | | |
| Balance | 84.2 | 82.3 | 89.7 | 83.1 | 88.0 | 87.0 | 84.46 | 83.81 |

# APPENDIX 5

## THE r LINEAR CORRELATION COEFFICIENT

Statistical correlation is used to establish whether there is a relationship between two groups of variables. The data from the two groups are plotted on the X and Y axes of an X-Y graph, and if they are linearly related, the data should lie on a straight line. The "best fit" straight line is defined by the stipulation that the sum of the squares of the vertical difference between the observed values and the fitted line should be a minimum. If the fit is very good, a linear correlation can be established. If the fit is very poor (large scatter), no linear relationship can be confirmed. The goodness of fit is measured by the correlation coefficient. We use r for the correlation coefficient and define it by the formula

$$r=\frac{\sum (x_i-X)\ \ (y_i-Y}{\sqrt{\sum (x_i-X)^2 \sum (y_i-Y)^2}}$$

where X = mean X value   Y = mean Y value

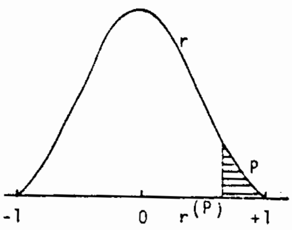
The correlation coefficient always lies between -1 and +1. If r is positive, then the regression has a positive slope, and as X increases, so does Y. If r is negative, then the regression line has a negative slope and as X increases, Y decreases.

If r = +1 or -1, the observed data all lie exactly on the regression line. If there is no correlation, r is zero. A correlation between X and Y cannot be proved if r is small.

Thus to establish a correlation between two sets of data, r must first be calculated. The number of data points (N) gives the degrees of freedom = N-2. Since the statistical test is two tailed, the confidence interval (CI) = 1-2P, where P is tabulated in the Table A5. For a 95% CI, let P=0.025.

The value of r in the Table is the minimum allowable value to establish a correlation at the chosen CI. Thus if the calculated value of r is below this value, a correlation cannot be established between the two sets of data. If the value of r is above this value, a correlation is established at the chosen confidence interval.

# TABLE A5: THE r-CORRELATION COEFFICIENT



## TABLE 5 THE CORRELATION COEFFICIENT

The table gives significant values of the correlation coefficient. Remember:
DEGREES OF FREEDOM = SAMPLE SIZE - 2.

| DF \ P | 0.200 | 0.100 | 0,050 | 0,025 | 0,010 | 0,005 | 0,0025 | 0,0010 | 0,0005 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0,8090 | 0,9511 | 0,9877 | 0,9969 | 0,9995 | 0,9999 | 1,0000 | 1,0000 | 1,0000 |
| 2 | 0,6000 | 0,8000 | 0,9000 | 0,9500 | 0,9800 | 0,9900 | 0,9950 | 0,9980 | 0,9990 |
| 3 | 0,4919 | 0,6870 | 0,8054 | 0,8783 | 0,9343 | 0,9587 | 0,9740 | 0,9859 | 0,9911 |
| 4 | 0,4257 | 0,6084 | 0,7293 | 0,8114 | 0,8822 | 0,9172 | 0,9417 | 0,9633 | 0,9741 |
| 5 | 0,3803 | 0,5509 | 0,6694 | 0,7545 | 0,8329 | 0,8745 | 0,9056 | 0,9350 | 0,9509 |
| 6 | 0,3468 | 0,5067 | 0,6215 | 0,7067 | 0,7887 | 0,8343 | 0,8697 | 0,9049 | 0,9249 |
| 7 | 0,3208 | 0,4716 | 0,5822 | 0,6664 | 0,7498 | 0,7977 | 0,8359 | 0,8751 | 0,8983 |
| 8 | 0,2998 | 0,4428 | 0,5494 | 0,6319 | 0,7155 | 0,7646 | 0,8046 | 0,8467 | 0,8721 |
| 9 | 0,2825 | 0,4187 | 0,5214 | 0,6021 | 0,6851 | 0,7348 | 0,7759 | 0,8199 | 0,8470 |
| 10 | 0,2678 | 0,3981 | 0,4973 | 0,5760 | 0,6581 | 0,7079 | 0,7496 | 0,7950 | 0,8233 |
| 11 | 0,2552 | 0,3802 | 0,4762 | 0,5529 | 0,6339 | 0,6835 | 0,7255 | 0,7717 | 0,8010 |
| 12 | 0,2443 | 0,3646 | 0,4575 | 0,5324 | 0,6120 | 0,6614 | 0,7034 | 0,7501 | 0,7800 |
| 13 | 0,2346 | 0,3507 | 0,4409 | 0,5140 | 0,5923 | 0,6411 | 0,6831 | 0,7301 | 0,7604 |
| 14 | 0,2260 | 0,3383 | 0,4259 | 0,4973 | 0,5742 | 0,6226 | 0,6643 | 0,7114 | 0,7419 |
| 15 | 0,2183 | 0,3271 | 0,4124 | 0,4821 | 0,5577 | 0,6055 | 0,6470 | 0,6940 | 0,7247 |
| 16 | 0,2113 | 0,3170 | 0,4000 | 0,4683 | 0.5425 | 0,5897 | 0,6308 | 0,6777 | 0,7084 |
| 17 | 0.2049 | 0,3077 | 0,3887 | 0,4555 | 0.5285 | 0,5751 | 0,6158 | 0,6624 | 0,6932 |
| 18 | 0,1991 | 0,2992 | 0,3783 | 0,4438 | 0,5155 | 0.5614 | 0,6018 | 0,6481 | 0,6788 |
| 19 | 0,1938 | 0,2914 | 0,3687 | 0,4329 | 0,5034 | 0,5487 | 0,5886 | 0,6346 | 0,6652 |
| 20 | 0,1888 | 0,2841 | 0,3598 | 0,4227 | 0,4921 | 0,5368 | 0,5763 | 0,6219 | 0,6524 |
| 21 | 0,1843 | 0,2774 | 0,3515 | 0,4132 | 0,4815 | 0,5256 | 0,5647 | 0,6099 | 0,6402 |
| 22 | 0,1800 | 0,2711 | 0,3438 | 0,4044 | 0,4716 | 0,5151 | 0,5537 | 0,5986 | 0,6287 |
| 23 | 0.1760 | 0,2653 | 0,3365 | 0,3961 | 0,4622 | 0,5052 | 0,5434 | 0,5879 | 0,6178 |
| 24 | 0,1723 | 0,2598 | 0,3297 | 0,3882 | 0,4534 | 0,4958 | 0,5336 | 0,5776 | 0,6074 |
| 25 | 0,1688 | 0,2546 | 0,3233 | 0,3809 | 0,4451 | 0,4869 | 0,5243 | 0,5679 | 0,5974 |
| 26 | 0,1655 | 0,2497 | 0,3172 | 0,3739 | 0,4372 | 0,4785 | 0,5154 | 0,5587 | 0,5880 |
| 27 | 0,1624 | 0,2451 | 0,3115 | 0,3673 | 0,4297 | 0,4705 | 0,5070 | 0,5499 | 0,5790 |
| 28 | 0,1594 | 0,2407 | 0,3061 | 0,3610 | 0,4226 | 0,4629 | 0,4990 | 0,5415 | 0,5703 |
| 29 | 0,1567 | 0,2366 | 0,3009 | 0,3550 | 0,4158 | 0,4556 | 0,4914 | 0,5334 | 0,5621 |
| 30 | 0,1540 | 0,2327 | 0,2960 | 0,3494 | 0,4093 | 0,4487 | 0,4840 | 0,5257 | 0,5541 |
| 31 | 0,1515 | 0,2289 | 0,2913 | 0,3440 | 0,4032 | 0,4421 | 0,4770 | 0,5184 | 0,5465 |
| 32 | 0,1491 | 0,2254 | 0,2869 | 0,3388 | 0,3972 | 0,4357 | 0,4703 | 0,5113 | 0,5392 |
| 33 | 0,1468 | 0,2220 | 0,2826 | 0,3338 | 0,3916 | 0,4296 | 0,4639 | 0,5045 | 0,5322 |
| 34 | 0,1446 | 0,2187 | 0,2785 | 0,3291 | 0,3862 | 0,4238 | 0,4577 | 0,4979 | 0,5254 |
| 35 | 0,1425 | 0,2156 | 0,2746 | 0,3246 | 0.3810 | 0,4182 | 0,4518 | 0,4916 | 0,5189 |
| 36 | 0,1405 | 0,2126 | 0,2709 | 0,3202 | 0,3760 | 0,4128 | 0,4461 | 0,4856 | 0,5126 |
| 37 | 0,1386 | 0,2097 | 0,2673 | 0,3160 | 0,3712 | 0,4076 | 0,4406 | 0,4797 | 0,5066 |
| 38 | 0,1368 | 0,2070 | 0,2638 | 0,3120 | 0,3665 | 0,4026 | 0,4353 | 0,4741 | 0,5007 |
| 39 | 0,1350 | 0,2043 | 0,2605 | 0,3081 | 0,3621 | 0,3978 | 0,4301 | 0,4686 | 0,4950 |
| 40 | 0,1333 | 0.2018 | 0,2573 | 0,3044 | 0,3578 | 0,3932 | 0,4252 | 0,4634 | 0,4896 |
| 45 | 0,1257 | 0,1903 | 0,2429 | 0,2876 | 0,3384 | 0,3721 | 0,4028 | 0,4394 | 0,4647 |
| 50 | 0,1192 | 0,1806 | 0,2306 | 0,2732 | 0,3218 | 0,3542 | 0,3836 | 0,4188 | 0,4432 |
| 60 | 0.1088 | 0,1650 | 0,2108 | 0,2500 | 0,2948 | 0,3248 | 0,3522 | 0,3850 | 0,4079 |
| 70 | 0,1007 | 0,1528 | 0,1954 | 0,2319 | 0,2737 | 0,3017 | 0,3274 | 0,3583 | 0,3798 |
| 80 | 0,0942 | 0,1430 | 0,1829 | 0,2172 | 0,2565 | 0,2830 | 0,3072 | 0,3364 | 0,3568 |
| 90 | 0.0888 | 0.1348 | 0,1726 | 0.2050 | 0.2422 | 0,2673 | 0,2903 | 0,3181 | 0,3376 |
| 100 | 0,0842 | 0,1279 | 0,1638 | 0,1946 | 0,2301 | 0,2540 | 0,2759 | 0,3025 | 0,3211 |
| 110 | 0,0803 | 0,1220 | 0,1562 | 0,1857 | 0,2196 | 0,2425 | 0,2635 | 0,2890 | 0,3068 |
| 120 | 0,0769 | 0,1168 | 0,1496 | 0,1779 | 0,2104 | 0,2324 | 0,2526 | 0,2771 | 0,2943 |
| 140 | 0,0712 | 0,1082 | 0,1386 | 0,1648 | 0,1951 | 0,2155 | 0,2343 | 0,2572 | 0,2733 |
| 160 | 0,0666 | 0,1012 | 0,1297 | 0,1543 | 0,1826 | 0,2019 | 0,2195 | 0,2411 | 0,2562 |
| 180 | 0.0628 | 0,0954 | 0,1223 | 0,1455 | 0,1723 | 0,1905 | 0,2072 | 0,2276 | 0,2420 |
| 200 | 0.0595 | 0,0905 | 0,1161 | 0,1381 | 0.1636 | 0,1809 | 0,1968 | 0,2162 | 0,2298 |

# APPENDIX 6

## THE t-DISTRIBUTION AND STATISTICAL EVALUATION OF DATA

### A6.1 THE t-DISTRIBUTION

In order to establish that two samples have been taken from two dissimilar populations, it is required to quantify the difference between the two samples. It will be assumed that the two populations are the same, unless it can be statistically proven at 95% confidence that they are, in fact different.

The t-statistic for 2 sample populations is a measure of the degree to which the samples differ. The t-statistic is calculated from the sample means, sample standard deviations and the size of each sample.

$$t_{n_1+n_2-2}=\frac{X_1-X_2}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}$$

where: $n_1$ = data points in sample 1

$n_2$ = data points in sample 2

X = sample mean

s = standard deviation

The number $n_1+n_2-2$ gives the degrees of freedom for the test. To establish a difference between the two populations, it is necessary to compare the data $t_{df}$ statistic with the theoretical

$t_{df}$ for the chosen confidence interval. The theoretical t-statistic can be found in standard statistical tables and is shown in Figure A6.1, corresponding to the degrees of freedom and P. The appropriate value of P is calculated from the confidence interval (CI):

$$P = 0.5(1-\frac{CI}{100})$$

If the data $t_{df}$-statistic is greater than the theoretical t-statistic, the 2 populations are proved to be statistically different at the chosen CI.

## A6.2 STATISTICAL EVALUATION OF EXPERIMENTAL DATA

The statistical calculations were done in a spreadsheet programme and the results are listed in Table A6. The following pages of the table are arranged as follows:

| | |
|---|---|
| Initial Baseline Period | A6.3 |
| Zeolite Dosing Period | A6.5 |
| Intermediate Dosing Period | A6.7 |
| HSA Calcite Dosing Period | A6.9 |
| Final Baseline Period | A6.11 |

## INITIAL BASELINE PERIOD

| | MEAN | STD DEV | N | MAX | MIN | F TEST | | DEGREES FREEDOM | POOLED STD DEV | T-STATISTIC | PROBAB-ILITY | STATISTICALLY DIFFERENT ? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DSVI C | 142.7 | 29.5 | 31 | 196.4 | 105.3 | 1.330 | PASS | 60 | 27.57 | -0.170 | <60% | NO |
| DSVI E | 143.9 | 25.5 | 31 | 190 | 110.1 | | | | | | | |
| MLSS C | 3.264 | 0.269 | 34 | 4.053 | 2.742 | 1.763 | FAIL | 63 | | -0.228 | <60% | NO |
| MLSS E | 3.281 | 0.357 | 34 | 4.824 | 2.608 | | | | | | | |
| VSS C | 2.759 | 0.222 | 34 | 3.450 | 2.270 | 1.632 | PASS | 66 | 0.255 | 0.183 | <60% | NO |
| VSS E | 2.748 | 0.284 | 34 | 3.681 | 2.126 | | | | | | | |
| ISS C | 0.504 | 0.099 | 34 | 0.732 | 0.344 | 2.056 | FAIL | 60 | | -0.969 | 60 - 80% | NO |
| ISS E | 0.533 | 0.142 | 34 | 1.143 | 0.240 | | | | | | | |
| TSS/VSS | 0.846 | 0.024 | 34 | 0.897 | 0.798 | 1.693 | FAIL | 63 | | 1.150 | 60 - 80% | NO |
| | 0.838 | 0.031 | 34 | 0.925 | 0.763 | | | | | | | |
| TKN IN | 87 | 17 | 35 | 115 | 61 | | | | | | | |
| TKN EFF C | 4.8 | 1.9 | 35 | 12.9 | 2.0 | 2.600 | FAIL | 58 | | 0.818 | <60% | NO |
| TKN EFF E | 4.5 | 1.2 | 35 | 8.3 | 2.1 | | | | | | | |
| COD IN | 989 | 66 | 35 | 1118 | 861 | | | | | | | |
| COD EFF C | 63.8 | 24.0 | 35 | 131.0 | 32.9 | 2.641 | FAIL | 57 | | 0.969 | 60 - 80% | NO |
| COD EFF E | 59.2 | 14.8 | 35 | 104.0 | 29.0 | | | | | | | |
| pH C | 7.87 | 0.14 | 19 | 8.2 | 7.64 | 4.397 | FAIL | 26 | | -0.522 | <60% | NO |
| pH E | 7.90 | 0.29 | 19 | 8.79 | 7.44 | | | | | | | |
| OUR C | 30.3 | 1.8 | 22 | 34.9 | 26.9 | 6.504 | FAIL | 27 | | 0.759 | <60% | NO |
| OUR E | 30.0 | 0.7 | 22 | 32.0 | 28.1 | | | | | | | |
| PHOSPHATE | | | | | | | | | | | | |
| I | 19.8 | 1.6 | 34 | 23.1 | 14.7 | | | | | | | |
| 1 C | 36.2 | 5.9 | 32 | 48.3 | 26.2 | 1.36 | pass | 63 | 5.49 | -1.607 | 80 - 90% | NO |
| 2 C | 38.1 | 6.3 | 33 | 50.6 | 27.2 | 1.24 | pass | 64 | 6.02 | -1.774 | 90 - 95% | NO |
| 3 C | 35.0 | 7.4 | 33 | 55.8 | 22.4 | 1.64 | pass | 64 | 6.67 | -2.013 | 95 - 98% | YES |
| 4 C | 19.7 | 7.4 | 33 | 52.5 | 10.2 | 1.79 | fail | 60 | | -1.225 | 60 - 80% | NO |
| 5 C | 9.5 | 9.9 | 32 | 57.0 | 2.4 | 2.72 | fail | 52 | | -0.211 | <60% | NO |
| E C | 7.6 | 5.0 | 34 | 20.0 | 2.1 | 1.16 | pass | 65 | 5.22 | 0.349 | <60% | NO |
| 1 E | 38.4 | 5.1 | 33 | 46.5 | 27.7 | | | | | | | |
| 2 E | 40.7 | 5.7 | 33 | 51.6 | 29.9 | | | | | | | |
| 3 E | 38.3 | 5.8 | 33 | 50.8 | 22.9 | | | | | | | |
| 4 E | 21.6 | 5.5 | 33 | 29.8 | 3.5 | | | | | | | |
| 5 E | 10.0 | 6.0 | 33 | 22.2 | 1.9 | | | | | | | |
| E E | 7.2 | 5.4 | 33 | 21.0 | 1.6 | | | | | | | |
| | 12.2 | 4.6 | 34 | 19.6 | 1.0 | 1.144 | PASS | 66 | 4.753 | -0.569 | <60% | NO |
| | 12.8 | 4.9 | 34 | 21.0 | 0.0 | | | | | | | |

# A6.4

NITRITE

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.091 | 0.087 | 32 | 0.486 | 0.003 | 4.99 | fail | 43 | | 0.978 | 60 - 80% | NO |
| 2 C | 0.075 | 0.030 | 33 | 0.152 | 0.016 | 1.64 | pass | 64 | 0.03 | -0.203 | <60% | NO |
| 3 C | 0.090 | 0.088 | 33 | 0.469 | 0.013 | 1.83 | fail | 60 | | 0.260 | <60% | NO |
| 4 C | 0.235 | 0.453 | 33 | 2.267 | 0.004 | 1.24 | pass | 64 | 0.48 | -0.143 | <60% | NO |
| 5 C | 2.193 | 4.665 | 33 | 20.530 | 0.006 | 1.43 | pass | 64 | 4.30 | 0.029 | <60% | NO |
| E C | 2.248 | 4.329 | 35 | 16.970 | 0.056 | 1.09 | fail | 69 | | -0.346 | <60% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.075 | 0.039 | 32 | 0.161 | 0.003 |
| 2 E | 0.077 | 0.038 | 33 | 0.177 | 0.004 |

| | | | | | |
|---|---|---|---|---|---|
| 3 E | 0.085 | 0.065 | 33 | 0.330 | 0.013 |
| 4 E | 0.252 | 0.505 | 33 | 2.582 | 0.011 |
| 5 E | 2.161 | 3.904 | 33 | 14.130 | 0.013 |
| E E | 2.599 | 4.144 | 35 | 12.510 | 0.073 |

TOTAL

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.488 | 0.608 | 33 | 2.734 | 0.000 | 7.91 | fail | 40 | | 1.838 | 90 - 95% | NO |
| 2 C | 0.173 | 0.045 | 33 | 0.318 | 0.084 | 1.14 | pass | 64 | 0.04 | 0.290 | <60% | NO |
| 3 C | 0.223 | 0.171 | 33 | 0.928 | 0.057 | 2.93 | fail | 52 | | 0.738 | <60% | NO |
| 4 C | 0.539 | 0.391 | 33 | 1.577 | 0.057 | 1.57 | pass | 64 | 0.44 | 0.782 | <60% | NO |
| 5 C | 7.505 | 4.111 | 33 | 24.038 | 3.586 | 2.07 | fail | 58 | | 0.344 | <60% | NO |
| E C | 10.066 | 4.013 | 33 | 26.963 | 5.830 | 2.46 | fail | 55 | | 0.295 | <60% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.281 | 0.216 | 33 | 0.925 | 0.000 |
| 2 E | 0.170 | 0.042 | 33 | 0.249 | 0.084 |
| 3 E | 0.197 | 0.100 | 33 | 0.517 | 0.064 |
| 4 E | 0.454 | 0.489 | 33 | 2.417 | 0.070 |
| 5 E | 7.205 | 2.855 | 33 | 13.483 | 3.586 |
| E E | 9.821 | 2.560 | 33 | 16.102 | 4.156 |

NITRATES

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.399 | 0.607 | 33 | 2.700 | 0.000 | 7.73 | fail | 40 | | 1.698 | 90 - 95% | NO |
| 2 C | 0.095 | 0.062 | 34 | 0.294 | 0.000 | 1.13 | pass | 67 | 0.06 | 0.305 | <60% | NO |
| 3 C | 0.129 | 0.127 | 34 | 0.577 | 0.000 | 2.46 | fail | 57 | | 0.770 | <60% | NO |
| 4 C | 0.295 | 0.340 | 34 | 0.947 | -0.867 | 3.12 | fail | 53 | | 1.482 | 80 - 90% | NO |
| 5 C | 5.068 | 3.006 | 34 | 13.008 | 0.000 | 1.06 | pass | 66 | 2.96 | 0.240 | <60% | NO |
| E C | 7.662 | 3.467 | 34 | 17.020 | -1.294 | 1.24 | pass | 66 | 3.67 | 0.512 | <60% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.209 | 0.218 | 33 | 0.864 | 0.000 |
| 2 E | 0.090 | 0.065 | 34 | 0.217 | 0.000 |
| 3 E | 0.109 | 0.081 | 34 | 0.391 | 0.000 |
| 4 E | 0.196 | 0.192 | 34 | 0.806 | -0.165 |
| 5 E | 4.896 | 2.919 | 34 | 12.892 | -0.647 |
| E E | 7.206 | 3.862 | 34 | 15.871 | -2.364 |

**ZEOLITE DOSING PERIOD**

| | MEAN | STD DEV | N | MAX | MIN | F TEST | | DEGREES FREEDOM | POOLED STD DEV | T-STATISTIC | PROBABILITY | STATISTIC INTERPRET |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DSVI C | 115.8 | 10.5 | 38 | 137.4 | 95.7 | 1.009 | PASS | 74 | 10.51 | -3.654 | >99.9 | YES |
| DSVI E | 124.6 | 10.5 | 38 | 147.4 | 103.0 | | | | | | | |
| MLSS C | 3.287 | 0.273 | 38 | 4.0 | 2.6 | 1.263 | PASS | 74 | 0.259 | -4.541 | >99.9 | YES |
| MLSS E | 3.557 | 0.243 | 38 | 4.0 | 2.8 | | | | | | | |
| VSS C | 2.704 | 0.189 | 38 | 3.2 | 2.2 | 1.047 | PASS | 74 | 0.191 | -2.053 | 95 - 98% | YES |
| VSS E | 2.794 | 0.194 | 38 | 3.2 | 2.3 | | | | | | | |
| ISS C | 0.583 | 0.142 | 38 | 1.1 | 0.4 | 2.182 | PASS | 74 | 0.121 | -6.452 | >99.9% | YES |
| ISS E | 0.763 | 0.096 | 38 | 0.9 | 0.4 | | | | | | | |
| TSS/VSS | 0.824 | 0.030 | 38 | 0.9 | 0.7 | 1.774 | PASS | 74 | 0.026 | 6.280 | >99.9% | YES |
| | 0.786 | 0.022 | 38 | 0.9 | 0.7 | | | | | | | |
| TKN IN | 103 | 21 | 38 | 150.6 | 80.1 | | | | | | | |
| TKN EFF C | 3.6 | 0.8 | 38 | 5.9 | 2.1 | 1.734 | PASS | 74 | 0.968 | -1.744 | 90 - 95% | NO |
| TKN EFF E | 4.0 | 1.1 | 38 | 6.6 | 2.4 | | | | | | | |
| COD IN | 986 | 47 | 38 | 1112.8 | 883.0 | | | | | | | |
| COD EFF C | 66.0 | 15.0 | 38 | 96.8 | 36.0 | 1.167 | PASS | 74 | 15.626 | 0.820 | <60% | NO |
| COD EFF E | 63.0 | 16.2 | 38 | 96.8 | 32.0 | | | | | | | |
| pH C | 7.82 | 0.18 | 27 | 8.3 | 7.3 | 1.077 | PASS | 52 | 0.174 | -1.221 | 60 - 80% | NO |
| pH E | 7.88 | 0.17 | 27 | 8.2 | 7.4 | | | | | | | |
| OUR C | 40.4 | 10.8 | 30 | 77.0 | 23.9 | 1.410 | PASS | 58 | 10.000 | 0.040 | <60% | NO |
| OUR E | 40.3 | 9.1 | 30 | 60.8 | 27.1 | | | | | | | |
| PHOSPHATE | | | | | | | | | | | | |
| I | 19.7 | 1.4 | 38 | 22.9 | 16.9 | | | | | | | |
| 1 C | 31.1 | 2.1 | 38 | 35.3 | 27.0 | 1.99 | fail | 68 | | -2.261 | 95 - 98% | YES |
| 2 C | 33.5 | 2.1 | 38 | 38.3 | 28.0 | 1.63 | pass | 74 | 2.45 | -3.876 | >99.9% | YES |
| 3 C | 24.4 | 2.8 | 39 | 29.8 | 15.6 | 1.12 | pass | 74 | 2.77 | -0.546 | <60% | NO |
| 4 C | 13.6 | 1.7 | 38 | 16.8 | 9.8 | 1.28 | pass | 74 | 1.61 | 1.392 | 80 - 90% | NO |
| 5 C | 8.7 | 1.7 | 38 | 11.7 | 5.4 | 1.61 | pass | 74 | 1.52 | 0.701 | <60% | NO |
| E C | 7.3 | 1.2 | 38 | 9.7 | 4.4 | 1.21 | pass | 74 | 1.13 | 5.104 | >99.9% | YES |
| 1 E | 32.4 | 2.9 | 38 | 37.0 | 26.9 | | | | | | | |
| 2 E | 35.7 | 2.7 | 38 | 41.3 | 30.2 | | | | | | | |
| 3 E | 24.8 | 2.7 | 37 | 29.8 | 19.4 | | | | | | | |
| 4 E | 13.1 | 1.5 | 38 | 15.9 | 9.1 | | | | | | | |
| 5 E | 8.5 | 1.3 | 38 | 10.8 | 5.8 | | | | | | | |
| E E | 6.0 | 1.1 | 38 | 8.0 | 3.5 | | | | | | | |
| | 12.4 | 1.9 | 38 | 16.2 | 9.0 | 1.280 | PASS | 74 | 1.823 | -3.170 | 99.5 - 99.8% | YES |
| | 13.8 | 1.7 | 38 | 17.0 | 10.3 | | | | | | | |

# A6.6

## NITRITE

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.117 | 0.046 | 38 | 0.3 | 0.0 | 1.23 | pass | 74 | 0.04 | -0.262 | <60% | NO |
| 2 C | 0.112 | 0.049 | 38 | 0.3 | 0.1 | 1.55 | pass | 74 | 0.04 | 0.202 | <60% | NO |
| 3 C | 0.138 | 0.101 | 38 | 0.7 | 0.0 | 1.20 | pass | 74 | 0.10 | -0.160 | <60% | NO |
| 4 C | 0.355 | 0.278 | 38 | 1.1 | 0.1 | 1.74 | pass | 74 | 0.33 | -1.047 | 60 - 80% | NO |
| 5 C | 1.334 | 0.973 | 38 | 4.3 | 0.3 | 1.47 | pass | 74 | 0.89 | 1.152 | 60 - 80% | NO |
| E C | 1.189 | 1.183 | 38 | 4.3 | 0.1 | 2.61 | fail | 63 | | 1.787 | 90 - 95% | NO |
| 1 E | 0.120 | 0.041 | 38 | 0.2 | 0.1 | | | | | | | |
| 2 E | 0.110 | 0.040 | 38 | 0.2 | 0.1 | | | | | | | |
| 3 E | 0.142 | 0.092 | 38 | 0.4 | 0.0 | | | | | | | |
| 4 E | 0.433 | 0.367 | 38 | 1.3 | 0.1 | | | | | | | |
| 5 E | 1.098 | 0.803 | 38 | 3.1 | 0.3 | | | | | | | |
| E E | 0.786 | 0.732 | 38 | 4.1 | 0.1 | | | | | | | |

## TOTAL

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.334 | 0.185 | 37 | 1.0 | 0.1 | 3.56 | fail | 57 | | -1.902 | 90 - 95% | NO |
| 2 C | 0.334 | 0.244 | 37 | 1.4 | 0.1 | 4.25 | fail | 52 | | 0.418 | <60% | NO |
| 3 C | 0.483 | 0.539 | 37 | 3.5 | 0.1 | 2.29 | fail | 63 | | 0.016 | <60% | NO |
| 4 C | 2.072 | 2.151 | 37 | 8.4 | 0.1 | 1.17 | pass | 73 | 2.24 | -0.533 | <60% | NO |
| 5 C | 16.529 | 11.467 | 37 | 44.3 | 6.5 | 2.95 | fail | 58 | | 1.843 | 90 - 95% | NO |
| E C | 17.422 | 10.635 | 37 | 40.9 | 7.5 | 1.17 | pass | 73 | 10.24 | 0.403 | <60% | NO |
| 1 E | 0.457 | 0.350 | 38 | 2.3 | 0.0 | | | | | | | |
| 2 E | 0.315 | 0.119 | 38 | 0.7 | 0.1 | | | | | | | |
| 3 E | 0.482 | 0.356 | 38 | 1.3 | 0.1 | | | | | | | |
| 4 E | 2.348 | 2.328 | 38 | 8.0 | 0.1 | | | | | | | |
| 5 E | 12.522 | 6.681 | 38 | 31.7 | 6.1 | | | | | | | |
| E E | 16.471 | 9.837 | 38 | 35.1 | 6.9 | | | | | | | |

## NITRATES

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.220 | 0.187 | 36 | 0.9 | -0.0 | 3.26 | fail | 57 | | -1.835 | 90 - 95% | NO |
| 2 C | 0.223 | 0.226 | 36 | 1.2 | 0.0 | 4.36 | fail | 50 | | 0.461 | <60% | NO |
| 3 C | 0.338 | 0.454 | 36 | 2.8 | -0.0 | 2.74 | fail | 58 | | 0.086 | <60% | NO |
| 4 C | 1.613 | 1.888 | 36 | 7.6 | -0.3 | 1.07 | pass | 72 | 1.92 | -0.477 | <60% | NO |
| 5 C | 14.026 | 9.084 | 36 | 38.0 | 5.5 | 2.32 | fail | 61 | | 1.541 | 80 - 90% | NO |
| E C | 15.652 | 9.274 | 36 | 36.6 | 6.0 | 1.07 | pass | 71 | 9.11 | 0.201 | <60% | NO |
| 1 E | 0.336 | 0.338 | 37 | 2.1 | -0.1 | | | | | | | |
| 2 E | 0.204 | 0.108 | 37 | 0.4 | 0.0 | | | | | | | |
| 3 E | 0.330 | 0.274 | 37 | 1.0 | -0.0 | | | | | | | |
| 4 E | 1.828 | 1.949 | 37 | 6.8 | -0.0 | | | | | | | |
| 5 E | 11.246 | 5.966 | 37 | 29.0 | 4.8 | | | | | | | |
| E E | 15.222 | 8.956 | 37 | 33.2 | 6.7 | | | | | | | |

INTERMEDIATE BASELINE DATA : STATISTICAL ANALYSIS

| DATE<br>DAY # | MEAN | STD | N | MAX | MIN | F TEST | | DEGREES FREEDOM | POOLED STD DEV | T- STATISTIC | PROBAB- ILITY | STATISTICALLY DIFFERENT ? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DSVI C | 156.4 | 14.9 | 14 | 188.9 | 138.7 | 1.540 | PASS | 26 | 13.57 | 0.290 | <60% | NO |
| DSVI E | 157.9 | 12.0 | 14 | 177.8 | 138.6 | | | | | | | |
| MLSS C | 3.202 | 0.32 | 13 | 3.774 | 2.558 | 1.433 | PASS | 24 | 0.298 | 0.187 | <60% | NO |
| MLSS E | 3.224 | 0.27 | 13 | 3.548 | 2.706 | | | | | | | |
| VSS C | 2.653 | 0.26 | 14 | 3.118 | 2.088 | 1.090 | PASS | 26 | 0.256 | 0.040 | <60% | NO |
| VSS E | 2.657 | 0.25 | 14 | 2.92 | 2.05 | | | | | | | |
| ISS C | 0.532 | 0.13 | 13 | 0.688 | 0.232 | 1.425 | PASS | 24 | 0.124 | 0.168 | <60% | NO |
| ISS E | 0.541 | 0.11 | 13 | 0.656 | 0.324 | | | | | | | |
| VSS/TSS C | 0.835 | 0.04 | 13 | 0.91 | 0.75 | 1.273 | PASS | 25 | 0.037 | -0.163 | <60% | NO |
| VSS/TSS E | 0.832 | 0.03 | 13 | 0.89 | 0.76 | | | | | | | |
| TKN IN | | | | | | | | | | | | |
| TKN EFF C | 5.13 | 1.04 | 12 | 7.3 | 3.2 | 1.228 | PASS | 22 | 1.099 | 0.279 | <60% | NO |
| TKN EFF E | 5.25 | 1.15 | 12 | 8 | 3.9 | | | | | | | |
| COD IN | | | | | | | | | | | | |
| COD EFF C | 80.29 | 15.64 | 11 | 102.1 | 45.8 | 1.803 | PASS | 19 | 18.375 | -1.435 | 80 - 90% | NO |
| COD EFF E | 68.77 | 21.00 | 10 | 91.7 | 20.8 | | | | | | | |
| pH C | 7.86 | 0.13 | 9 | 8.05 | 7.62 | 1.254 | PASS | 16 | 0.122 | -0.963 | 60 - 80% | NO |
| pH E | 7.81 | 0.12 | 9 | 7.92 | 7.6 | | | | | | | |
| OUR C | 30.00 | 0.00 | 12 | 30 | 30 | | | | | | | |
| OUR E | 30.00 | 0.00 | 12 | 30 | 30 | | | | | | | |
| PHOSPHATE | | | | | | | | | | | | |
| I | | | | | | | | | | | | |
| 1 C | 34.27 | 5.42 | 12 | 40 | 22.3 | 2.17 | pass | 22 | 4.63 | -1.507 | 80 - 90% | NO |
| 2 C | 39.77 | 5.77 | 12 | 47.9 | 27.6 | 1.73 | pass | 22 | 5.12 | -1.128 | 60 - 80% | NO |
| 3 C | 34.05 | 5.69 | 12 | 42.2 | 22.5 | 1.42 | pass | 22 | 5.25 | -0.738 | <60% | NO |
| 4 C | 21.72 | 3.86 | 12 | 28.7 | 13.5 | 1.33 | pass | 22 | 3.61 | -1.221 | 60 - 80% | NO |
| 5 C | 9.98 | 1.76 | 12 | 12.9 | 5.7 | 1.75 | pass | 22 | 2.06 | -0.515 | <60% | NO |
| E C | 9.38 | 1.95 | 12 | 12.9 | 4.9 | 1.33 | pass | 22 | 2.11 | -0.698 | <60% | NO |
| 1 E | 31.42 | 3.68 | 12 | 34.9 | 21.3 | | | | | | | |
| 2 E | 37.41 | 4.38 | 12 | 41.8 | 26.6 | | | | | | | |
| 3 E | 32.47 | 4.77 | 12 | 36.8 | 21 | | | | | | | |
| 4 E | 19.92 | 3.34 | 12 | 22.8 | 11.2 | | | | | | | |
| 5 E | 9.54 | 2.32 | 12 | 12.9 | 4.2 | | | | | | | |
| E E | 8.78 | 2.25 | 12 | 11.8 | 3.4 | | | | | | | |

NITRITE

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.16 | 0.06 | 11 | 0.302 | 0.096 | 3.90 | fail | 17 | | 1.240 | 60 - 80% | NO |
| 2 C | 0.17 | 0.06 | 12 | 0.334 | 0.104 | 2.99 | pass | 18 | 0.09 | 1.553 | 80 - 90% | NO |
| 3 C | 0.14 | 0.03 | 12 | 0.207 | 0.102 | 1.32 | pass | 22 | 0.03 | -0.387 | <60% | NO |
| 4 C | 0.14 | 0.04 | 12 | 0.242 | 0.098 | 2.53 | pass | 22 | 0.03 | -1.034 | 60 - 80% | NO |
| 5 C | 0.22 | 0.07 | 12 | 0.329 | 0.119 | 1.57 | pass | 22 | 0.08 | 1.945 | 90 - 95% | NO |
| E C | 0.73 | 0.20 | 12 | 1.1 | 0.334 | 1.65 | pass | 22 | 0.24 | -1.874 | 90 - 95% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.21 | 0.12 | 12 | 0.485 | 0.094 |
| 2 E | 0.22 | 0.11 | 12 | 0.477 | 0.115 |
| 3 E | 0.13 | 0.03 | 12 | 0.207 | 0.094 |
| 4 E | 0.13 | 0.03 | 12 | 0.183 | 0.09 |
| 5 E | 0.28 | 0.08 | 12 | 0.469 | 0.196 |
| E E | 0.55 | 0.26 | 12 | 1.197 | 0.3 |

TOTAL

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.27 | 0.08 | 11 | 0.487 | 0.189 | 15.67 | fail | 12 | | 1.902 | 90 - 95% | NO |
| 2 C | 0.26 | 0.09 | 12 | 0.513 | 0.196 | 2.25 | pass | 22 | 0.12 | 1.386 | 80 - 90% | NO |
| 3 C | 0.21 | 0.04 | 12 | 0.301 | 0.124 | 1.38 | pass | 22 | 0.05 | 1.243 | 60 - 80% | NO |
| 4 C | 0.20 | 0.06 | 12 | 0.346 | 0.11 | 1.32 | pass | 22 | 0.06 | -0.065 | <60% | NO |
| 5 C | 7.52 | 1.99 | 12 | 10.371 | 4.87 | 2.14 | pass | 22 | 2.49 | 1.501 | 80 - 90% | NO |
| E C | 8.04 | 2.01 | 12 | 11.541 | 5.206 | 1.90 | pass | 22 | 2.42 | 1.626 | 80 - 90% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.46 | 0.33 | 12 | 1.264 | 0.167 |
| 2 E | 0.33 | 0.14 | 12 | 0.616 | 0.181 |
| 3 E | 0.23 | 0.05 | 12 | 0.327 | 0.153 |
| 4 E | 0.20 | 0.07 | 12 | 0.346 | 0.11 |
| 5 E | 9.05 | 2.91 | 12 | 13.815 | 5.35 |
| E E | 9.65 | 2.77 | 12 | 13.981 | 5.493 |

NITRATES

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.12 | 0.06 | 12 | 0.205 | 0 | 23.88 | fail | 12 | | 1.851 | 90 - 95% | NO |
| 2 C | 0.11 | 0.05 | 12 | 0.205 | 0.027 | 1.05 | pass | 22 | 0.05 | 0.687 | <60% | NO |
| 3 C | 0.08 | 0.05 | 12 | 0.186 | 0 | 1.24 | pass | 22 | 0.06 | 1.182 | 60 - 80% | NO |
| 4 C | 0.08 | 0.05 | 12 | 0.173 | 0 | 1.49 | pass | 22 | 0.06 | 0.417 | <60% | NO |
| 5 C | 7.32 | 2.01 | 12 | 10.248 | 4.734 | 2.04 | pass | 22 | 2.48 | 1.449 | 80 - 90% | NO |
| E C | 7.35 | 2.03 | 12 | 10.936 | 4.106 | 1.82 | pass | 22 | 2.41 | 1.849 | 90 - 95% | NO |
| | 0.00 | 0.00 | 9 | 0 | 0 | | | | | | | |
| 1 E | 0.27 | 0.28 | 12 | 1.081 | 0.03 | | | | | | | |
| 2 E | 0.13 | 0.05 | 12 | 0.218 | 0.033 | | | | | | | |
| 3 E | 0.11 | 0.06 | 12 | 0.201 | 0.021 | | | | | | | |
| 4 E | 0.09 | 0.06 | 12 | 0.199 | 0 | | | | | | | |
| 5 E | 8.79 | 2.87 | 12 | 13.619 | 5.145 | | | | | | | |
| E E | 9.16 | 2.73 | 12 | 13.679 | 5.11 | | | | | | | |

CALCITE DOSING DATA : STATISTICAL ANALYSIS

| DATE<br>DAY # | MEAN | STD | N | MAX | MIN | F TEST | | DEGREES FREEDOM | POOLED STD DE | T- STATISTIC | STATISTICAL INTERPRETATION | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DSVI C | 139.4 | 8.8 | 32 | 154.1 | 123 | 2.507 | FAIL | 53 | | -10.607 | >99.9% | YES |
| DSVI E | 108.5 | 13.9 | 32 | 141.4 | 91.6 | | | | | | | |
| MLSS C | 3.275 | 0.20 | 33 | 3.718 | 2.904 | 2.219 | FAIL | 57 | | 2.606 | 98 - 99% | YES |
| MLSS E | 3.435 | 0.29 | 33 | 4.51 | 3.08 | | | | | | | |
| VSS C | 2.762 | 0.16 | 33 | 3.104 | 2.476 | 2.977 | FAIL | 50 | | 1.673 | 80 - 90% | NO |
| VSS E | 2.857 | 0.28 | 32 | 3.746 | 2.542 | | | | | | | |
| ISS C | 0.513 | 0.10 | 33 | 0.692 | 0.044 | 1.156 | PASS | 63 | 0.095 | 2.755 | 99-99.5% | YES |
| ISS E | 0.578 | 0.09 | 32 | 0.764 | 0.166 | | | | | | | |
| VSS/TSS C | 0.844 | 0.03 | 33 | 0.985 | 0.785 | 1.415 | PASS | 63 | 0.026 | -1.953 | 90 - 95% | NO |
| VSS/TSS E | 0.831 | 0.02 | 32 | 0.956 | 0.813 | | | | | | | |
| TKN IN | 95 | | 31 | 116 | 72 | | | | | | | |
| TKN EFF C | 4.9 | 1.7 | 32 | 13.4 | 2.9 | 1.553 | PASS | 63 | 1.516 | 0.212 | <60% | NO |
| TKN EFF E | 5.0 | 1.3 | 33 | 11 | 3.1 | | | | | | | |
| COD IN | | | | 1248 | 821 | | | | | | | |
| COD EFF C | 50.7 | 10.5 | 33 | 83.3 | 35.6 | 1.176 | PASS | 63 | 10.96 | 1.687 | 90 - 95% | NO |
| COD EFF E | 55.3 | 11.4 | 32 | 88.4 | 34.5 | | | | | | | |
| pH C | 7.85 | 0.13 | 26 | 8.15 | 7.63 | 1.510 | PASS | 50 | 0.118 | -1.459 | 80 - 90% | NO |
| pH E | 7.80 | 0.11 | 26 | 7.93 | 7.61 | | | | | | | |
| OUR C | 35.4 | 4.52 | 27 | 44.2 | 24.4 | 1.036 | PASS | 52 | 4.479 | 2.130 | 95 - 98% | YES |
| OUR E | 32.8 | 4.44 | 27 | 45.8 | 27.71 | | | | | | | |
| PHOSPHATE | | | | | | | | | | | | |
| I | | | 32 | 28.6 | 15.2 | | | | | | | |
| 1 C | 29.3 | 5.1 | 33 | 47.7 | 22.3 | 1.69 | pass | 64 | 4.60 | -0.262 | <60% | NO |
| 2 C | 34.7 | 6.5 | 33 | 58.8 | 27.1 | 1.06 | pass | 64 | 6.40 | -0.831 | <60% | NO |
| 3 C | 29.6 | 4.8 | 33 | 48.7 | 23.4 | 1.06 | pass | 63 | 4.84 | -0.514 | <60% | NO |
| 4 C | 16.9 | 2.9 | 32 | 26.5 | 13.5 | 1.17 | pass | 63 | 2.78 | -0.111 | <60% | NO |
| 5 C | 10.2 | 2.5 | 33 | 17.3 | 6.7 | 1.50 | pass | 64 | 2.28 | -1.148 | 60 - 80% | NO |
| E C | 9.6 | 2.7 | 32 | 17.1 | 4.8 | 1.62 | pass | 63 | 2.43 | -1.233 | 60 - 80% | NO |
| 1 E | 29.0 | 4.0 | 33 | 45.6 | 22.8 | | | | | | | |
| 2 E | 33.4 | 6.3 | 33 | 56.1 | 23.7 | | | | | | | |
| 3 E | 29.0 | 4.9 | 32 | 46.7 | 23 | | | | | | | |
| 4 E | 16.9 | 2.7 | 33 | 27 | 14 | | | | | | | |
| 5 E | 9.6 | 2.0 | 33 | 15.7 | 5.8 | | | | | | | |
| E E | 8.9 | 2.1 | 33 | 15.7 | 4.7 | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.242 | 0.171 | 33 | 0.894 | 0.049 |
| 2 E | 0.194 | 0.079 | 33 | 0.517 | 0.1 |
| 3 E | 0.106 | 0.035 | 33 | 0.224 | 0.041 |
| 4 E | 0.102 | 0.027 | 33 | 0.153 | 0.045 |
| 5 E | 0.163 | 0.067 | 32 | 0.312 | 0.066 |
| E E | 0.441 | 0.232 | 31 | 0.919 | 0.079 |

TOTAL

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.278 | 0.162 | 33 | 0.963 | 0.114 | 3.79 | fail | 48 | | 3.089 | >99.8% | YES |
| 2 C | 0.266 | 0.185 | 33 | 1.158 | 0.125 | 2.25 | fail | 57 | | 0.422 | <60% | NO |
| 3 C | 0.140 | 0.048 | 33 | 0.254 | 0.027 | 1.33 | pass | 64 | 0.04 | 0.599 | <60% | NO |
| 4 C | 0.317 | 0.685 | 33 | 3.004 | 0.014 | 196.98 | fail | 32 | | -1.724 | 90 - 95% | NO |
| 5 C | 10.353 | 2.715 | 33 | 19.805 | 6.359 | 1.36 | pass | 64 | 2.95 | 0.682 | <60% | NO |
| E C | 11.307 | 2.949 | 33 | 17.863 | 6.359 | 1.15 | pass | 64 | 3.05 | 0.246 | <60% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.468 | 0.315 | 33 | 1.83 | 0.171 |
| 2 E | 0.282 | 0.124 | 33 | 0.829 | 0.114 |
| 3 E | 0.147 | 0.042 | 33 | 0.248 | 0.071 |
| 4 E | 0.111 | 0.049 | 33 | 0.231 | 0.008 |
| 5 E | 10.847 | 3.161 | 33 | 19.251 | 6.822 |
| E E | 11.493 | 3.156 | 33 | 18.696 | 7.325 |

NITRATES

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.087 | 0.161 | 40 | 0.829 | -0.14 | 2.90 | fail | 64 | | 1.986 | 90 - 95% | NO |
| 2 C | 0.076 | 0.179 | 40 | 0.957 | -0.14 | 2.09 | pass | 78 | 0.15 | -0.104 | <60% | NO |
| 3 C | 0.038 | 0.065 | 40 | 0.201 | -0.1 | 1.03 | pass | 78 | 0.06 | -0.276 | <60% | NO |
| 4 C | 0.086 | 0.455 | 40 | 2.871 | -0.319 | 65.32 | pass | 78 | 0.32 | -1.090 | 60 - 80% | NO |
| 5 C | 8.443 | 4.614 | 40 | 19.698 | -0.131 | 1.16 | pass | 78 | 4.80 | 0.350 | <60% | NO |
| E C | 9.001 | 4.939 | 40 | 17.187 | -0.262 | 1.07 | pass | 78 | 5.02 | 0.123 | <60% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.186 | 0.275 | 40 | 1.14 | -0.362 |
| 2 E | 0.072 | 0.124 | 40 | 0.551 | -0.149 |
| 3 E | 0.034 | 0.064 | 40 | 0.19 | -0.106 |
| 4 E | 0.007 | 0.056 | 40 | 0.125 | -0.145 |
| 5 E | 8.819 | 4.978 | 40 | 19.098 | -0.193 |
| E E | 9.139 | 5.109 | 40 | 17.954 | -0.21 |

FINAL BASELINE DATA : STATISTICAL ANALYSIS

| DATE<br>DAY # | MEAN | STD | N | MAX | MIN | F TEST | | DEGREES FREEDOM | POOLED STD DEV | T-STATISTIC | STATISTICAL INTERPRETATION | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DSVI C | 146.6 | 12.6 | 16 | 177.3 | 125.7 | 3.010 | FAIL | 25 | | -3.302 | >99.5% | YES |
| DSVI E | 134.6 | 7.3 | 16 | 150.2 | 123.1 | | | | | | | |
| MLSS C | 3.280 | 0.224 | 15 | 3.714 | 2.84 | 1.256 | PASS | 29 | 0.211 | 0.090 | <60% | NO |
| MLSS E | 3.287 | 0.200 | 16 | 3.686 | 2.878 | | | | | | | |
| VSS C | 2.699 | 0.148 | 15 | 2.954 | 2.4 | 1.143 | PASS | 27 | 0.143 | 1.049 | 60 - 80% | NO |
| VSS E | 2.754 | 0.138 | 14 | 3.046 | 2.58 | | | | | | | |
| ISS C | 0.598 | 0.106 | 14 | 0.848 | 0.44 | 3.145 | FAIL | 26 | | -0.647 | <60% | NO |
| ISS E | 0.577 | 0.060 | 14 | 0.68 | 0.488 | | | | | | | |
| VSS/TSS C | 0.818 | 0.02 | 13 | 0.849 | 0.772 | 1.000 | PASS | 25 | 0.020 | 1.212 | 60 - 80% | NO |
| VSS/TSS E | 0.827 | 0.02 | 14 | 0.850 | 0.795 | | | | | | | |
| TKN IN | 102 | | | 126 | 72 | | | | | | | |
| TKN EFF C | 4.7 | 0.4 | 16 | 5.3 | 3.9 | 1.633 | PASS | 30 | 0.440 | -1.061 | 60 - 80% | NO |
| TKN EFF E | 4.5 | 0.5 | 16 | 5.4 | 3.6 | | | | | | | |
| COD IN | 1008 | | | 1152 | 906 | | | | | | | |
| COD EFF C | 67.7 | 20.4 | 16 | 110 | 34.8 | 1.553 | PASS | 30 | 18.525 | -0.229 | <60% | NO |
| COD EFF E | 66.2 | 16.4 | 16 | 106 | 43 | | | | | | | |
| pH C | 7.73 | 0.13 | 14 | 7.92 | 7.43 | 1.672 | PASS | 26 | 0.118 | 0.447 | <60% | NO |
| pH E | 7.75 | 0.10 | 14 | 7.94 | 7.6 | | | | | | | |
| OUR C | 37.55 | 4.04 | 26 | 46.4 | 31.6 | 1.000 | PASS | 50 | 4.037 | -0.378 | <60% | NO |
| OUR E | 37.98 | 4.04 | 26 | 47.7 | 33.8 | | | | | | | |
| PHOSPHATE | | | | | | | | | | | | |
| I | 20.4 | 0.9 | 14 | 22.2 | 18.7 | | | | | | | |
| 1 C | 29.0 | 2.6 | 15 | 32.2 | 22.2 | 1.41 | pass | 28 | 2.39 | -0.046 | <60% | NO |
| 2 C | 34.9 | 2.9 | 15 | 39.3 | 29.6 | 1.16 | pass | 29 | 2.76 | -0.639 | <60% | NO |
| 3 C | 28.2 | 3.1 | 15 | 32.5 | 20.4 | 1.76 | pass | 29 | 2.73 | -0.265 | <60% | NO |
| 4 C | 15.4 | 0.7 | 15 | 16.8 | 14.7 | 11.67 | fail | 29 | | 1.804 | 80 - 90% | NO |
| 5 C | 11.2 | 1.0 | 15 | 13.6 | 9.5 | 3.79 | fail | 29 | | -0.877 | 60 - 80% | NO |
| E C | 10.8 | 1.1 | 15 | 13.6 | 9.2 | 3.18 | fail | 29 | | -1.101 | 60 - 80% | NO |
| 1 E | 28.9 | 2.2 | 15 | 31.4 | 23.4 | | | | | | | |
| 2 E | 34.3 | 2.7 | 16 | 38.2 | 29.4 | | | | | | | |
| 3 E | 27.9 | 2.3 | 16 | 31.7 | 24.2 | | | | | | | |
| 4 E | 16.6 | 2.4 | 16 | 24.6 | 13.6 | | | | | | | |
| 5 E | 10.7 | 2.0 | 16 | 13.6 | 5.6 | | | | | | | |
| E E | 10.1 | 1.9 | 16 | 12.4 | 5 | | | | | | | |
| | 6.9 | 7.0 | 15 | 13 | -11.1 | 1.005 | pass | 28 | 7.000 | 0.107 | <60% | NO |
| | 7.2 | 7.0 | 15 | 14.1 | -11 | | | | | | | |
| NITRITE | | | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.271 | 0.069 | 16 | 0.379 | 0.168 |
| 2 E | 0.269 | 0.055 | 16 | 0.334 | 0.177 |
| 3 E | 0.220 | 0.059 | 16 | 0.312 | 0.158 |
| 4 E | 0.533 | 0.960 | 16 | 4.206 | 0.16 |
| 5 E | 0.387 | 0.246 | 16 | 1.243 | 0.162 |
| E E | 0.786 | 0.685 | 16 | 3.294 | 0.181 |

TOTAL

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | 0.215 | 0.086 | 16 | 0.447 | 0.135 | 2.78 | fail | 25 | | 1.592 | 80 - 90% | NO |
| 2 C | 0.195 | 0.054 | 16 | 0.332 | 0.116 | 5.35 | fail | 30 | | 1.469 | 80 - 90% | NO |
| 3 C | 0.132 | 0.044 | 16 | 0.252 | 0.077 | 2.24 | pass | 30 | 0.06 | 0.425 | <60% | NO |
| 4 C | 1.558 | 1.765 | 16 | 6.8955 | 0.052 | 12.99 | fail | 30 | | -2.741 | 98 - 99% | NO |
| 5 C | 10.951 | 4.522 | 16 | 24.43 | 5.119 | 1.52 | pass | 30 | 5.08 | 0.759 | <60% | NO |
| E C | 11.405 | 3.299 | 16 | 18.783 | 5.247 | 1.89 | pass | 30 | 3.97 | 1.144 | 80 - 90% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.281 | 0.144 | 16 | 0.621 | 0.097 |
| 2 E | 0.245 | 0.124 | 16 | 0.646 | 0.116 |
| 3 E | 0.141 | 0.067 | 16 | 0.324 | 0.071 |
| 4 E | 0.303 | 0.490 | 16 | 2.077 | 0.045 |
| 5 E | 12.315 | 5.579 | 16 | 31.24 | 4.736 |
| E E | 13.009 | 4.536 | 16 | 26.039 | 4.991 |

NITRATES

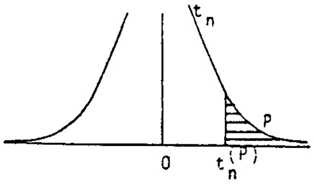
| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 C | -0.022 | 0.094 | 17 | 0.173 | -0.175 | 2.94 | fail | 26 | | 0.711 | <60% | NO |
| 2 C | -0.042 | 0.088 | 17 | 0.199 | -0.225 | 2.54 | pass | 32 | 0.12 | 0.488 | <60% | NO |
| 3 C | -0.081 | 0.079 | 17 | 0.084 | -0.197 | 1.61 | pass | 32 | 0.09 | 0.234 | <60% | NO |
| 4 C | -0.386 | 1.224 | 17 | 3.1065 | -2.178 | 6.38 | fail | 32 | | 0.533 | <60% | NO |
| 5 C | 10.042 | 5.067 | 17 | 24.115 | -0.224 | 1.48 | pass | 32 | 5.64 | 0.612 | <60% | NO |
| E C | 9.792 | 4.371 | 17 | 18.408 | -0.4 | 1.51 | pass | 32 | 4.89 | 1.020 | 60 - 80% | NO |

| | | | | | |
|---|---|---|---|---|---|
| 1 E | 0.010 | 0.160 | 17 | 0.453 | -0.214 |
| 2 E | -0.023 | 0.140 | 17 | 0.391 | -0.21 |
| 3 E | -0.074 | 0.100 | 17 | 0.166 | -0.218 |
| 4 E | -0.216 | 0.484 | 17 | 0.07 | -2.129 |
| 5 E | 11.226 | 6.165 | 17 | 31.012 | -0.224 |
| E E | 11.504 | 5.366 | 17 | 25.363 | -0.514 |

# TABLE A6: THE t-DISTRIBUTION

TABLE 2 THE t-DISTRIBUTION

The table gives the value of $t_n^{(P)}$
where $n$ is the degrees of freedom
i.e. $P = P[t_n \geq t_n^{(P)}]$



| DF \ P | 0,200 | 0,100 | 0,050 | 0,025 | 0,010 | 0,005 | 0,0025 | 0,0010 | 0,0005 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,376 | 3,078 | 6,314 | 12,706 | 31,821 | 63,657 | 127,322 | 318,313 | 636,633 |
| 2 | 1,061 | 1,886 | 2,920 | 4,303 | 6,965 | 9,925 | 14,089 | 22,327 | 31,599 |
| 3 | 0,978 | 1,638 | 2,353 | 3,182 | 4,541 | 5,841 | 7,453 | 10,215 | 12,924 |
| 4 | 0,941 | 1,533 | 2,132 | 2,776 | 3,747 | 4,604 | 5,598 | 7,173 | 8,610 |
| 5 | 0,920 | 1,476 | 2,015 | 2,571 | 3,365 | 4,032 | 4,773 | 5,893 | 6,869 |
| 6 | 0,906 | 1,440 | 1,943 | 2,447 | 3,143 | 3,707 | 4,317 | 5,208 | 5,959 |
| 7 | 0,896 | 1,415 | 1,895 | 2,365 | 2,998 | 3,499 | 4,029 | 4,785 | 5,408 |
| 8 | 0,889 | 1,397 | 1,860 | 2,306 | 2,896 | 3,355 | 3,833 | 4,501 | 5,041 |
| 9 | 0,883 | 1,383 | 1,833 | 2,262 | 2,821 | 3,250 | 3,690 | 4,297 | 4,781 |
| 10 | 0,879 | 1,372 | 1,812 | 2,228 | 2,764 | 3,169 | 3,581 | 4,144 | 4,587 |
| 11 | 0,876 | 1,363 | 1,796 | 2,201 | 2,718 | 3,106 | 3,497 | 4,025 | 4,437 |
| 12 | 0,873 | 1,356 | 1,782 | 2,179 | 2,681 | 3,055 | 3,428 | 3,930 | 4,318 |
| 13 | 0,870 | 1,350 | 1,771 | 2,160 | 2,650 | 3,012 | 3,372 | 3,852 | 4,221 |
| 14 | 0,868 | 1,345 | 1,761 | 2,145 | 2,624 | 2,977 | 3,326 | 3,787 | 4,140 |
| 15 | 0,866 | 1,341 | 1,753 | 2,131 | 2,602 | 2,947 | 3,286 | 3,733 | 4,073 |
| 16 | 0,865 | 1,337 | 1,746 | 2,120 | 2,583 | 2,921 | 3,252 | 3,686 | 4,015 |
| 17 | 0,863 | 1,333 | 1,740 | 2,110 | 2,567 | 2,898 | 3,222 | 3,646 | 3,965 |
| 18 | 0,862 | 1,330 | 1,734 | 2,101 | 2,552 | 2,878 | 3,197 | 3,610 | 3,922 |
| 19 | 0,861 | 1,328 | 1,729 | 2,093 | 2,539 | 2,861 | 3,174 | 3,579 | 3,883 |
| 20 | 0,860 | 1,325 | 1,725 | 2,086 | 2,528 | 2,845 | 3,153 | 3,552 | 3,850 |
| 21 | 0,859 | 1,323 | 1,721 | 2,080 | 2,518 | 2,831 | 3,135 | 3,527 | 3,819 |
| 22 | 0,858 | 1,321 | 1,717 | 2,074 | 2,508 | 2,819 | 3,119 | 3,505 | 3,792 |
| 23 | 0,858 | 1,319 | 1,714 | 2,069 | 2,500 | 2,807 | 3,104 | 3,485 | 3,768 |
| 24 | 0,857 | 1,318 | 1,711 | 2,064 | 2,492 | 2,797 | 3,091 | 3,467 | 3,745 |
| 25 | 0,856 | 1,316 | 1,708 | 2,060 | 2,485 | 2,787 | 3,078 | 3,450 | 3,725 |
| 26 | 0,856 | 1,315 | 1,706 | 2,056 | 2,479 | 2,779 | 3,067 | 3,435 | 3,707 |
| 27 | 0,855 | 1,314 | 1,703 | 2,052 | 2,473 | 2,771 | 3,057 | 3,421 | 3,690 |
| 28 | 0,855 | 1,313 | 1,701 | 2,048 | 2,467 | 2,763 | 3,047 | 3,408 | 3,674 |
| 29 | 0,854 | 1,311 | 1,699 | 2,045 | 2,462 | 2,756 | 3,038 | 3,396 | 3,659 |
| 30 | 0,854 | 1,310 | 1,697 | 2,042 | 2,457 | 2,750 | 3,030 | 3,385 | 3,646 |
| 31 | 0,853 | 1,309 | 1,696 | 2,040 | 2,453 | 2,744 | 3,022 | 3,375 | 3,633 |
| 32 | 0,853 | 1,309 | 1,694 | 2,037 | 2,449 | 2,738 | 3,015 | 3,365 | 3,622 |
| 33 | 0,853 | 1,308 | 1,692 | 2,035 | 2,445 | 2,733 | 3,008 | 3,356 | 3,611 |
| 34 | 0,852 | 1,307 | 1,691 | 2,032 | 2,441 | 2,728 | 3,002 | 3,348 | 3,601 |
| 35 | 0,852 | 1,306 | 1,690 | 2,030 | 2,438 | 2,724 | 2,996 | 3,340 | 3,591 |
| 36 | 0,852 | 1,306 | 1,688 | 2,028 | 2,434 | 2,719 | 2,990 | 3,333 | 3,582 |
| 37 | 0,851 | 1,305 | 1,687 | 2,026 | 2,431 | 2,715 | 2,985 | 3,326 | 3,574 |
| 38 | 0,851 | 1,304 | 1,686 | 2,024 | 2,429 | 2,712 | 2,980 | 3,319 | 3,566 |
| 39 | 0,851 | 1,304 | 1,685 | 2,023 | 2,426 | 2,708 | 2,976 | 3,313 | 3,558 |
| 40 | 0,851 | 1,303 | 1,684 | 2,021 | 2,423 | 2,704 | 2,971 | 3,307 | 3,551 |
| 45 | 0,850 | 1,301 | 1,679 | 2,014 | 2,412 | 2,690 | 2,952 | 3,282 | 3,520 |
| 50 | 0,849 | 1,299 | 1,676 | 2,009 | 2,403 | 2,678 | 2,937 | 3,261 | 3,496 |
| 60 | 0,848 | 1,296 | 1,671 | 2,000 | 2,390 | 2,660 | 2,915 | 3,232 | 3,460 |
| 70 | 0,847 | 1,294 | 1,667 | 1,994 | 2,381 | 2,648 | 2,899 | 3,211 | 3,435 |
| 80 | 0,846 | 1,292 | 1,664 | 1,990 | 2,374 | 2,639 | 2,887 | 3,195 | 3,416 |
| 90 | 0,846 | 1,291 | 1,662 | 1,987 | 2,369 | 2,632 | 2,878 | 3,183 | 3,402 |
| 100 | 0,845 | 1,290 | 1,660 | 1,984 | 2,364 | 2,626 | 2,871 | 3,174 | 3,391 |
| 110 | 0,845 | 1,289 | 1,659 | 1,982 | 2,361 | 2,621 | 2,865 | 3,166 | 3,381 |
| 120 | 0,845 | 1,289 | 1,658 | 1,980 | 2,358 | 2,617 | 2,860 | 3,160 | 3,374 |
| 140 | 0,844 | 1,288 | 1,656 | 1,977 | 2,353 | 2,611 | 2,852 | 3,150 | 3,361 |
| 160 | 0,844 | 1,287 | 1,654 | 1,975 | 2,350 | 2,607 | 2,847 | 3,142 | 3,352 |
| 180 | 0,844 | 1,286 | 1,653 | 1,973 | 2,347 | 2,603 | 2,842 | 3,136 | 3,346 |
| 200 | 0,843 | 1,286 | 1,653 | 1,972 | 2,345 | 2,601 | 2,839 | 3,132 | 3,340 |
| ∞ | 0,841 | 1,282 | 1,645 | 1,960 | 2,327 | 2,576 | 2,807 | 3,091 | 3,291 |

# APPENDIX 7

## THERMO-GRAVIMETRIC ANALYSIS TESTS

Thermo-gravimetric analysis (TGA) tests for zeolite and HSA calcite were carried out by the Physical Chemistry Department at the University of Cape Town. The test shows weight loss of a sample as it is heated from room temperature to 640°C. The resulting plot of weight vs temperature is useful to determine the temperature at which bonded and unbonded water is driven off, the temperature at which combustion occurs and other possible decomposition.

The TGA test for zeolite (Figure A7.1) shows a weight loss of 22% over the temperature range 40 to 640°C. Since the zeolite is specified by the manufacturers to have 22% water by mass and water loss must occur before combustion, the conclusion of the test is that no combustion of zeolite occurs below 640°C.

The TGA test for HSA calcite (Figure A7.2) shows a progressive weight loss of 13% in the temperature range 40 to 640°C. Since the calcite has no bonded water, the weight loss can be attributed to the gradual combustion of the calcite to calcium oxide and carbon dioxide. The steep slope of the curve towards the end of the temperature range indicates that further mass loss would probably have occurred if heating had continued to above 640°C.

FIGURE A7.1: ZEOLITE TGA TEST RESULT

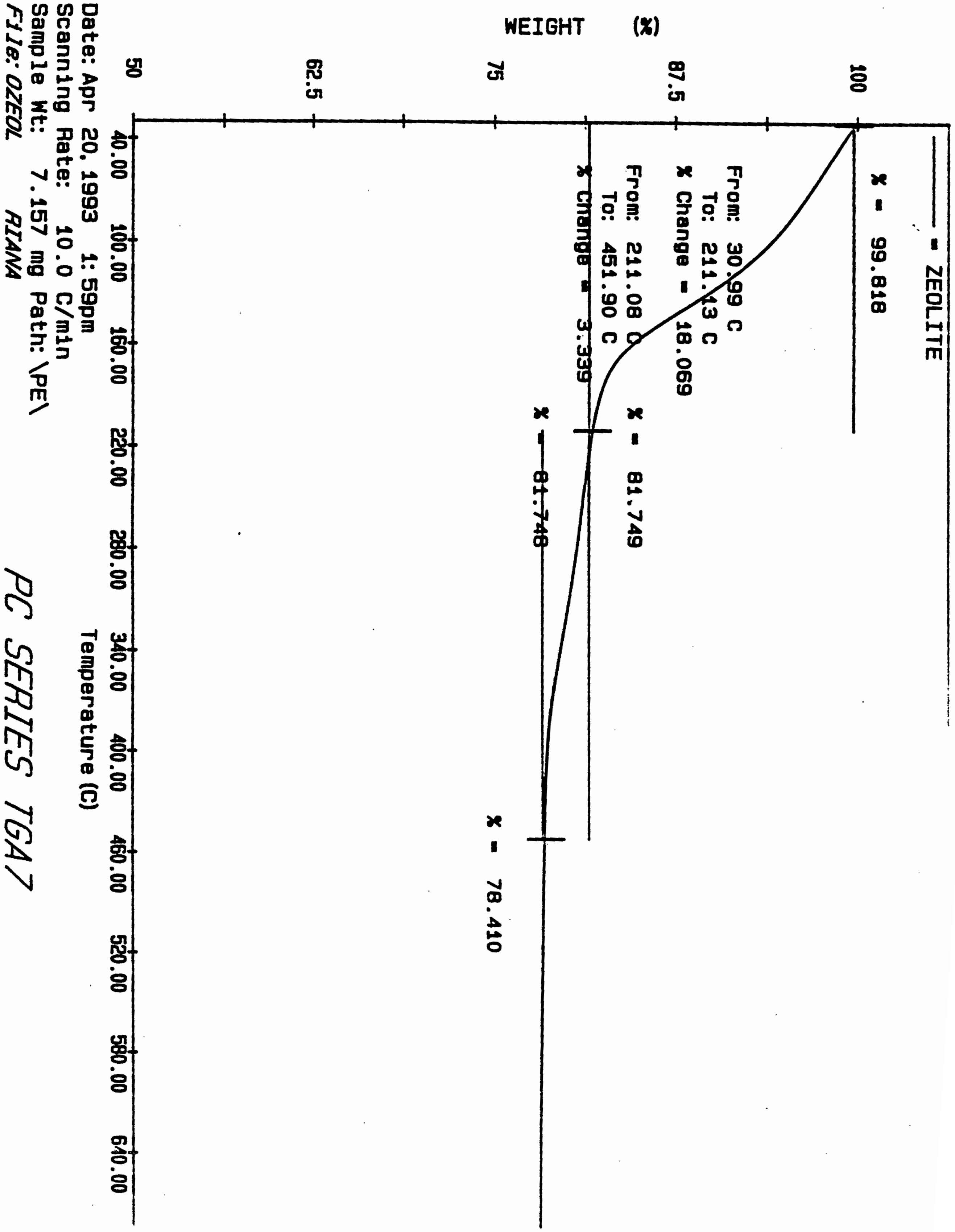
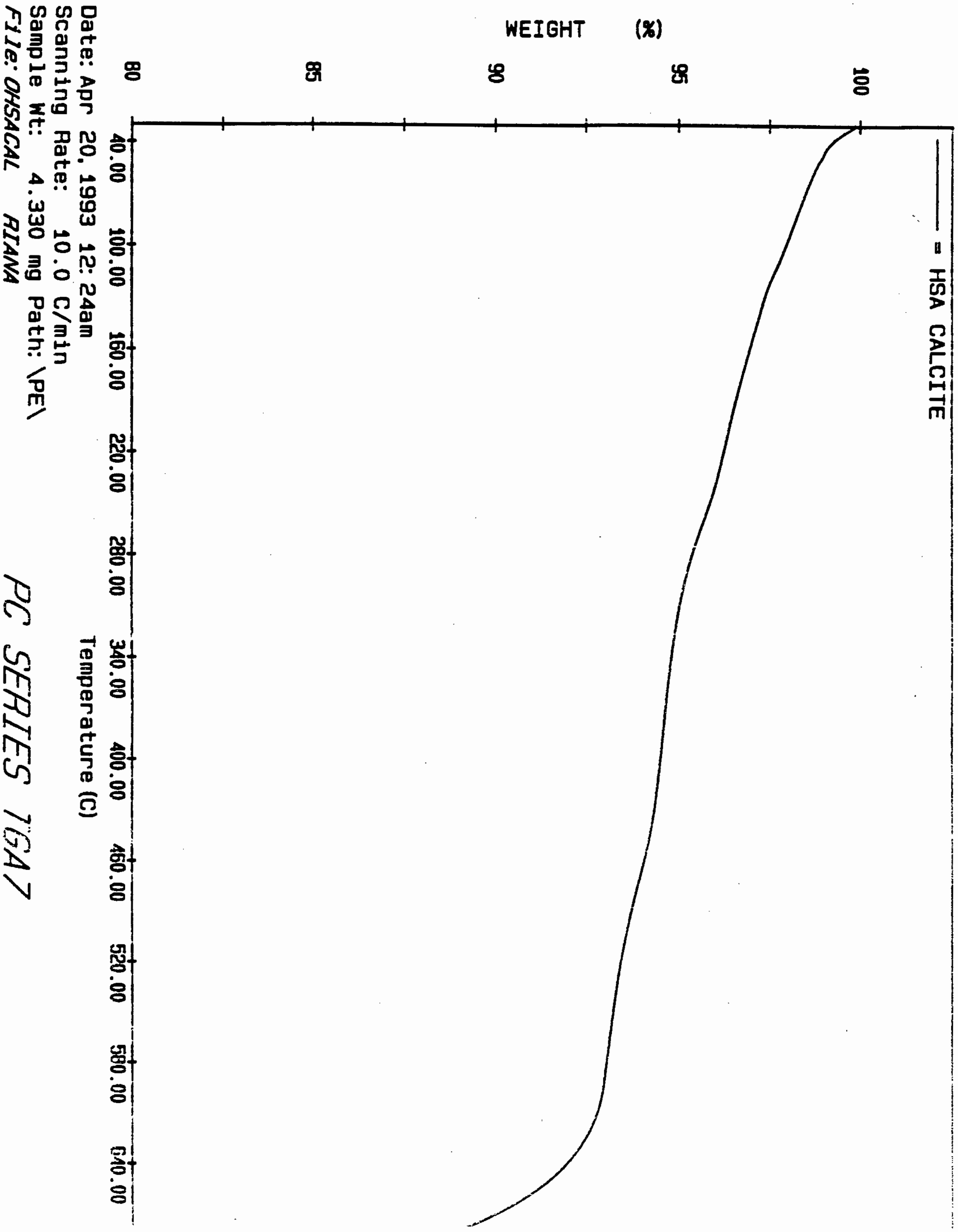


FIGURE A7.2: HSA CALCITE TGA TEST RESULT



# APPENDIX 8

## CALCIUM CARBONATE SATURATION IN WASTEWATER

The following calculation estimates the amount of dosed HSA calcite expected to dissolve in the sewage sludge. When combined with the expected combustion of the calcite in the incineration step of the VSS test, an HSA calcite mass balance can be performed.

1. **Initial sewage state**

Total dissolved solids = 400mg/l

Calcium concentration = 50-60mg/l

Alkalinity = 310 mg/l as $CaCO_3$

pH = 7.5

2. **Add one teaspoon of $NaHCO_3$ per 20l influent**

(ie. 149 mg/l as $CaCO_3$)

Alkalinity = 460mg/l as $CaCO_3$

pH = 7.8

3. **Nitrification of 50mg/l TKN reduces Alkalinity by 7.14 mg/l as $CaCO_3$ for every mg N nitrified**

Alkalinity = 460 - (7.14 * 50)

= 103mg/l as $CaCO_3$

4. **Denitrification of 40mgN/l increases Alkalinity by 3.57 mg/l as $CaCO_3$ for every mg N denitrified.**

Alkalinity = 103 + (3.57 * 40)

$= 246$ mg/l as $CaCO_3$

## 5. Final State

Alkalinity = 246 mg/l as $CaCO_3$

Calcium saturation state = 70 mg/l

Initial calcium concentration = 50-60mg/l

∴ Addition of 20mg/l of HSA calcite to the wastewater influent is expected to dissolve partially ie. 10-20mg/l.